The Transition to Resilient Housing*

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Abstract

We study how households adapt to rising natural-disaster risk through durable investments in their homes. We develop a model with housing vintages in which households invest in resilient housing capital through renovation of an existing stock of homes. In the model, disaster risk raises the value of adapted housing, while adoption depends on renovation costs, adaptation-specific costs, and the slow turnover of the housing stock. To measure adaptation directly, we construct new property-level measures from the text of building permits and MLS listings. We document three facts: adaptation reduces post-disaster repair activity, adapted homes command sizable premia that emerge only after the early 2000s, and adaptation accumulates only gradually in high-risk areas. We use the model to interpret these facts jointly and quantify the importance of adaptation. The post-2003 rise in premia in risky areas is consistent with a sharp increase in disaster risk. Adaptation is valuable but diffusion is slow because adjustment costs limit the transition to resilient housing. In the baseline, adaptation mitigates only 7 percent of the welfare cost of rising disaster risk. However, subsidizing adaptation investment costs can nearly eliminate this gap, absorbing half of the welfare loss at a fiscal cost below 0.2 percent of income.

*The views expressed here are solely those of the authors and do not necessarily represent those of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

1 Introduction

As storm and disaster risk rises, a central question is how households adjust. One possible response is anticipatory adaptation through durable housing investment. By making structural improvements before disasters occur, households may reduce future damage to their homes. These investments are widely discussed by policymakers as a way to improve resilience in exposed areas, but their importance as a margin of private adjustment is not well understood. This paper studies the role of durable anticipatory adaptation in household responses to rising natural-disaster risk.

To study this question, the paper makes two contributions. First, it develops a model of housing vintages in which households invest in durable housing capital subject to the structure of the existing housing stock. The model provides a framework for linking disaster risk, the value of adapted housing, and observed adaptation choices. Second, the paper builds a new property-level dataset from the unstructured text of building permits and home listings to measure adaptation directly. These data make it possible to distinguish adapted from non-adapted investment and to discipline the model with moments on both prices and quantities, allowing us to quantify the importance of adaptation in mitigating natural-disaster damages.

Resilient homes must be produced through renovation of an existing stock of housing. The paper develops a model in which homes differ by vintage and adaptation status, and households choose whether to renovate into adapted or non-adapted capital. In the model, adapted housing is valued only for the protection it provides against disaster risk, not through any direct preference for resilience itself. In the framework, higher disaster risk raises the relative value of adapted housing, so resilience premia reflect the future protection adapted homes provide against disaster losses, differential depreciation, and the pricing of insurance. Because newly adapted and older adapted homes embody different remaining streams of protection, the model also gives structure to variation in premia across housing types. By contrast, the physical adoption of adaptation depends on separate margins: the cost of renovation, the additional cost of installing resilient features, and the slow turnover of the existing housing stock. As a result, rising risk can generate substantial revaluation of resilience even when the stock of adapted homes expands only gradually. The model therefore provides a framework for using prices to identify the value of resilience and quantities to identify the frictions that slow its adoption.

Taking the model to the data requires measuring adaptation directly. That is difficult in housing markets because standard transaction and permit data record housing characteristics and construction activity, but do not separately code whether an investment is intended to

reduce storm damage. In practice, adaptation appears in the same unstructured text that also describes ordinary renovation and general construction. The paper addresses this by constructing new property-level measures of adaptation from the text of building permits and MLS listings.

The first step is to determine which housing features should count as adaptation. Following an approach related to Hassan et al. (2019), we compare building guidance for storm-resistant construction to more general construction guidance and identify the terms that are disproportionately associated with storm protection. Using building resource guides from the Department of Energy's Building America Solution Center, we separate hurricane- and tornado-related documents from other guides and rank n-grams by their relative similarity to the two corpora. We then organize the resulting terms into feature-specific categories such as roofs, windows and doors, siding, garages, basements, decks, roof edges, and yards. This yields a dictionary that distinguishes adaptation features associated with storm protection from ordinary housing features.

We search for these features in both permits and listings, and mark a property as adapted when adaptation language appears together with a housing feature in the same sentence. The two sources play different roles. Permits identify when an adaptation investment takes place, allowing us to measure the timing of adaptation investment directly. Listings provide complementary information on market prices and other characteristics, such as size and age, of the home present at the time of sale.

These measures create empirical counterparts to the objects in the model. They allow us to distinguish newly adapted properties from older adapted properties and to separate the value of resilience from the value of renovation more generally. This mapping lets us study prices and quantities in a way that matches the theory.

Using these data, we uncover three empirical facts. First, adaptation provides real protection. After disaster events, permitting activity on unadapted properties rises sharply, while the response for adapted properties is much smaller; this difference remains within age bins, indicating that it is not simply driven by newer housing. Second, adapted homes command sizable premia. Using repeat sales with property fixed effects, we compare properties to themselves over time, absorbing time-invariant unobservable characteristics of the property. Properties that acquire adaptation permits between sales are revalued upward, the premium is larger for newly adapted homes than for older adapted homes, and for older adapted homes the premium is essentially absent before 2003 and rises sharply thereafter. Third, adaptation accumulates only gradually: in high-risk counties, resilient investment increases over the sample, but the adapted share of the housing stock remains modest even after decades of adjustment. We use the model to interpret these facts jointly, to discipline the calibration,

and to quantify the role of disaster risk and adaptation costs in shaping the transition of the housing stock.

The calibration maps these reduced-form facts into model parameters and yields three quantitative results. First, the post-2003 rise in adaptation premia is consistent with a large increase in disaster risk in high-risk areas: the model matches the data with an increase in annual disaster probability from 0.1 percent to 2.5 percent. Second, adaptation provides substantial protection when disasters occur: in the calibrated model, adapted homes lose less than half as much value in a disaster as non-adapted homes, and newly adapted homes command larger premia because they embody a longer remaining stream of resilience benefits. Third, the slow growth of adapted housing reflects costs rather than a lack of value. To reconcile large premia with limited adoption, the model requires adaptation to be much more expensive than ordinary renovation and subject to an additional hurdle. As a result, adaptation remains modest in equilibrium, at about 6.8 percent of the housing stock.

The model implies that durable anticipatory adaptation is quantitatively meaningful but limited in equilibrium. In the calibrated high-risk regime, the economy converges to an adapted share of 6.8 percent of the housing stock and an adaptation permit share of 8.4 percent. As a result, adaptation offsets only 7.3 percent of the welfare loss from the climate transition in the baseline. Still, the model shows that this margin is economically real: relative to a no-adaptation counterfactual, the economy recovers faster from disaster shocks and sustains a higher housing aggregate. The policy counterfactuals show that this limited role is driven by costs. Lowering the variable cost of adapted investment produces large responses on both margins of adoption. A 25 percent subsidy raises the terminal adaptation share to 17.5 percent, and a 50 percent subsidy raises it to 41.3 percent. The welfare effects are correspondingly large: the share of climate-transition welfare loss mitigated rises from 7.3 percent in the baseline to 20.6 percent and 49.0 percent under the two subsidies. These results suggest that adaptation is not negligible, but that its aggregate role depends critically on the costs households face in converting existing housing into resilient capital.

Related Literature. This paper contributes to the literature on anticipatory responses to climate change and disaster risk. Recent macroeconomic work emphasizes that climate change affects behavior not only through realized damages, but also through forward-looking adjustments in migration, investment, and other adaptation margins. Bilal and Rossi-Hansberg (2023) and Fried (2021), for example, study how agents respond in anticipation of future climate risk. Our paper is closest to this literature in spirit, but differs in the adjustment margin it studies. Existing work often infers adaptation indirectly from aggregate damage outcomes or analyzes private and public adaptation jointly. By contrast, we observe

private anticipatory adaptation directly in the housing market. This allows us to measure its effect on disaster losses, its capitalization into house prices, and its diffusion through the housing stock, and to quantify the value of this margin as well as the frictions that limit its adoption.

This paper also contributes to the literature asking whether climate and disaster risk are priced in asset markets. Recent work in finance studies the pricing of climate risk across asset classes, including real estate, equities, and fixed income, and distinguishes between physical and transition risk (Engle et al., 2020). In housing markets, existing evidence suggests that capitalization depends importantly on beliefs and attention. (Giglio et al., 2020) show that the relative prices of flood-zone properties decline when attention to climate risk rises, while (Bernstein et al., 2019), (Baldauf et al., 2020) and (Bakkensen and Barrage, 2018) provide related evidence on sea-level-rise exposure and belief heterogeneity. Our paper complements this literature by observing the pricing of resilience directly. We measure the premium associated with resilient housing characteristics within the same market and trace how that premium evolves over time.

2 Model of Adaptation with Housing Vintages

To guide our empirical analysis and interpret the findings, we develop a model of the housing market that incorporates climate risk and adaptation decisions. The model provides a framework for understanding how prices and quantities of adapted and non-adapted housing behave in an economy with disaster risk, incomplete markets, and frictions to investment. We present the key elements here; full derivations and proofs are collected in Appendix **??**.

2.1 Environment

We consider an infinite-horizon small open economy populated by a continuum of landlords and a representative tenant household. Time is discrete. The economy faces two sources of uncertainty: disaster risk and idiosyncratic renovation costs.

Disaster risk. At any date t, the economy is in one of two states: normal (N) or disaster (D). The disaster state follows a Markov process with transition matrix

$$\mathbf{\Pi} = \begin{bmatrix} 1-x & x \\ 1 & 0 \end{bmatrix}, \qquad 0 < x < 1,$$

so that a disaster occurs with probability x conditional on the previous period being normal, and the economy always returns to normal after a disaster.[1] Our central experiment considers a permanent increase in x from x^L to x^H, representing the effect of climate change on disaster frequency.

Housing capital. The housing stock is heterogeneous along two dimensions:

- *Vintage*: new (n) versus old (o). New structures depreciate into old over time.
- *Adaptation status*: adapted ($a = 1$) versus non-adapted ($a = 0$). Adaptation refers to structural features—impact-resistant roofing, storm shutters, reinforced construction—that provide physical resilience against disasters.

There are thus four types of housing capital: $(a, v) \in \{0, 1\} \times \{n, o\}$. Landlords invest only in new structures; old structures arise endogenously through depreciation of new capital.

Durability of adapted housing. Adaptation provides resilience through two channels. First, adapted structures suffer less physical destruction when a disaster strikes:

$$\tau_1 < \tau_0, \tag{1}$$

where τ_a is the fraction of type-a housing destroyed in a disaster. Second, adapted structures depreciate at a slower rate in normal times:

$$\delta_{1,v} < \delta_{0,v}, \qquad v \in \{n, o\}, \tag{2}$$

reflecting higher build quality. These two properties—lower destruction and slower depreciation—are the fundamental sources of value from adaptation.

2.2 Landlords

A continuum of landlords own single-family rental properties. Landlords are heterogeneous in their fixed cost of renovation, χ^i, drawn from a continuous distribution $F(\chi)$ with density $f(\chi)$. This heterogeneity generates extensive margin of renovation and adaptation.

Each landlord i maximizes the present discounted value of dividends:

$$\max \; E_t \sum_{k=0}^{\infty} \beta^k \frac{\lambda_{t+k}}{\lambda_t} \Pi_{S_{t+k-1}}^{S_{t+k}} \; d_{t+k}^i, \tag{3}$$

[1] This one-period disaster assumption is without loss of generality for our purposes. What matters is the expected frequency x, which we allow to shift permanently at the start of the transition experiment.

where $\beta\lambda_{t+k}/\lambda_t$ is the stochastic discount factor of the representative household who owns equity in the landlord, and $\Pi_{S_{t+k-1}}^{S_{t+k}}$ denotes the transition probability between disaster states.

Period-t dividends are:

$$\begin{aligned} d_t^i = & \underbrace{z_{n,t}h_{n,t}^i + z_{o,t}h_{o,t}^i}_{\text{rental income}} - \underbrace{\sum_{a\in\{0,1\}} \phi_a\left(\frac{i_{a,n,t}^i}{h_t^i}\right) h_t^i}_{\text{convex adjustment costs}} \\ & - \underbrace{h_t^i \cdot \chi^i \cdot \mathbf{1}_{\{\text{any investment}>0\}}}_{\text{fixed cost of renovation}} - \underbrace{h_t^i \cdot \kappa^A \cdot \mathbf{1}_{\{i_{1,n,t}^i>0\}}}_{\text{adaptation hurdle cost}} \\ & - \underbrace{\sum_{a,v} \pi_0(a)\, m_{a,v,t}^i\, h_{a,v,t}^i}_{\text{insurance premiums}} + \underbrace{\mathbf{1}_{[S_t=D]} \sum_{a,v} m_{a,v,t-1}^i\, \tau_a\, p_{a,v,t}\, h_{a,v,t-1}^i}_{\text{insurance payouts in disasters}} \\ & + \underbrace{b_{t+1}^i - (1+r_t)b_t^i}_{\text{net borrowing}}, \end{aligned} \tag{4}$$

where $h_{n,t}^i \equiv h_{0,n,t}^i + h_{1,n,t}^i$ and $h_{o,t}^i \equiv h_{0,o,t}^i + h_{1,o,t}^i$ denote total new and old housing, $h_t^i = h_{n,t}^i + h_{o,t}^i$ is total stock, $z_{v,t}$ are competitive rental rates, $i_{a,n,t}^i$ is investment in new type-a structures, and b_t^i denotes net financial assets. We discuss each component in turn.

Adjustment costs. Investment in new structures incurs type-specific convex costs:

$$\phi_a(\iota) = \frac{\zeta_a}{\theta_c}\iota^{\theta_c}, \qquad \theta_c > 1, \quad a \in \{0,1\}, \tag{5}$$

where $\iota \equiv i_{a,n,t}^i/h_t^i$ is the investment rate. The parameter ζ_a governs the level of marginal adjustment costs for each type. A natural restriction is $\zeta_1 > \zeta_0$: adapting is costlier per unit than standard renovation, reflecting the specialized materials and techniques required.

Fixed costs. The fixed cost χ^i generates two separate extensive margins for renovation and adaptation. Each period, a landlord draws χ^i from a continuous distribution $F(\chi)$ on $[0, \bar{\chi}]$. To renovate (invest in non-adapted housing), the surplus from general investment Δ_0 must exceed χ^i. To adapt (invest in adapted housing), the surplus from adaptation net of the hurdle cost, $\Delta_1 - \kappa^A$, must also exceed χ^i. Since both decisions use the same draw, landlords with low χ^i do both, landlords with intermediate χ^i renovate but do not adapt, and landlords with high χ^i do neither. The hurdle κ^A captures the additional coordination, information, and sourcing costs specific to adaptation. Together, χ^i and κ^A allow the model to have separation between renovation rate and adapted renovation rate.

Borrowing constraint Each landlord faces a collateral constraint on borrowing:

$$b^i_{t+1} \geq -\theta \sum_{a,v} p_{a,v,t}\, h^i_{a,v,t}, \tag{6}$$

where $\theta \in (0,1)$ is the maximum loan-to-value ratio and $p_{a,v,t}$ is the market price of type-(a,v) housing. Let $\mu^i_t \geq 0$ denote the multiplier on this constraint. When the constraint binds ($\mu^i_t > 0$), landlords face a shadow cost of borrowing that exceeds the market interest rate, creating a wedge in their investment decisions. The collateral constraint also implies that adapted housing, which commands a higher price, provides greater borrowing capacity.

Housing stock evolution The housing stock evolves according to depreciation, disaster destruction, and new investment. For new housing of adaptation type a:

$$h^i_{a,n,t+1} = \left(1 - \delta_{a,n} - \tau_a \cdot \mathbf{1}_{[S_{t+1}=D]}\right) h^i_{a,n,t} + i^i_{a,n,t}. \tag{7}$$

New structures depreciate into old at rate $\delta_{a,n}$. Old structures accumulate the depreciated new stock and themselves depreciate at rate $\delta_{a,o}$:

$$h^i_{a,o,t+1} = \left(1 - \delta_{a,o} - \tau_a \cdot \mathbf{1}_{[S_{t+1}=D]}\right) h^i_{a,o,t} + \delta_{a,n}\, h^i_{a,n,t}. \tag{8}$$

Investment at t becomes productive housing at $t+1$ (time-to-build), so reconstruction after a disaster takes at least one period regardless of financial resources.

2.3 Insurance

Landlords can purchase insurance against disaster-related destruction. For each housing type (a,v), the landlord chooses a coverage level $m^i_{a,v,t} \in [0,1]$. The per-unit premium rate depends on adaptation status:

$$\pi_0(a) = \gamma \cdot x \cdot \tau_a \cdot \bar{p}_{a,n}, \tag{9}$$

where $\gamma \leq 1$ is a subsidy factor. When $\gamma < 1$, insurance is subsidized below actuarially fair rates. Because $\tau_1 < \tau_0$, adapted housing faces lower premiums: $\pi_0(1) < \pi_0(0)$.

If a disaster strikes, insurance pays $m^i_{a,v,t-1} \cdot \tau_a \cdot p_{a,v,t} \cdot h^i_{a,v,t-1}$—the coverage ratio times the market value of destroyed housing. Insurance provides financial compensation but does not prevent physical destruction. The housing stock evolves according to actual destruction rates regardless of coverage.

2.4 Household

The demand side is characterized by a representative household with CES preferences over new and old housing services:

$$U = E_t \sum_{k=0}^{\infty} \beta^k \frac{1}{1-\sigma} \left[C_{t+k}^{\kappa} H_{t+k}^{1-\kappa} \right]^{1-\sigma}, \qquad H_t = \left(\alpha H_{n,t}^{\rho} + (1-\alpha) H_{o,t}^{\rho} \right)^{1/\rho}. \tag{10}$$

The household earns exogenous income Y_t, holds equity in landlords, pays rent for housing services, and trades a risk-free bond at rate r_t. The elasticity of substitution between new and old housing, $1/(1-\rho)$, governs how the rental premium for new housing responds to changes in relative supply.

The household's intratemporal optimality yields rental prices as functions of consumption and housing stocks:

$$z_{n,t} = \frac{1-\kappa}{\kappa} \alpha H_{n,t}^{\rho-1} H_t^{1-\rho} \frac{C_t}{H_t}, \tag{11}$$

$$z_{o,t} = \frac{1-\kappa}{\kappa} (1-\alpha) H_{o,t}^{\rho-1} H_t^{1-\rho} \frac{C_t}{H_t}. \tag{12}$$

The household does not distinguish between adapted and non-adapted housing in its rental demand.[2] The price premium for adapted housing arises entirely from the supply side through lower expected depreciation, lower destruction, and lower insurance costs.

2.5 Asset Prices and Investment Decisions

The equilibrium level of adaptation in the economy is determined by the interaction of two forces. On the *demand side*, the asset pricing equations determine the market premium for adapted housing. This premium is driven by the durability advantage of adapted structures (lower δ and τ), the probability of disasters (x), and the insurance regime. On the *supply side*, the landlord's investment problem determines how much adaptation is produced. Supply is governed by the convex adjustment costs (ζ_a), the fixed costs of renovation (χ^i) and adaptation (κ^A), and the borrowing constraint. In equilibrium, the adaptation premium and the adapted housing stock are jointly determined: the premium must be high enough to induce the marginal landlord to bear the cost of adapting, and the quantity of adapted housing must be consistent with the rental market clearing. We characterize each side in turn.

[2]This assumption captures the idea that adaptation features (e.g., impact windows, reinforced roofing) do not directly affect the flow of housing services in normal times. Their value comes entirely from resilience to disasters, which is capitalized into asset prices through the landlord's investment problem.

The constant-returns-to-scale structure of the landlord problem implies that equilibrium asset prices can be characterized by shadow price recursions that are common across all landlords.

The price of new adapted housing satisfies:

$$p_{1,n,t}(1-\mu_t\theta) = z_{n,t} - \pi_0(1)m_{1,n,t} + \beta\, E_t\left[\frac{\lambda_{t+1}}{\lambda_t}\Pi_{S_t}^{S_{t+1}}\left(\underbrace{p_{1,n,t+1}(1-\delta_{1,n}) + p_{1,o,t+1}\delta_{1,n}}_{\text{depreciation and aging}}\underbrace{-\tau_1\, p_{1,n,t+1}\cdot \mathbf{1}_{[S_{t+1}=D]}}_{\text{disaster destruction}} + \underbrace{m_{1,n,t}\,\tau_1\, p_{1,n,t+1}\cdot \mathbf{1}_{[S_{t+1}=D]}}_{\text{insurance payout}}\right)\right], \tag{13}$$

with analogous expressions for $p_{0,n,t}$, $p_{1,o,t}$, and $p_{0,o,t}$ (reported in Appendix **??**).

Equation (13) is a standard asset pricing equation. The left-hand side includes the collateral wedge $(1-\mu_t\theta)$: when the borrowing constraint binds, the effective price is reduced because the asset relaxes the constraint, adding a liquidity premium. On the right-hand side, the current payoff consists of rental income net of insurance premiums. The continuation value has three components. First, the unit depreciates from new to old at rate $\delta_{1,n}$, with the remaining new capital valued at $p_{1,n,t+1}$ and the depreciated portion at $p_{1,o,t+1}$. Second, in a disaster, a fraction τ_1 of the stock is destroyed, representing a capital loss. Third, insurance provides a financial payout proportional to coverage $m_{1,n,t}$ that partially offsets the capital loss.

Steady-state adaptation premium In steady state, prices are constant ($p_{a,v,t} = p_{a,v}$ for all t) and the stochastic discount factor satisfies $\beta E[\lambda'/\lambda] = \beta/(1+r^*)$. Define the *effective user cost* of old housing of type a as:

$$u_{a,o} \equiv (1-\mu\theta) - \beta\left[1 - \delta_{a,o} - x\tau_a(1-m_{a,o})\right], \tag{14}$$

where $x\tau_a(1-m_{a,o})$ is the expected uninsured destruction rate per period.

Proposition 2.1 (Steady-State Adaptation Premium)**.** *Suppose $\tau_0 > \tau_1$ and $\delta_{0,o} \geq \delta_{1,o}$. Then:*

(i) ***(Existence)*** *In the absence of insurance and borrowing constraints ($m_{a,o} = 0$, $\mu = 0$), the steady-state adaptation premium for old housing is:*

$$\frac{p_{1,o} - p_{0,o}}{p_{0,o}} = \frac{\beta\left[\underbrace{(\delta_{0,o} - \delta_{1,o})}_{\text{depreciation gap}} + \underbrace{x(\tau_0 - \tau_1)}_{\text{expected destruction gap}}\right]}{1 - \beta(1 - \delta_{1,o} - x\tau_1)} > 0. \tag{15}$$

(ii) ***(Increasing in disaster risk)*** *The premium is strictly increasing in x:*

$$\frac{\partial}{\partial x}\left(\frac{p_{1,o}-p_{0,o}}{p_{0,o}}\right)>0. \tag{16}$$

(iii) ***(Decomposition)*** *When $x=0$, the premium is $\beta(\delta_{0,o}-\delta_{1,o})/[1-\beta(1-\delta_{1,o})]$, reflecting only the depreciation advantage. The incremental contribution of disaster risk is approximately linear in x for small x.*

Proof. Part (i) follows directly from equation (**??**) with $m_{a,o}=0$ and $\mu=0$. Since z_o is common across types, $p_{1,o}/p_{0,o}=u_{0,o}/u_{1,o}$. Substituting and simplifying:

$$\begin{aligned}\frac{p_{1,o}-p_{0,o}}{p_{0,o}}&=\frac{u_{0,o}}{u_{1,o}}-1=\frac{u_{0,o}-u_{1,o}}{u_{1,o}}\\&=\frac{\beta\left[(\delta_{0,o}-\delta_{1,o})+x(\tau_0-\tau_1)\right]}{1-\beta(1-\delta_{1,o}-x\tau_1)}.\end{aligned}$$

The numerator is positive by assumption. The denominator is positive provided the discount rate exceeds the net return on adapted housing, which is required for finite asset values.

For part (ii), write the premium as $N(x)/D(x)$ where $N(x)=\beta[(\delta_{0,o}-\delta_{1,o})+x(\tau_0-\tau_1)]$ and $D(x)=1-\beta(1-\delta_{1,o}-x\tau_1)$. Then:

$$\frac{\partial}{\partial x}\frac{N}{D}=\frac{N'D-ND'}{D^2}=\frac{\beta(\tau_0-\tau_1)D-N\cdot\beta\tau_1}{D^2}.$$

Substituting and simplifying, the numerator of this derivative is:

$$\beta(\tau_0-\tau_1)\left[1-\beta(1-\delta_{1,o})\right]+\beta^2x\tau_1(\tau_0-\tau_1)-\beta^2\tau_1(\delta_{0,o}-\delta_{1,o})-\beta^2x\tau_1(\tau_0-\tau_1).$$

The x-terms cancel, leaving $\beta(\tau_0-\tau_1)[1-\beta(1-\delta_{1,o})]-\beta^2\tau_1(\delta_{0,o}-\delta_{1,o})$. A sufficient condition for this to be positive is $(\tau_0-\tau_1)[1-\beta(1-\delta_{1,o})]>\beta\tau_1(\delta_{0,o}-\delta_{1,o})$, which holds when the destruction gap is not negligible relative to the depreciation gap—the empirically relevant case.[3]

Part (iii) is immediate from inspecting (15) at $x=0$ and noting that $N(x)$ is linear in x while $D(x)$ moves slowly for small x. □

Corollary 2.2 (Insurance and the Adaptation Premium)**.** *Consider the steady state with $\mu=0$ and full insurance coverage ($m_{a,o}=1$). Under three insurance pricing regimes, the adaptation premium for old housing is:*

[3] In fact, for our calibrated parameters the destruction channel dominates, making this condition hold comfortably.

(i) ***Type-dependent, actuarially fair*** *($\pi_0(a) = x\tau_a p_{a,o}$):*

$$\frac{p_{1,o} - p_{0,o}}{p_{0,o}} = \frac{\beta(\delta_{0,o} - \delta_{1,o}) + x(\tau_0 - \tau_1)}{1 - \beta(1 - \delta_{1,o}) + x\tau_1} > 0. \tag{17}$$

(ii) ***Free, fully subsidized*** *($\pi_0(a) = 0$):*

$$\frac{p_{1,o} - p_{0,o}}{p_{0,o}} = \frac{\beta(\delta_{0,o} - \delta_{1,o})}{1 - \beta(1 - \delta_{1,o})} \geq 0. \tag{18}$$

(iii) ***Type-independent, actuarially fair (pooling)*** *($\pi_0(a) = \bar{\pi}$):*

$$\frac{p_{1,o} - p_{0,o}}{p_{0,o}} = \frac{\beta(\delta_{0,o} - \delta_{1,o})}{1 - \beta(1 - \delta_{1,o})} \geq 0. \tag{19}$$

The proof follows from substituting each premium structure into the steady-state pricing equation (see Appendix **??**). The adaptation premium reflects private incentives to adapt, driven by disaster risk net of insurance. When insurance is actuarially fair and type-dependent (Case i), the insurer charges more for riskier properties, so the full disaster risk channel $x(\tau_0 - \tau_1)$ is capitalized into prices alongside the depreciation gap. When insurance is fully subsidized or pooled across types (Cases ii and iii), the premium payment either does not exist or does not vary with adaptation status. The disaster risk channel drops out, and the premium reflects only the depreciation advantage of adapted housing. If depreciation rates are equalized ($\delta_{0,o} = \delta_{1,o}$), the premium vanishes entirely.

Optimal investment The investment decision has both an intensive and extensive margin. On the intensive margin, a landlord who has decided to invest in adapted housing chooses the investment rate to equate marginal cost to the discounted shadow value:

$$\zeta_1 \left(\frac{i^i_{1,n,t}}{h^i_t} \right)^{\theta_c - 1} = \beta \, E_t \left[\frac{\lambda_{t+1}}{\lambda_t} \Pi_{S_t}^{S_{t+1}} \, p_{1,n,t+1} \right]. \tag{20}$$

The left-hand side is the marginal adjustment cost; the right-hand side is the discounted expected value of an additional unit of adapted new housing next period.

On the extensive margin, two separate cutoffs determine participation. Define the per-unit surplus from investment of type a as:

$$\Delta_{a,t} \equiv \max_{\iota \geq 0} \left\{ \iota \cdot \mathcal{Q}_{a,n,t} - \phi_a(\iota) \right\}, \tag{21}$$

where $\mathcal{Q}_{a,n,t} \equiv \beta\, E_t\Big[\frac{\lambda_{t+1}}{\lambda_t}\Pi_{S_t}^{S_{t+1}}\, p_{a,n,t+1}\Big]$ is the discounted shadow value of type-a new capital. A landlord renovates (invests in non-adapted housing) if the surplus from general investment exceeds the fixed cost:

$$\chi^i \leq \chi^*_{0,t} \equiv \Delta_{0,t}. \tag{22}$$

Independently, a landlord adapts (invests in adapted housing) if the surplus from adaptation, net of the hurdle, exceeds the same fixed cost:

$$\chi^i \leq \chi^*_{1,t} \equiv \max\left\{0,\ \Delta_{1,t} - \kappa^A\right\}. \tag{23}$$

The fraction of landlords renovating is $F(\chi^*_{0,t})$ and the fraction adapting is $F(\chi^*_{1,t})$. Since both decisions use the same draw χ^i, every landlord who adapts also renovates (because $\chi^*_{1,t} \leq \chi^*_{0,t}$ whenever $\kappa^A > 0$), but most renovators do not adapt. When κ^A is large or $\Delta_{1,t}$ is small, $\chi^*_{1,t}$ is close to zero and few landlords adapt even though many renovate.

Price-quantity divergence. The structure of the model implies an asymmetry between the speed of price and quantity adjustment. Asset prices are forward-looking: a permanent increase in disaster probability x raises the shadow values $p_{1,v}$ relative to $p_{0,v}$ immediately, because the pricing recursions in (13) capitalize the entire future stream of benefits from adaptation. Both cutoffs $\chi^*_{0,t}$ and $\chi^*_{1,t}$ jump on impact through the surpluses $\Delta_{a,t}$. The physical housing stock, however, adjusts gradually: only fractions $F(\chi^*_{0,t})$ and $F(\chi^*_{1,t})$ of landlords invest per period. The transition from a low-adaptation to a high-adaptation steady state takes many periods, governed by the distribution $F(\chi)$ and the rate at which the old non-adapted stock depreciates.

2.6 Equilibrium

Aggregate housing stocks are $H_{a,v,t} = \int h^i_{a,v,t}\, di$. Aggregate investment of type a is $I_{a,n,t} = F(\chi^*_{a,t}) \cdot y^*_{a,t} \cdot H_t$, where $y^*_{a,t}$ is the optimal investment rate from the intensive margin FOC. In steady state, the stock shares satisfy:

$$s_{a,n} = \frac{F(\chi^*_a) \cdot y^*_a}{\delta_{a,n} + \tau_a x}, \qquad s_{a,o} = \frac{\delta_{a,n} \cdot s_{a,n}}{\delta_{a,o} + \tau_a x}. \tag{24}$$

Rental markets clear when household demand equals aggregate supply: $H^d_{n,t} = H_{n,t}$ and $H^d_{o,t} = H_{o,t}$. The economy takes the world interest rate r^*_t as given (small open economy assumption), and a potentially subsidized insurance system satisfies its budget through an

external transfer Ω_t, so that $\mathcal{X}_t = \mathcal{P}_t + \Omega_t$ where $\mathcal{X}_t$ denotes aggregate payouts and $\mathcal{P}_t$ aggregate premiums. The resource constraint is:

$$B_{t+1} = (1 + r_t^*)B_t + Y_t + \Omega_t - C_t - \sum_a I_{a,n,t} - \mathcal{A}_t, \tag{25}$$

where B_t denotes net foreign assets and $\mathcal{A}_t$ denotes aggregate adjustment costs.

A competitive equilibrium is a collection of prices $\{z_{n,t}, z_{o,t}, p_{a,v,t}\}$, household allocations, landlord policies (investment, insurance, borrowing), and aggregate states such that households and landlords optimize, rental markets clear, and the resource constraint holds. The full definition is in Appendix **??**.

3 Data

The empirical analysis requires classifying properties into the four types defined by the model—renovated adapted, non-renovated adapted, renovated non-adapted, and non-renovated non-adapted—and tracking their prices and quantities over time. We construct these distinctions from the text of property listings and building permits using natural language processing.

3.1 Measuring adaptations and renovations

Our primary data come from two CoreLogic datasets. The MLS dataset contains 69 million property listings for over 30 million unique properties across 27,645 ZIP codes spanning 1990–2022, with free-text descriptions of features and amenities. The Building Permits dataset provides permit-level records of renovation and construction activity, including project descriptions, estimated job values, and completion status. Both datasets contain unstructured text that describes what was built, upgraded, or advertised, but neither systematically codes whether a given feature constitutes climate adaptation. We develop a procedure to extract this information in three steps.

Step 1: Constructing the Adaptation Dictionary We begin by extracting all contiguous bigrams and trigrams appearing at least 100 times in MLS listing descriptions. Table A1 displays the most frequently occurring n-grams after removing stop words and generic housing terms.

To determine which of these n-grams correspond to climate adaptations, we compare building guidance from the Department of Energy's Building America Solution Center (BASC) specifically to construct storm-resistant homes versus other general guidance. The BASC

publishes detailed resource guides specifying best practices for residential construction across a range of climate hazards. We scrape all BASC resource guides and classify them as hurricane or tornado-related if they contain the word "hurricane" or "hurricanes." or "tornado" or "tornadoes." Figure A1 displays an example page from these guides.

We use Sentence-BERT (SBERT) to generate vector embeddings for each BASC document and each n-gram from the listings corpus. For each n-gram, we compute cosine similarity with every hurricane-related document and every non-hurricane document, retaining the maximum similarity score in each category. The log-odds ratio of these maximum similarities measures how strongly each n-gram is associated with hurricane-related building guidance relative to general construction guidance. Table A2 displays the 50 highest-ranked n-grams.

Some of the highly scored terms in our dictionary are more about damage from hurricane or structural parts of the home which are overly exposed to hurricanes than structural adaptations which offer protection from hurricane. A research assistant then manually review N-grams with high log-odds, and includes the relevant adaptation specific phrases in our final dictionary.

Step 2. Feature-Specific Keywords We organize the resulting adaptation keywords by housing feature—roof, windows and doors, siding, garage, basement and storm shelter, deck, roof edge, and yard—to enable feature-specific analysis. Table 1 presents the complete dictionary.[4]

Throughout the analysis, we maintain a consistent set of housing features (roof, windows and doors, siding, garage, basement, deck, roof edge, yard) across both data sources. This is necessary to ensure that the adaptation and non-adaptation categories are composed of the same types of construction work. Without this restriction, differences in premia or permit responses could reflect differences in the mix of features being compared rather than the presence or absence of adaptation.

Step 3. Scoring Text and Identifying Adaptations We apply the dictionary to both listings and permits using the same procedure. For each text, we flag co-occurrences of feature keywords (e.g., "roof," "windows") and adaptation keywords (e.g., "metal," "impact") within the same sentence. A property or permit is marked as adapted if any such co-occurrence is detected. Table A3 presents an example MLS listing with an identified adaptation feature ("Glass Impact front door"). The algorithm identifies the co-occurrence of "door" (feature keyword) and "impact" (adaptation keyword) within a single sentence. Table A4 displays an

[4]We augment the SBERT-derived dictionary with intuitive additions (e.g., "hurricane-proof") and generate all pluralized forms to improve matching accuracy (e.g., "metal roof," "metal roofs").

Table 1: Hurricane-Adaptation Keywords by Housing Feature

Feature	**Hurricane Keywords**
Yard	sloped yard
Roof	hurricane grade, hurricane-grade, hurricane rated, hurricane rating, hurricane proof, hurricane resistant, metal, hurricane, clay, steel roofs, aluminum, concrete, enclosed soffits, hip roof, patio tile roof, roof bracing, wall connectors, hurricane straps, tornado straps, braced, bracing
Roof Edge	hurricane grade, hurricane-grade, hurricane rated, hurricane rating, hurricane rated, hurricane proof, hurricane resistant, enclosed soffits, covered soffits, gutters hurricane, hurricane gutters, metal, roof edge protection, drip edge fastening
Siding	hurricane grade, hurricane-grade, hurricane rated, hurricane rating, hurricane-rated, hurricane proof, hurricane resistant, exterior hurricane, siding hurricane, metal, steel, wall sheathing
Windows & Doors	hurricane grade, hurricane-grade, hurricane rated, hurricane rating, hurricane-rated, hurricane resistant, door hurricane, hurricane door, storm door, doors storm, shutters hurricane, doors impact, hurricane panels, hurricane shutters, outside shutters, hurrican shutter, hurricane proof, hurricane impact, impact doors, hurricane panels, hurricane window, hurricane french doors, impact doors, storm panels, storm entry doors, impact glass door, storm shutters, impact sliding doors, hurricane glass, storm proof, storm windows, insulated doors, coverings including shutters, storm entry door, impact windows, hurricane accordian shutters, storm security doors, insulated sliding door, storm screen doors, storm security door, storm rated, impact glass, impact resistant, storm resistant, storm glass, shutters covered, covered shutters
Deck	hurricane grade, hurricane-grade, patio hurricane, covered patio storm, metal patio cover, metal covered
Garage	hurricane grade, hurricane-grade, hurricane rated, hurricane rating, hurricane rated, hurricane proof, hurricane resistant, metal, hurricane shutters, garage door hurricane, storm rated, hurricane strength, hurricane reinforced, storm doors, strength garage door
Basement	storm room, hurricane room, tornado room, tornado safe features, tornado safety features, hurricane safe features, hurricane safety features, storm safe features, storm safety features, safe room, shelter, w tornado safety, enhanced tornado safety, tornado safe, hurricane safe, storm safe

Notes: Complete dictionary of hurricane adaptation keywords organized by housing feature. Each feature category includes associated synonyms used for matching in permits and listings text (e.g., yard synonyms include lawn, garden, yardspace, backyard, courtyard).

example building permit for an impact window and door retrofit, where the homeowner is "replacing non impact windows and doors with impact," at a job value of $40,070.

Step 4. Scoring Renovations We further distinguish *newly installed* adaptations by identifying sentences in home listings that contain both adaptation keywords and renovation indicators (e.g., "upgraded," "newly installed," "renovated," "replacing"). This allows us to separate the stock of existing adaptations from the flow of new adaptation investments. For permits, a renovation is identified by the existence of the permit itself, so the feature synonym alone suffices.

The scoring procedure, applied to both data sources, maps each property into one of the four types defined by the model. The *adaptation dimension* comes from permits. A property is classified as adapted if a building permit with an adaptation feature was filed at any point before the listing date. This provides precise timing of when adaptation occurred. Separately, the MLS listing text indicates whether adaptation features are mentioned at the time of sale, offering a complementary measure that captures the cumulative stock of adaptations including those installed before our permit data begins. The *renovation dimension* comes from listings. A property is classified as recently renovated if the listing text contains renovation language (e.g., "upgraded," "newly installed," "remodeled"). This classification is available only from listings, not from permits, because permits record all construction activity (including routine maintenance) while the listing text selectively highlights renovations that sellers consider value-relevant.

Renovated adapted properties correspond to new adapted capital ($a = 1, v = n$) in the model: they have been recently upgraded with adaptation features. Non-renovated adapted properties correspond to old adapted capital ($a = 1, v = o$): they were adapted at some earlier date but have not been recently renovated. Renovated non-adapted properties are standard renovations without adaptation, providing a benchmark for the value of renovation alone. Non-renovated non-adapted properties form the omitted category in our regressions.

3.2 Prices and Investment Variables

Hedonic prices. We construct hedonic prices using repeat-sales methods. For properties with multiple transactions at least 180 days apart, we regress log price per square foot on property fixed effects and month-of-year fixed effects:

$$\ln\left(\frac{p_{it}}{sqft_i}\right) = \alpha_i + \gamma_{m(t)} + \varepsilon_{it}, \tag{26}$$

where α_i absorbs all time-invariant property quality and $\gamma_{m(t)}$ absorbs seasonal patterns. The residuals capture price movements net of permanent property characteristics. We estimate this separately for adapted and non-adapted properties, yielding type-specific hedonic price

indices. All price variables are winsorized at the 2nd and 98th percentiles.

Investment measures. We aggregate permit counts and job values to the county-quarter level separately for general renovations, adaptation-specific renovations, and total activity. The adaptation share of renovation permits—the fraction involving adaptation features—corresponds to the model's adaptation rate conditional on renovation, governed by $\Delta_{1,t} \geq \kappa^A$. We also construct stocks of adapted and non-adapted housing at the county level by cumulating permits over time.

3.3 Additional Data and Sample

We merge the housing data with three additional sources. County-level employment comes from the Quarterly Census of Employment and Wages (QCEW), which we use to construct Bartik labor demand instruments. Climate risk measures come from FEMA's National Risk Index (NRI), which combines expected annual loss from hurricanes and tornadoes with building value to produce a risk score at the county level. We classify counties as high-risk if this score exceeds 0.20. Disaster events come from the Spatial Hazard Events and Loss Database (SHELDUS), which records per-capita property damage at the county-quarter level. We define a disaster event as a county-quarter in the top 100 of the property damage distribution. County demographic characteristics come from the 2008–2012 American Community Survey.

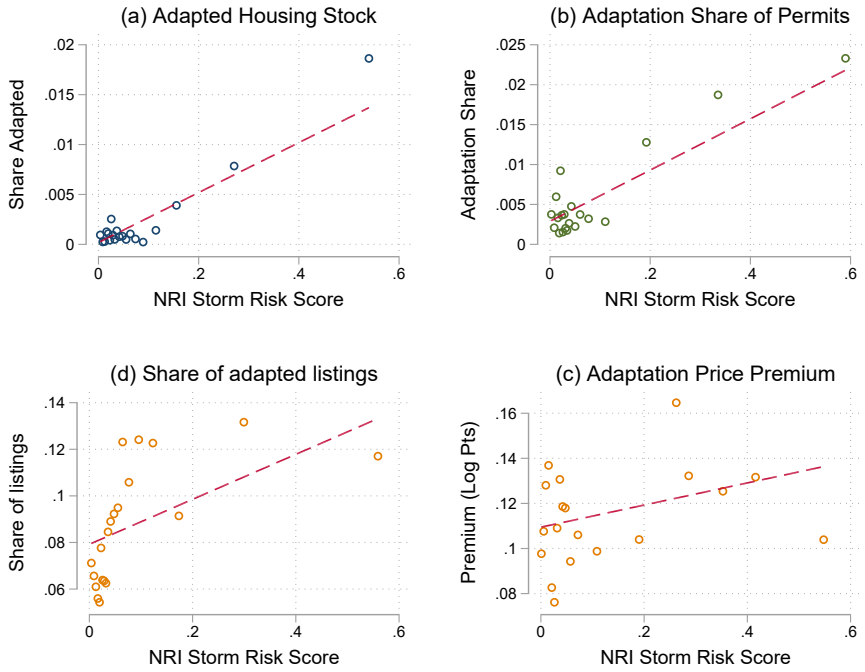
Our estimation sample includes 2,847 counties observed quarterly from 2000Q1 through 2022Q4, yielding approximately 260,000 county-quarter observations. We restrict to counties with at least 1,000 housing units and mean quarterly permit activity exceeding 10 permits. The listing-level sample for price premia regressions contains approximately 7.3 million observations in high-risk counties after merging with adaptation status and risk data.

3.4 Validation

We validate our text-based measures by examining whether they exhibit the cross-sectional patterns predicted by the model. Proposition 2.1 implies that both the quantity of adapted housing and its price premium should be increasing in disaster risk x. We test these predictions using a 2019 county-level cross-section.

Figure A2 displays the geographic distribution of adaptation investment. Adaptation activity is overwhelmingly concentrated in hurricane-prone areas along the Gulf Coast and Atlantic seaboard, particularly in Florida, the Carolinas, and the Gulf states. Counties in the interior and western United States show little to no adaptation activity. This sharp

Figure 1: Adaptation and Storm Risk: Cross-Sectional Validation



Notes: 2019 county-level cross-section. Panel (a): adapted stock share. Panel (b): adaptation permits as share of total permits. Panel (c): hedonic price premium (log points). Panel (d): share of listings mentioning adaptation features.

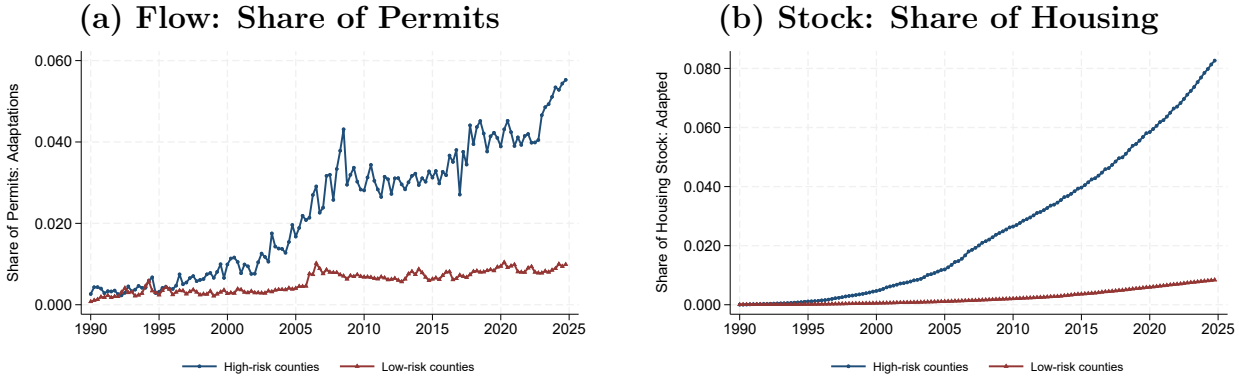
geographic concentration is reassuring: our algorithm identifies features specific to regions facing hurricane and storm risk, rather than picking up generic renovation language.

Figure 1 provides a more systematic test, plotting four measures of adaptation against the NRI storm risk score using binscatters with quadratic fits. Panel (a) shows that the adapted housing stock share rises from near zero in low-risk counties to approximately 2% in the highest-risk counties. Panel (b) shows the adaptation share of renovation permits follows a similar gradient. Panel (c) shows the hedonic price premium for adaptation ranges from approximately 8 log points in low-risk counties to 15 log points in the highest-risk counties, consistent with Proposition 2.1. Panel (d) shows the share of MLS listings mentioning adaptation features rises from roughly 6% to 13% across the risk distribution, exceeding the permit-based shares because listings reflect the cumulative stock of adaptations.

These patterns confirm that our measures capture economically meaningful variation. Adaptation is concentrated where storm risk is highest, the adapted share of stocks, flows, and listings is increasing in risk, and the price premium is larger in riskier areas.

These patterns confirm that our measures capture economically meaningful variation.

Figure 2: Adaptation Quantities Over Time



Notes: Panel (a): adaptation permits as a share of total renovation permits, by quarter. Panel (b): cumulative adapted housing stock as a share of total stock, constructed from permits. High-risk counties defined as FEMA NRI risk value ≥ 0.20.

Adaptation is concentrated where storm risk is highest, the adapted share of stocks, flows, and listings is increasing in risk, and the price premium is larger in riskier areas.

Figures 2 complement the cross-sectional evidence with the time-series dimension. Panel a plots the adaptation share of renovation permits over time, separately for high-risk and low-risk counties. In high-risk counties, the flow share rises gradually from roughly 1% in the early 1990s to about 5–6% by the early 2020s. Low-risk counties remain near zero throughout. Figure 2 plots the cumulative adapted stock share. In high-risk counties, the share rises steadily from near zero to approximately 7–8% over three decades, reflecting the slow accumulation of adapted units through annual permit flows.

4 Empirical results and Calibration

For our baseline calibration, we fix the discount factor $\beta = 0.96$, interest rate $r = 0.96$, CRRA risk aversion paramter $\sigma = 2.0$, income $Y = 1.0$ (normalized), Cobb Douglas consumption share $\kappa = 0.7$ (housing share $= 0.3$).

4.1 Price Premia for Adapted Housing

We estimate adaptation price premia by comparing closed prices of properties with adaptation permits to otherwise similar properties without them. Following the model's distinction between new and old adapted capital, we further separate properties along a second dimension: whether the listing advertises recent renovations. This produces four property types: *renovated adapted* (permit-adapted with advertised renovations, corresponding to new adapted capital $a = 1, v = n$), *non-renovated adapted* (permit-adapted without advertised renovations,

corresponding to old adapted capital $a = 1, v = o$), *renovated non-adapted* (no adaptation permit but advertised renovations, a benchmark for renovation value alone), and *non-renovated non-adapted* (the omitted category). Table 2 reports the results, restricting all columns to high-risk counties.

Columns (1)–(3) progressively saturate fixed effects. The raw adaptation premium of 57.2 log points (column 1) drops to 7.7 with zip × year × month FE (column 2) and is stable at 8.7 with additional age bin controls (column 3). Location drives most of the raw correlation; home age adds little once location and time are controlled. Column (4) decomposes the premium into the four property types. Renovated adapted properties command 10.3 log points, non-renovated adapted properties 8.0, and renovated non-adapted properties 3.9. Adaptation adds roughly 6 percentage points of value beyond renovation alone.

Columns (5)–(6) add property fixed effects, absorbing all time-invariant unobservables at the property level: location, lot characteristics, construction quality, and any other permanent features that may correlate with both adaptation status and price. Identification comes solely from within-property price changes across repeat sales. The pooled adaptation premium under property FE is 6.1 log points (column 5): properties that acquire adaptation permits between sales are revalued upward, net of any fixed property-level confounders. The decomposition (column 6) yields 12.7 for renovated adapted and 6.4 for non-renovated adapted properties, a ratio of roughly 2:1, consistent with the model's prediction that recently adapted capital offers a longer remaining stream of resilience benefits.

Column (7) tests whether the premium changed over time. We split the sample at 2003, estimating separate coefficients for each property type in the pre-2003 and post-2003 periods, with property fixed effects allowed to shift across periods. The result is sharp. Non-renovated adapted properties had a premium of 0.2 log points (insignificant) pre-2003 and 7.4 log points ($p < 0.01$) post-2003. The market was not pricing resilience of existing adapted properties before the early 2000s. Renovated adapted properties rose from 7.4 to 13.5 log points, with the pre-2003 level reflecting renovation quality rather than disaster risk. Because these estimates include property fixed effects, the post-2003 increase cannot be attributed to changes in which properties transact or to unobserved property characteristics; it reflects a genuine within-property revaluation of adaptation.

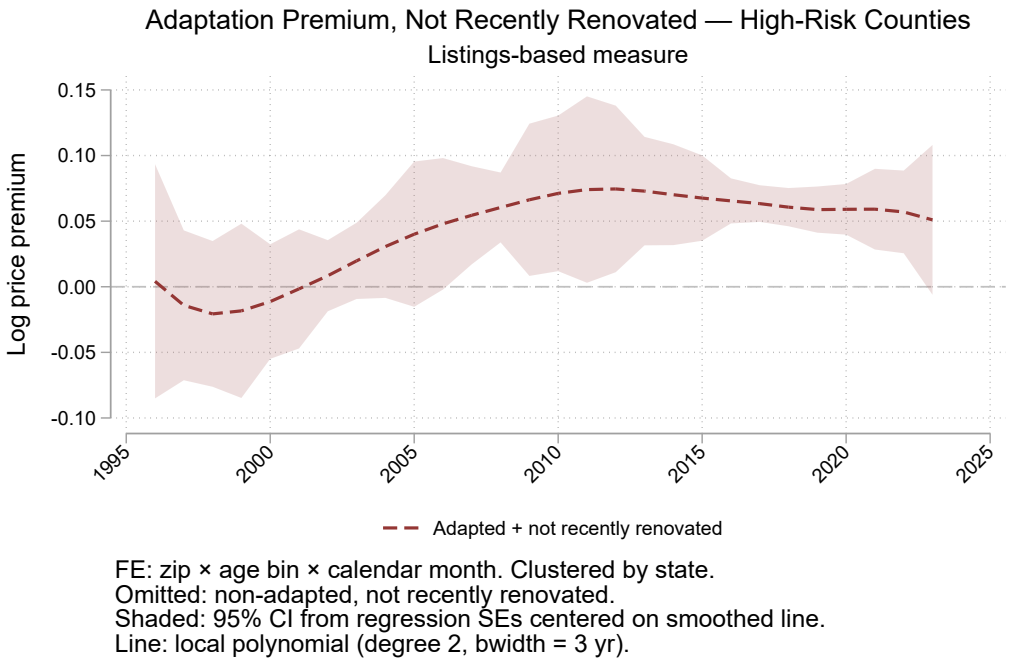
Table 3 decomposes the adaptation premium by housing feature. Each column reports the within-property premium from a separate regression with property FE, zip × year FE, and calendar month FE. Column (1) uses the permits-based measure; columns (2)–(5) use listings-based indicators for specific features. The premia are positive and precisely estimated across all features: 6.2% for the permits-based measure, 6.7% for windows and doors, 7.3% for roof, and 5.4% for garage adaptations. The consistency across features indicates that the

Table 2: Adaptation Price Premium: Permits-Based Measure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Adapted	0.572***	0.077***	0.087***		0.061***		
	(0.125)	(0.001)	(0.001)		(0.001)		
Adapted × Adv. renovations				0.103***		0.127***	
				(0.002)		(0.002)	
Adapted × Not adv. renovations				0.080***		0.064***	
				(0.002)		(0.002)	
Not adapted × adv. renovations				0.039***		0.079***	
				(0.004)		(0.004)	
Adapted × Adv. renovations × Post-2003							0.135***
							(0.002)
Adapted × Not adv. renovations × Post-2003							0.074***
							(0.003)
Not adapted × adv. renovations × Post-2003							0.084***
							(0.004)
Adapted × Adv. renovations × Pre-2003							0.074***
							(0.010)
Adapted × Not adv. renovations × Pre-2003							0.002
							(0.012)
Not adapted × adv. renovations × Pre-2003							0.044***
							(0.007)
R^2	0.018	0.548	0.610	0.549	0.858	0.847	0.847
N	7,347,645	7,297,844	6,527,005	7,297,844	4,644,013	4,707,072	4,197,925
Zip × Year × Month FE		Y	Y	Y	Y	Y	Y
Age Bin FE			Y				
Property FE					Y	Y	Y
Pre/Post-2003 Interactions							Y
Repeat Sales Only					Y	Y	Y

Notes: Dependent variable is log price per square foot (winsorized). "Adapted" indicates a building permit for adaptation work filed before listing. "Adv. renovations" indicates renovation language in MLS text. Omitted category: non-renovated non-adapted properties. All columns restrict to high-risk counties (FEMA NRI risk value ≥ 0.20). Columns (5)–(7) include property fixed effects with repeat sales (≥ 180 days between transactions). Column (7) allows property FE to vary across pre/post-2003 periods. Standard errors clustered by state. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure 3: Adaptation Premium Over Time: Non-Renovated Adapted Properties



Notes: Year-by-year coefficients on *non-renovated adapted* × *year* from a regression with property FE and zip × year × month FE. Adaptation defined via building permits. Line: local polynomial (degree 2, bandwidth 3 years). Shaded: 95% CI from state-clustered SEs. High-risk counties (NRI $\geq$ 0.20), repeat sales ($\geq$ 180 days).

market values resilience broadly rather than pricing a single salient upgrade, and that the permits-based and listings-based measures capture similar underlying variation.

Figure 3 traces the non-renovated adapted premium at annual frequency. The premium hovers near zero through the late 1990s and rises steadily from around 2003–2005, reaching approximately 10 log points by the early 2020s. The timing coincides with the active 2004–2005 Atlantic hurricane seasons and Katrina. These results provide three moments for calibration. The pre-2003 non-renovated adapted premium of zero, combined with externally calibrated depreciation rates δ, implies that the initial destruction channel $x^L(\tau_0 - \tau_1)$ was negligible. The post-2003 premium of 7.4 log points pins down the post-transition probability x^H. The 2:1 vintage ratio between renovated and non-renovated adapted properties identifies the depreciation rate $\delta_{1,n}$ at which new adapted capital transitions to old. Corollary 2.2 further shows that the existence of a premium responsive to disaster risk is consistent with at least partially type-dependent insurance pricing.

Table 3: Adaptation Price Premium by Feature

	(1) Permits	(2) Listings (any)	(3) Windows & Doors	(4) Roof	(5) Garage
Adapted (permits)	0.062***				
	(0.001)				
Any adaptation (listings)		0.047***			
		(0.013)			
Windows & doors (listings)			0.067***		
			(0.006)		
Roof (listings)				0.073***	
				(0.002)	
Garage (listings)					0.054***
					(0.001)
R^2	0.763	0.763	0.763	0.763	0.763
N	5,658,840	5,658,840	5,658,840	5,658,840	5,658,840
Zip × Year FE	Y	Y	Y	Y	Y
Month FE	Y	Y	Y	Y	Y
Property FE	Y	Y	Y	Y	Y

Notes: Dependent variable is log price per square foot. Each column reports the within-property premium for a different adaptation measure. Column (1) uses the permits-based indicator (any adaptation permit filed before listing). Columns (2)–(5) use listings-based indicators from MLS text. All columns include property FE, zip × year FE, and calendar month FE, restricting to high-risk counties (NRI ≥ 0.20). Standard errors clustered by state. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4.2 Permit Costs: Adapted vs. General Renovations

Building permits record the estimated job value of each project, providing a measure of how much landlords spend on adapted vs. general renovations. In the model, the total expenditure per project of type a is $\phi_a(y_a^*) = (\zeta_a/\theta_c)(y_a^*)^{\theta_c}$. Substituting the optimal investment rate $y_a^* = (\beta p_{a,n}/\zeta_a)^{1/(\theta_c-1)}$, the ratio of adapted to non-adapted expenditure per permit is

$$\frac{\phi_1(y_1^*)}{\phi_0(y_0^*)} = \left(\frac{\zeta_0}{\zeta_1}\right)^{1/(\theta_c-1)} \left(\frac{p_{1,n}}{p_{0,n}}\right)^{\theta_c/(\theta_c-1)}. \tag{27}$$

The observed permit cost ratio reflects two opposing forces. Higher marginal costs for adaptation ($\zeta_1 > \zeta_0$) reduce the ratio through the first term: landlords invest less per project when costs are steep. A higher shadow price for adapted housing ($p_{1,n} > p_{0,n}$) increases the ratio through the second term: the greater value of adapted capital encourages more investment. Whether adapted permits are cheaper or more expensive in total depends on which force dominates. The curvature θ_c governs the relative strength of each channel.

To distinguish these forces, we reshape the permit data into a panel where each observation is a county × quarter × feature × type (adapted or general renovation), and regress log average job value on an indicator for adapted permits. Table 4 reports the pooled results with progressive fixed effect saturation. Table A6 reports the same regression estimated

Table 4: Permit Cost Gap: Pooled Across Features

	(1)	(2)	(3)	(4)	(5)
Adapted	–0.619***	–0.740***	–0.641***	–0.715***	–0.481***
	(0.104)	(0.115)	(0.089)	(0.095)	(0.064)
R^2	0.011	0.231	0.500	0.598	0.749
N	814,820	814,820	814,659	814,659	813,968
Feature FE		Y	Y	Y	
County FE			Y	Y	
Quarter FE				Y	Y
Feature × County FE					Y

Notes: Dependent variable is log average job value per permit at the county × quarter × feature × type level. "Adapted" indicates hurricane-adaptation permits. Omitted category: general renovation permits of the same feature. Weighted by the number of permits with non-missing job values. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

separately by housing feature. Table A7 adds a pre/post-2004 interaction to test whether the cost gap changed with rising disaster risk perceptions. All regressions weight by the number of permits with non-missing job values.

Pooling across features (Table 4), adapted permits have average job values roughly 48 log points below general renovation permits in the tightest specification (column 5, feature × county + quarter FE). In levels, this corresponds to adapted permits costing about 62% of general permits. Inverting equation (27), the marginal cost ratio satisfies $\ln(\zeta_1/\zeta_0) = \theta_c \ln(p_{1,n}/p_{0,n}) - (\theta_c - 1)\ln(\phi_1/\phi_0)$. Using the new-housing adaptation premium from Table 2 ($\ln(p_{1,n}/p_{0,n}) \approx 0.05$) and the pooled expenditure gap ($\ln(\phi_1/\phi_0) \approx -0.48$), this implies $\zeta_1/\zeta_0 \approx 2.3$ for $\theta_c = 2.5$, or $\zeta_1/\zeta_0 \approx 1.8$ for $\theta_c = 2.0$. The marginal cost of adaptation is substantially higher than standard renovation, but the lower equilibrium investment rate more than offsets this, producing the observed pattern of cheaper adapted permits. This aggregate gap, however, masks substantial heterogeneity across features.

Table A6 reveals that the cost gap is concentrated in features where adapted and general renovations differ in project scope. For windows and doors, the coefficient is -0.03 and insignificant: within a county, replacing windows with impact-rated products costs approximately the same as replacing them with standard products. Roof shows a similarly negligible gap (-0.02, insignificant). These are the two highest-volume adaptation features, and for both, the per-project cost of adaptation is indistinguishable from the cost of a standard renovation. By contrast, garage (-1.83, $p < 0.01$) and basement (-0.48, $p < 0.01$) show large negative gaps, reflecting the fact that adapted garage work (reinforcing a door) and adapted basement work (installing a storm shelter) are narrower in scope than full garage or basement remodels.

Table A7 shows that the cost gap is stable over time. The post-2004 interaction is small and insignificant for nearly all features, indicating that the relative cost of adaptation did not change as disaster risk perceptions increased. This is consistent with the model, where ζ_a is a structural technology parameter unaffected by beliefs about disaster probability x. The stability of the cost gap contrasts with the large shift in the adaptation price premium (Table 2), reinforcing the interpretation that the post-2004 premium increase reflects a demand-side revaluation of resilience rather than a supply-side change in construction costs.

4.3 Disaster Response and the Damage Function

We estimate the physical protection value of adaptation using a local projection event study around disaster events. The specification is

$$y_{i,t+h} = \alpha_i + \gamma_{r(i),t} + \beta_h \cdot D_{it} + \delta \cdot \log(\text{stock})_{it} + \varepsilon_{i,t+h},$$

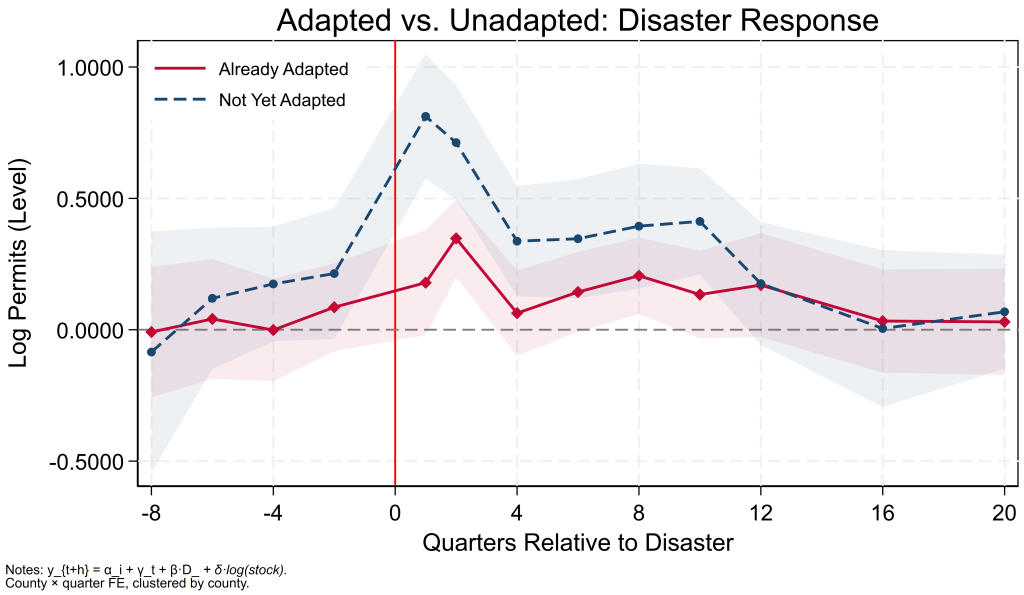
where $y_{i,t+h}$ is log building permits in county i at horizon h, D_{it} is an indicator for a top-100 property-damage disaster, α_i is a county fixed effect, and $\gamma_{r(i),t}$ is a risk-decile $\times$ quarter fixed effect that absorbs time-varying shocks common to counties with similar disaster exposure. We control for log housing stock to account for scale differences across counties. The impulse response $\{\beta_h\}$ traces out the permit response from 8 quarters before to 20 quarters after the disaster, with pre-event coefficients serving as a test of parallel trends. Standard errors are clustered by county.

Figure 4 plots β_h separately for permits on already-adapted and not-yet-adapted properties. The two lines diverge sharply at impact. Permits on unadapted properties spike by approximately 0.8 log points in the quarter after the disaster and remain elevated for roughly 3 years before returning to baseline. Permits on adapted properties show a much smaller response, peaking around 0.2 log points. The gap at impact is approximately 0.6 log points. Pre-event coefficients are near zero for both groups, supporting the parallel trends assumption.

This result identifies the destruction gap in the model. Unadapted properties require substantial post-disaster repair (τ_0 large), while adapted properties largely avoid damage (τ_1 small). The near-zero response of adapted properties is consistent with adaptation providing close to full physical protection: the features identified in our permits data (impact-resistant roofing, storm shutters, reinforced construction) prevent the structural damage that generates repair permits.

A natural concern is that adapted properties may simply be newer, and newer properties suffer less damage regardless of adaptation status or newer properties might be adapted

Figure 4: Disaster Event Study: Adapted vs. Unadapted Properties



Notes: Local projection impulse responses of log building permits to a top-100 disaster event, estimated separately for already-adapted and not-yet-adapted properties. Specification includes county FE, risk-decile × quarter FE, and log housing stock as a control. Shaded areas are 90% confidence intervals from county-clustered standard errors.

because of updated building codes. If so, the gap in Figure 4 could reflect property age rather than the protective effect of private adaptation. Figures 5 and 6 address this by estimating the same specification within property age bins, holding vintage approximately fixed. For new properties (age 0–9), the gap is clean: unadapted spike to roughly 0.65 log points while adapted properties show essentially no response. For properties aged 10–19, the gap is even wider: unadapted reach nearly 0.9 log points at impact while adapted respond modestly (approximately 0.2). Within both age groups, adaptation sharply reduces the permit response. The protection effect is not an artifact of property age.

These estimates discipline two parameters in the calibration. The near-zero permit response of adapted properties pins down $\tau_1 \approx 0$: adaptation provides approximately complete physical protection. The spike for unadapted properties identifies τ_0. Together with the price premia, these moments allow us to separately identify the physical protection value of adaptation (from the event study) and the market's capitalization of that protection (from the premium).

Tables A8 and A9 present these results in regression form with progressive fixed effect saturation. Table A8 reports the disaster coefficient at $h = 2$ and $h = 4$ for permits filed on adapted and unadapted properties. At $h = 2$, unadapted properties see a permit increase

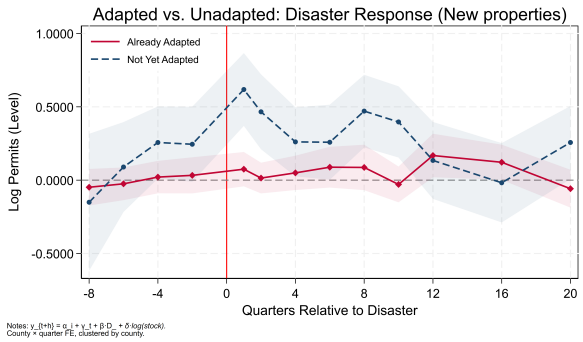


Figure 5: Disaster Response: Age 0–9

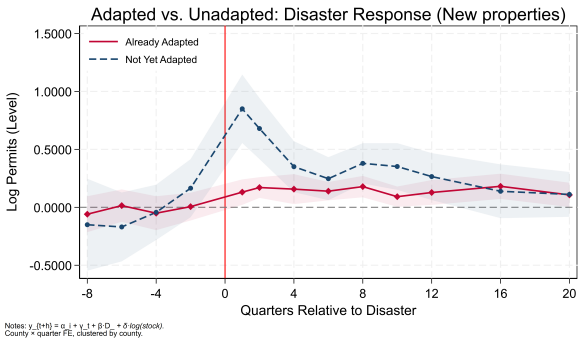


Figure 6: Disaster Response: Age 10–19

Notes: Same specification as Figure 4, estimated separately by property age bin. Left panel: properties aged 0–9 years. Right panel: properties aged 10–19 years.

of 0.77 log points in the most saturated specification (column 4), while adapted properties see 0.35. Both are precisely estimated, and the roughly 2:1 gap is stable across all four columns. At $h = 4$, the responses diverge further: unadapted properties remain elevated at 0.33 log points ($p < 0.05$), while the adapted response has fallen to 0.08 and is statistically indistinguishable from zero. Adapted properties not only suffer less initial damage but recover faster, consistent with the model's prediction that lower τ_1 means less stock needs to be rebuilt.

Table A9 separates the permit response by type of work rather than type of property. General renovation permits spike by 1.03–1.19 log points at $h = 2$, while adaptation permits increase by 0.44–0.50. The general renovation response is roughly double the adaptation response across all specifications. Disasters trigger large-scale repair and reconstruction, but most of this activity restores properties to their pre-disaster condition rather than upgrading them with resilience features. The adaptation response, while positive, is modest relative to the scale of reconstruction. In the model, this asymmetry arises because the adaptation hurdle κ_A and higher adjustment costs $\zeta_1 > \zeta_0$ apply regardless of whether renovation is voluntary or disaster-induced. A disaster pushes landlords past the renovation fixed cost χ^i (damaged properties must be repaired), but it does not change the calculus of whether to adapt during that repair.

4.4 Supply Elasticity of Renovation and Adaptation

We estimate how renovation and adaptation investment respond to exogenous changes in housing prices. The supply elasticity measures how readily the market converts price signals into physical investment. If adaptation faces higher adjustment costs than general renovation, its elasticity should be lower, explaining why the adapted stock adjusts slowly despite rising

premia.

We instrument for housing prices using a Bartik (shift-share) demand shock. The instrument combines county-level industry employment shares from 2000Q1 with leave-one-out state-level industry employment growth:

$$B_{it} = \sum_j s_{ij,0} \cdot g_{-i,j,t},$$

where $s_{ij,0}$ is the employment share of industry j in county i at baseline, and $g_{-i,j,t}$ is the quarter-on-quarter growth rate of industry j employment in county i's state, excluding county i itself. The leave-one-out construction ensures that the instrument is not mechanically correlated with county-level shocks. We cumulate the quarterly flow shocks and take 4-quarter differences to construct the instrument $\Delta_4 B_{it}^{cum}$, which captures the predicted labor demand shock over the past year.

The first stage regresses the change in hedonic renovation prices on the instrument:

$$\Delta_h p_{it} = \alpha_i + \gamma_t + \pi \cdot \Delta_4 B_{it}^{cum} + \mathbf{X}_{it}'\delta + u_{it},$$

where $\Delta_h p_{it} = p_{i,t+h} - p_{it}$ is the change in log hedonic price over horizon h, α_i and γ_t are county and quarter fixed effects, and $\mathbf{X}_{it}$ includes four lags of the dependent variable in changes. The second stage regresses the change in investment on the instrumented price:

$$\Delta_h \iota_{it} = \alpha_i + \gamma_t + \beta \cdot \widehat{\Delta_h p_{it}} + \mathbf{X}_{it}'\delta + \varepsilon_{it},$$

where ι_{it} is log permits per unit housing stock (asinh-transformed). The coefficient β is the supply elasticity: the percentage change in investment per percentage change in price. All specifications weight by log county employment and cluster standard errors by county. For adaptation investment, we use general renovation prices as the endogenous variable and add the Bartik $\times$ disaster risk interaction as a second instrument. The logic is that Bartik shocks raise housing demand generally, and adaptation is one margin along which landlords respond to the resulting price signal.

Figure 8 plots the first-stage relationship: the Bartik shock predicts renovation price changes that grow over horizons, confirming instrument relevance. The F-statistics in Table 5 range from 21 to 64, well above conventional thresholds.

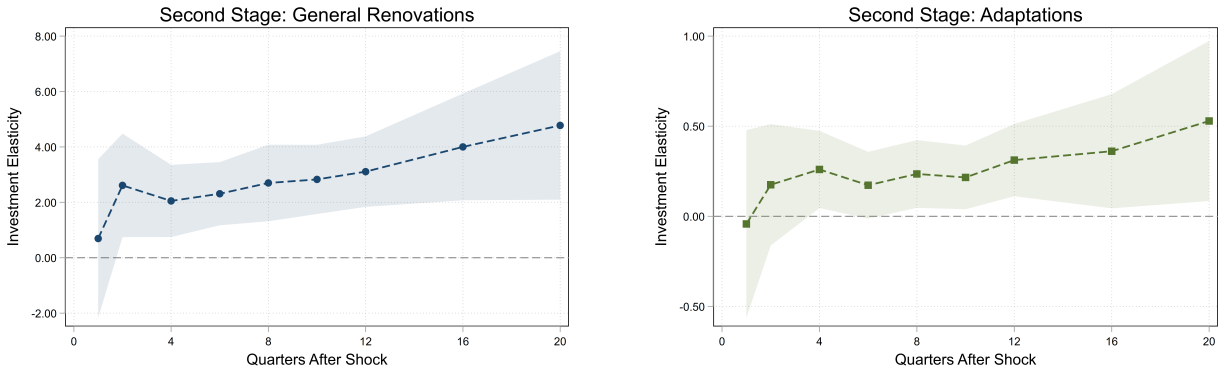
Table 5 reports the second-stage elasticities. The OLS estimate for general renovations is near zero (0.041, column 1), reflecting simultaneity bias: unobserved demand shocks move prices and quantities together, compressing the estimated supply response. Instrumenting with the Bartik shock removes this bias. The IV elasticity for general renovations is 2.6 at

Table 5: Supply Elasticity: General Renovations vs. Adaptations

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	IV	IV	IV	IV	IV
Dep. var.:	General	General	General	Adaptation	Adaptation	Adaptation
Horizon:	$h = 2$	$h = 2$	$h = 4$	$h = 2$	$h = 4$	$h = 4$
Δ Price (General Renovations)	0.041	2.611**		0.188		
	(0.038)	(1.118)		(0.200)		
Δ Price (General Renovations)			2.699***		0.264**	0.285*
			(0.827)		(0.123)	(0.172)
Δ Price (General Renovations) X high risk						–0.513
						(0.734)
First-stage F	.	21.3	63.6	22.5	64.5	1.3
R^2	0.176	–0.008	–0.121	0.219	0.107	0.046
N	30,746	23,991	23,737	23,991	23,737	23,737
County FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Lagged Investment Controls		Y	Y	Y	Y	Y
Weighted by Employment	Y	Y	Y	Y	Y	Y

Notes: Dependent variable is the change in log permits per unit housing stock (asinh-transformed) between t and $t + h$. The endogenous variable in all columns is the change in hedonic price of general renovations over the same horizon. Instrument: Bartik demand shock (columns 2–3), Bartik + Bartik $\times$ disaster risk (columns 4–6). Column (6) adds an interaction of the instrumented price with a high-risk county indicator. All columns weighted by log county employment. Lagged investment controls: four quarterly lags of the dependent variable in changes. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure 7: Supply Elasticity: General Renovations (left) vs. Adaptations (right)



Notes: IV second-stage coefficients from local projection of investment on instrumented general renovation price, plotted at each horizon h. Left panel: general renovation permits (instrument: Bartik). Right panel: adaptation permits (instrument: Bartik + Bartik $\times$ risk). Shaded: 90% CI from county-clustered SEs. Note the difference in y-axis scales: general renovations range from 0 to approximately 8, while adaptations range from -0.5 to 1.

$h = 2$ (column 2, $p < 0.05$) and 2.7 at $h = 4$ (column 3, $p < 0.01$). These are large elasticities: a 10% increase in renovation prices generates a 26–27% increase in renovation permits within one year.

The adaptation elasticity is an order of magnitude smaller. The same price increase generates 0.19 log points of adaptation investment at $h = 2$ (column 4, insignificant) and 0.26 at $h = 4$ (column 5, $p < 0.05$). The ratio of general to adaptation elasticities is roughly 10:1. Column (6) tests whether adaptation responds more strongly in high-risk counties by interacting the instrumented price with a high-risk indicator. The interaction is negative and insignificant (-0.51, $p > 0.10$): the low adaptation elasticity is not driven by low-risk counties where adaptation has little value. Even in disaster-prone areas, the supply response of adaptation to price signals is muted.

Figure 7 plots the second-stage elasticities for both investment types across all horizons. The contrast is visible in the y-axis scales alone: general renovations (left) range from 0 to 8, while adaptations (right) range from -0.5 to 1. The general renovation elasticity rises from about 0.7 at $h = 1$ to 2.6 at $h = 2$, stabilizes around 2.5–3 through $h = 12$, and continues growing at longer horizons. The adaptation elasticity is near zero at $h = 1$, rises to about 0.25 by $h = 4$, and reaches 0.5 only after 5 years. Renovation investment responds quickly and strongly to price signals; adaptation investment responds slowly and weakly. In the model, this gap identifies the higher adjustment cost for adaptation ($\zeta_1 > \zeta_0$) and the fixed hurdle cost κ^A.

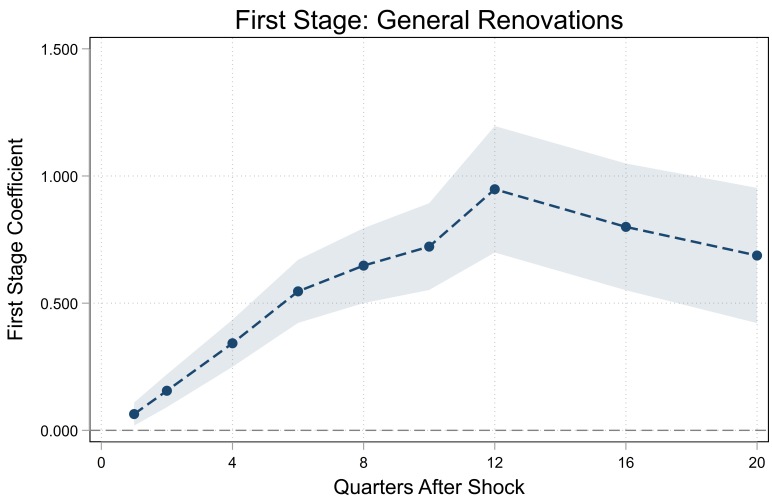


Figure 8: First Stage: Bartik Demand Shock and Renovation Prices

Notes: First-stage coefficients from local projection of the change in hedonic renovation price on the Bartik demand shock, plotted at each horizon h. Specification includes county FE, quarter FE, four lags of investment in changes, weighted by log county employment. Shaded: 90% CI from county-clustered SEs.

5 Calibration

We calibrate the model at an annual frequency. The strategy proceeds in three steps, each tied to a distinct set of observable moments. First, cross-sectional price premia between adapted and non-adapted housing identify the disaster probability and the damage function. Second, the relative volume of adaptation permits disciplines the hurdle cost of adaptation. Third, the dynamic response of construction permits after disasters pins down the cost function curvature. Table 6 collects all parameter values and Table 7 reports the fit.

5.1 Disaster Risk and the Damage Function

The central identification challenge is to recover the disaster probability x and the damage differential $\tau_0 - \tau_1$ from market prices. The adaptation premium—the price gap between otherwise identical adapted and non-adapted properties—provides a direct window into these objects.

For old housing, the shadow price satisfies $p_{a,o} = z_o/[1 - \beta(1 - \delta_{ao} - \tau_a x)]$. Because both types earn the same rent z_o, the premium depends only on the difference in effective depreciation:

$$\ln \frac{p_{1,o}}{p_{0,o}} \approx \frac{\beta\,(\tau_0 - \tau_1)\,x}{1 - \beta(1 - \bar{\delta})}, \tag{28}$$

where $\bar{\delta}$ is an average depreciation rate. The premium is increasing in both the disaster probability x and the damage gap $\tau_0 - \tau_1$. We set $\tau_0 = 0.35$ and $\tau_1 = 0.15$ based on engineering estimates of structural damage to non-adapted and adapted housing in hurricane-prone areas, implying a 20 percentage point damage reduction from adaptation. Given this damage differential, we invert the observed adaptation premium of 7.4 log points to recover $x^H = 0.0251$—a disaster strikes roughly one year in forty.

The premium also depends on the CES weight α through the equilibrium stock composition, which feeds back into rents. We jointly invert α and x^H from the adaptation premium (7.4 log points) and the vintage premium on non-adapted housing (3.9 log points in the data), obtaining $\alpha = 0.373$. The procedure converges in three iterations. The adapted vintage premium (6.78 model vs. 6.10 data) and the non-adapted vintage premium (4.06 model vs. 3.90 data) are close to their targets, though not matched exactly since only two moments pin two parameters.

5.2 Adaptation Volume and the Hurdle Cost

The adaptation premium reveals how the *market* values resilience; the share of adaptation permits reveals how many landlords *act* on that value. In the data, adaptation-related permits account for approximately 4% of total residential construction permits. In the model, this share equals

$$\text{Adaptation permit share} = \frac{\text{frac_adapt} \times y_1}{\text{frac_general} \times y_0 + \text{frac_adapt} \times y_1},$$

where $\text{frac_adapt} = \max(0, \Delta_1 - \kappa_A)/\bar{\chi}$ is the fraction of landlords who choose to adapt. The key lever is the hurdle cost κ_A: raising it shrinks the net surplus from adaptation $\Delta_1 - \kappa_A$, reducing the mass of adapters.

We set $\kappa_A = 0.018$ to match the observed permit share. At this value, the model produces an adaptation permit share of 4.9%, with 1.6% of landlords adapting each period and an equilibrium adaptation share of 6.8% of the housing stock. The net surplus from adaptation is small: $\Delta_1 - \kappa_A = 0.003$, compared to $\Delta_0 = 0.035$ for general renovation. This implies that the hurdle cost consumes 85% of the gross adaptation surplus, leaving adaptation profitable only for landlords with very low fixed costs.

The cost ratio $\phi_1/\phi_0 = 0.61$ is close to its data counterpart of 0.62. Despite higher per-unit costs—adapted investment costs 11% more per unit than non-adapted ($\phi_1/y_1 = 0.326$ vs. $\phi_0/y_0 = 0.294$)—the total adjustment cost for an adapting landlord is lower in absolute terms because adapted investment operates at a smaller scale ($y_1 = 0.065$ vs. $y_0 = 0.118$).

5.3 Cost Function Curvature and Dynamics

The curvature of the adjustment cost function $\phi(y) = (\zeta/\theta_c)\, y^{\theta_c}$ governs how quickly the housing stock adjusts after shocks. With the uniform fixed-cost distribution, the aggregate supply elasticity equals $(\theta_c+1)/(\theta_c-1)$. We target an elasticity of approximately 3, consistent with estimates from the literature, which implies $\theta_c = 2$.

The scale parameters $\zeta_0 = 5$ and $\zeta_1 = 10$ jointly determine the level of investment in each housing type and the speed of recovery after disasters. Setting $\zeta_1/\zeta_0 = 2$ reflects the greater complexity of adapted construction. The upper bound of the fixed cost distribution, $\bar{\chi} = 0.204$, is set to generate a renovation rate of 17%, close to the 20% observed in the data.

We assess the dynamic implications through the generalized impulse response function (GIRF), which traces the permit response after a disaster realization at $SS(x^H)$. The model captures the medium-run dynamics well: at horizons of 1–3 years, model and data general permit responses are closely aligned (0.35 vs. 0.46 at year 1; 0.31 vs. 0.38 at year 2; 0.22 vs. 0.24 at year 3). Two features of the data are harder to match. First, the impact response is attenuated in the model (0.70 vs. 1.08), likely because the model lacks construction delays that would concentrate permit issuance in the immediate aftermath. Second, the data show persistent permit elevation at year 5 (0.45) that the model cannot generate, as the GIRF converges to steady state; this may reflect slow-moving regulatory or insurance changes not captured in the model.

As an out-of-sample validation, Figure 9 overlays the model's permit IRFs from two extreme counterfactual economies against property-level permit data split by adaptation status. The no-adaptation economy ($\kappa_A \to \infty$) is compared to permits issued to unadapted properties, and the full-adaptation economy ($\tau_0 = \tau_1$, $\kappa_A = 0$) to permits issued to adapted properties. The model captures the key qualitative pattern: unadapted properties exhibit a large, front-loaded permit response that decays over several years, while adapted properties show a muted and flatter response. Quantitatively, the model tracks the adapted-property IRF well but understates the impact response for unadapted properties, consistent with the attenuation noted in the general permit IRF.

5.4 External Parameters

Several parameters are set to standard values from the literature. The discount factor $\beta = 0.96$ implies a 4.2% annual discount rate. Risk aversion $\sigma = 2$ is in the middle of the range commonly used in macro models. The consumption share $\kappa = 0.70$ implies that housing services account for 30% of expenditure. The CES substitution parameter $\rho = 0.5$ implies an elasticity of substitution between new and old housing of 2. Depreciation rates—$\delta_{0n} = 0.05$,

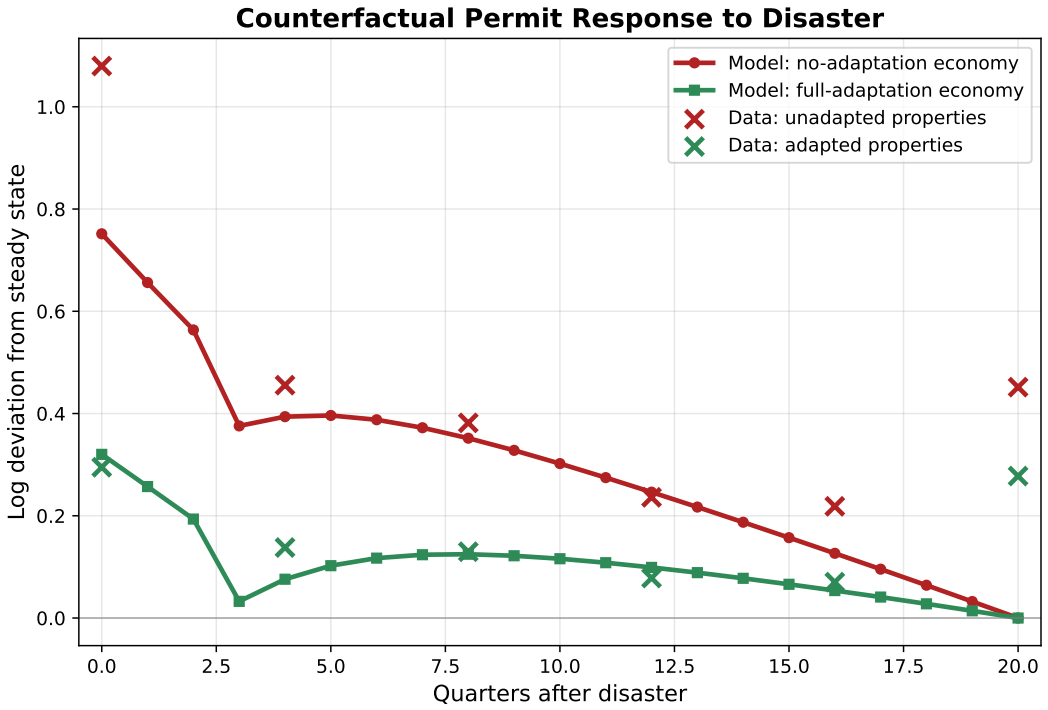


Figure 9: Out-of-sample validation: permit IRFs from counterfactual economies vs. property-level data. Red: no-adaptation economy (model) and unadapted property permits (data). Green: full-adaptation economy (model) and adapted property permits (data).

$\delta_{1n} = 0.03$ for the new-to-old transition, and $\delta_{0o} = \delta_{1o} = 0.02$ for permanent depreciation of old housing—are set to reflect the slower aging of adapted structures.

6 Model Results

We use the calibrated model to study three counterfactual exercises centered on a permanent regime shift in disaster probability from $x_l = 0.001$ to $x_h = 0.025$. First, we characterize how adaptation responds endogenously to the climate transition. Second, we quantify the welfare value of adaptation technology by comparing the baseline economy to one where adaptation is unavailable. Third, we evaluate the scope for adaptation subsidies financed by lump-sum taxation.

6.1 Adaptation Response to the Climate Regime Shift

We model the climate transition as an MIT shock: at $t = 0$, agents learn that disaster probability has permanently increased from x_l to x_h. Figure 10 displays the transition dynamics.

Table 6: Calibrated Parameters

Parameter	Description	Value
Panel A: Preferences & Technology		
β	Discount factor	0.960
σ	Risk aversion (CRRA)	2.0
κ	Consumption weight in utility	0.70
α	CES weight on new housing	0.3731
ρ	CES substitution parameter	0.50
Panel B: Disaster Risk		
x^H	Annual disaster probability (post-2003)	0.0251
x^L	Annual disaster probability (pre-2003)	0.0010
τ_0	Non-adapted destruction share	0.35
τ_1	Adapted destruction share	0.15
γ	Insurance parameter	1.00
Panel C: Depreciation		
δ_{0n}	Non-adapted, new $\rightarrow$ old	0.050
δ_{1n}	Adapted, new $\rightarrow$ old	0.030
δ_{0o}	Non-adapted, old depreciation	0.020
δ_{1o}	Adapted, old depreciation	0.020
Panel D: Renovation Costs		
ζ_0	General adjustment cost scale	5.0
ζ_1	Adaptation adjustment cost scale	10.0
θ_c	Cost curvature	2.0
$\bar{\chi}$	Fixed cost upper bound	0.2036
κ_A	Adaptation hurdle cost	0.0180

Notes: α and x^H are jointly inverted from the adapted–old housing premium (7.4 log pts) and the renovated housing premium (3.9 log pts). $\bar{\chi}$ is set to match a 20% renovation rate. All other parameters are set based on prior information or manual calibration.

At the initial steady state $SS(x_l)$, adaptation is essentially absent. The surplus from adapted investment, Δ_1, barely exceeds the hurdle cost $\kappa_A = 0.018$, leaving a net gain of only $\Delta_1 - \kappa_A \approx 0$, so virtually no landlords find it profitable to adapt. The renovation rate is 13.8%, but all of it flows into standard (type-0) housing.

The regime shift changes the calculus. Higher disaster risk raises the shadow value of resilient housing: the adaptation premium on old housing—$\ln(p_{1,o}/p_{0,o})$—overshoots from 0.3 to 8.0 log points on impact before settling to 7.4 at $SS(x_h)$ (panel g), and the premium on new housing follows a similar pattern, jumping from 4.4 to 12.6 and converging to 10.1 log points. The vintage premium (panel h), by contrast, *falls* sharply: the non-adapted vintage premium drops from 15.9 to 4.1 log points between steady states. With elevated destruction risk, new housing depreciates into old more quickly, compressing the quality gap between new and old vintages.

Table 7: Moment Fit

Moment	Model	Data
Panel A: Price Premia (log points)		
Adapted vs. non-adapted (old housing)	7.40	7.40
Renovated vs. old (non-adapted)	4.06	3.90
Renovated vs. old (adapted)	6.78	6.10
Panel B: Supply & Renovation		
Supply elasticity (total, PE)	3.00	2.70
Renovation rate	0.170	0.200
Adaptation permit share (%)	4.9	4.0
Cost ratio ϕ_1/ϕ_0	0.612	0.620
Panel C: Disaster IRF — General Permits		
General permits, $h = 0$ (year 0)	0.701	1.080
General permits, $h = 4$ (year 1)	0.349	0.456
General permits, $h = 8$ (year 2)	0.314	0.382
General permits, $h = 12$ (year 3)	0.217	0.236
General permits, $h = 16$ (year 4)	0.110	0.218
General permits, $h = 20$ (year 5)	0.000	0.452
RMSE	0.250	

Notes: Panel A premia are matched by construction via joint inversion of α and x^H. The supply elasticity equals $(\theta_c + 1)/(\theta_c - 1)$ with the uniform fixed-cost distribution. The cost ratio is the average adjustment cost per adaptation permit relative to per general permit: $\phi_1(y_1^*)/\phi_0(y_0^*)$.

Despite the immediate repricing of adaptation value, the extensive-margin response is gradual. The adaptation rate remains near zero for roughly the first 10 periods, then rises slowly and reaches its half-life only at $t \approx 21$ (panel b). This lag reflects the forward-looking nature of investment: the adaptation cutoff $\chi_1^* = \Delta_1 - \kappa_A$ depends on the shadow price of adapted new housing, which itself adjusts gradually as the stock composition evolves. The general renovation rate initially *dips* from 13.8% to 12.9% on impact—as old housing becomes relatively less scarce in the short run—before rising to its new steady state of 17.0%. The share of adaptation permits in total permits reaches 8.4% at the new steady state (panel c). The adaptation share of the housing stock is a slow-moving state variable: it reaches only 3.0% at $t = 60$ and 5.1% at $t = 100$, still short of its terminal value of 6.8% (panel a).

Rents rise during the transition (panel d) as housing becomes scarcer, with old housing rents increasing by 42%—roughly double the 18% increase in new housing rents—reflecting the disproportionate destruction of old housing under higher disaster risk. The housing aggregate falls by 26% between the two steady states (panel e). On the intensive margin, adapted investment y_1 rises by 5% on impact (panel f), while non-adapted investment y_0 initially falls by 3% before gradually increasing. This asymmetry is consistent with the immediate repricing of adaptation value: the shadow price of adapted new housing $p_{1,n}$ jumps

and opens a persistent gap above $p_{0,n}$ (panel i).

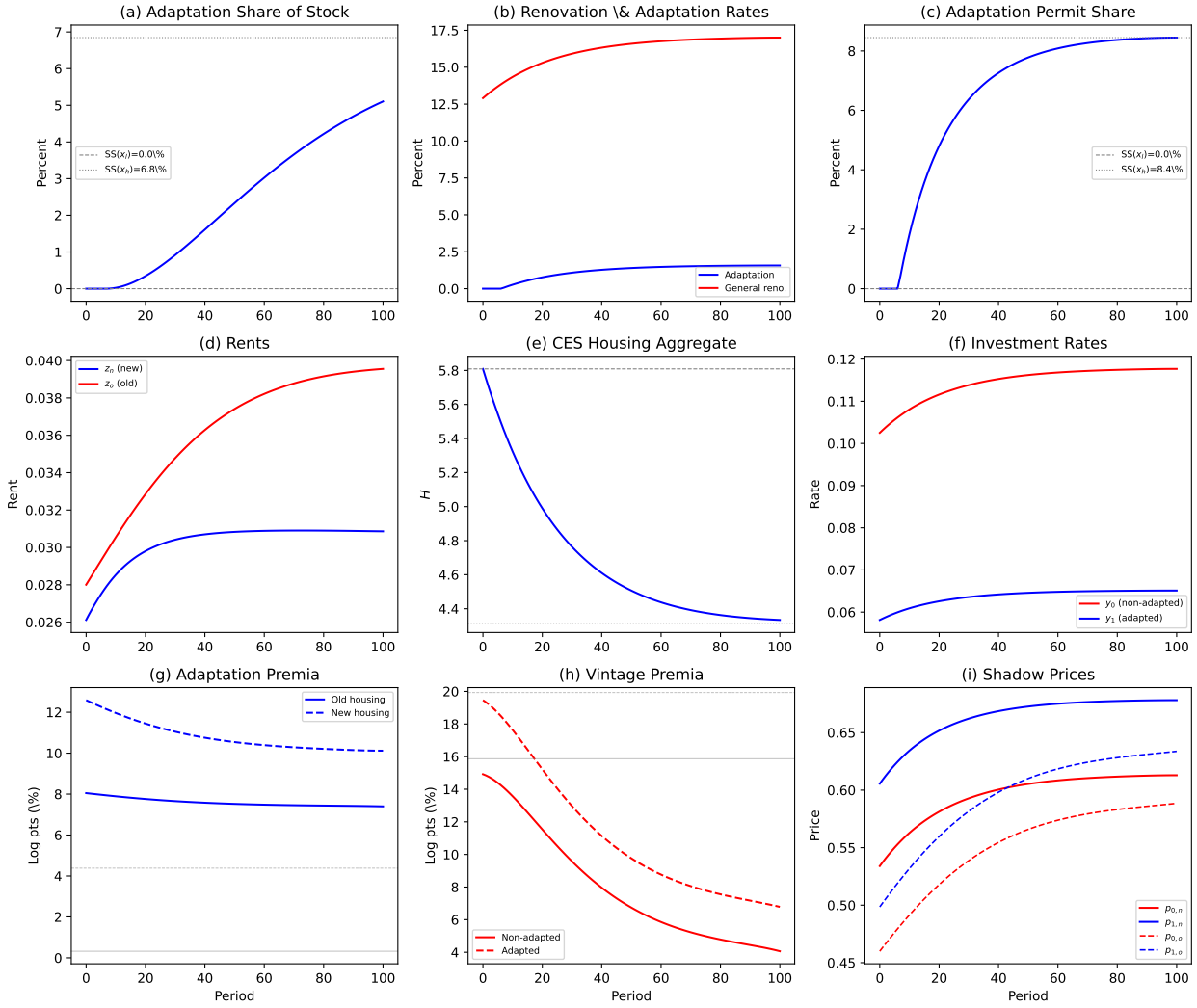


Figure 10: Baseline transition dynamics following a permanent increase in disaster probability from $x_l = 0.001$ to $x_h = 0.025$. Dashed gray lines indicate the initial steady state $SS(x_l)$; dotted gray lines indicate the terminal steady state $SS(x_h)$.

6.2 Welfare Value of Adaptation

To measure the welfare value of adaptation technology, we compare the baseline economy to a counterfactual where adaptation is prohibitively costly ($\kappa_A \to \infty$), so that only standard renovation occurs. Welfare is computed as the expected present discounted value of utility at each steady state, accounting for the full dynamic cost of disaster events through the generalized impulse response function (GIRF).

Specifically, steady-state welfare is

$$W = \frac{u_{ss} + x \cdot \Delta W}{1 - \beta}, \tag{29}$$

where u_{ss} is the period utility at the deterministic steady state and $\Delta W = \sum_{s=0}^{T} \beta^s [u(C_s^{\text{girf}}, H_s^{\text{girf}}) - u_{ss}]$ is the present discounted welfare cost of a single disaster event. The GIRF captures the full multi-period recovery: housing stocks are destroyed on impact and rebuild gradually with a half-life of approximately 20 periods. Income drops by 2.5% on impact and recovers via an AR(1) process.

Figure 11 illustrates the comparison. Panel (a) shows that the baseline economy maintains a modestly higher housing aggregate than the no-adaptation counterfactual along the transition. Panel (b) displays the GIRF recovery paths at $SS(x_h)$: with adaptation, the initial housing destruction is smaller and recovery proceeds slightly faster. The per-disaster welfare cost is $\Delta W = -1.35$ with adaptation versus -1.46 without—the no-adaptation disaster is 8% more costly.

Our summary metric compares steady-state welfare across regimes:

$$\text{Mitigation} = 1 - \frac{W(x_l) - W(x_h, \text{adapt})}{W(x_l) - W(x_h, \text{no adapt})}. \tag{30}$$

This measures the fraction of the total regime-shift welfare loss that is absorbed by having access to adaptation technology. In the baseline calibration, adaptation mitigates 7.3% of the welfare loss from the climate transition. This reflects the modest equilibrium adaptation share of 6.8%: most of the housing stock remains non-adapted, so the aggregate resilience gain is limited.

6.3 Adaptation Subsidies

The modest equilibrium adaptation share suggests scope for policy intervention. We consider a subsidy that covers a fraction $s \in [0, 0.5]$ of the *variable adjustment cost* for adapted investment, $\phi_1(y_1) = (\zeta_1/\theta_c) y_1^{\theta_c}$. Landlords face an effective cost $(1 - s)\phi_1(y_1)$, equivalent to operating with $\zeta_1^{\text{eff}} = (1 - s)\zeta_1$. The subsidy is financed by a lump-sum tax on the representative household, with fiscal cost $\text{Tax}_t = s \cdot \phi_1(y_{1,t})$ per period. We solve for the transition equilibrium iterating to a fixed point between the tax and the endogenous adaptation rate.

Unlike a subsidy to the fixed hurdle cost κ_A—which operates solely through the extensive margin—the variable-cost subsidy works through both margins simultaneously. On the

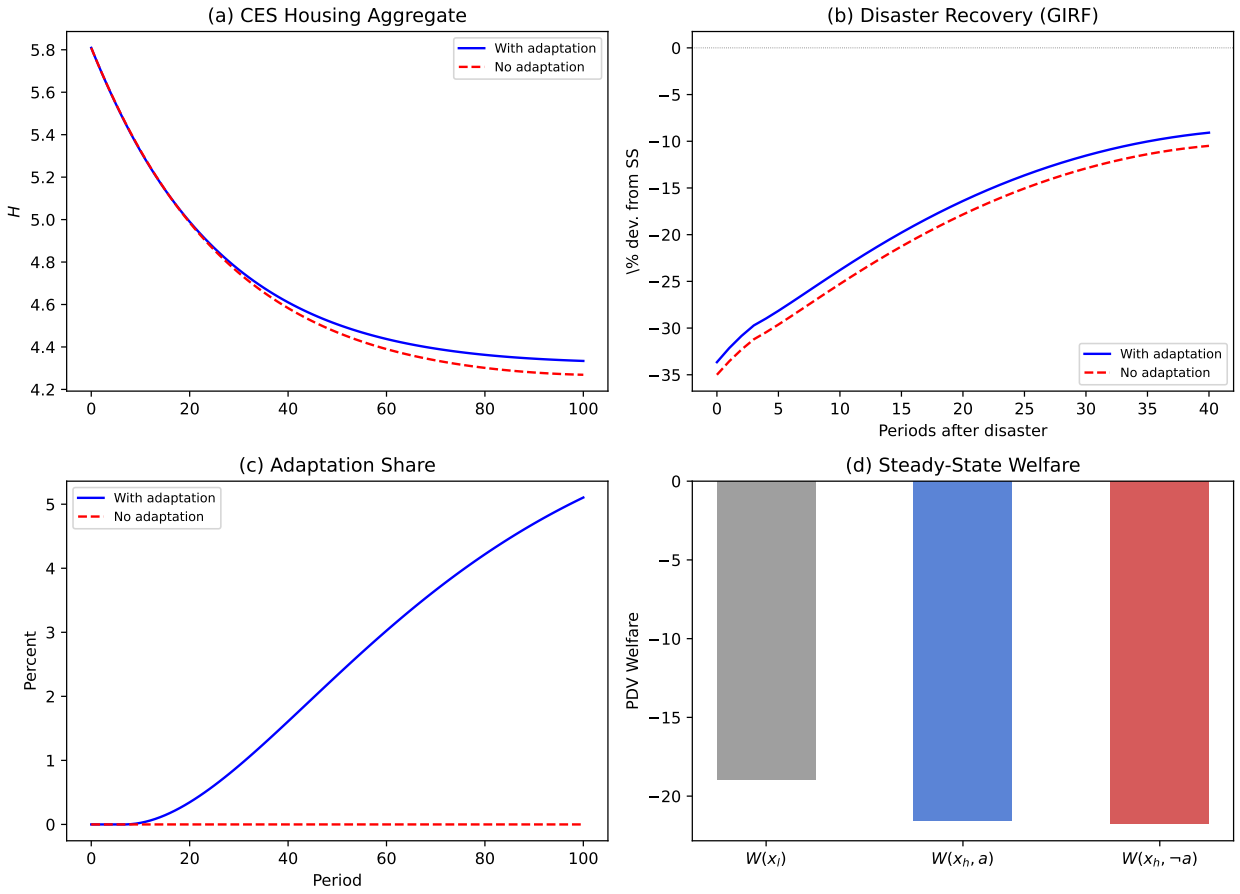


Figure 11: Welfare comparison: baseline economy with adaptation versus no-adaptation counterfactual. Panel (b) shows the GIRF housing recovery path after a single disaster at $SS(x_h)$. Panel (d) displays steady-state PDV welfare including disaster risk.

intensive margin, each adapting landlord invests more: the optimal rate rises from $y_1 = 0.065$ at $s = 0$ to 0.082 at $s = 25\%$ and 0.110 at $s = 50\%$. On the extensive margin, the higher investment rate raises the surplus Δ_1 and therefore the adaptation cutoff $\chi_1^* = \Delta_1 - \kappa_A$, drawing in more landlords. This dual channel produces a convex relationship between the subsidy rate and the adaptation share.

Table 8 and Figure 12 report the results. A 25% subsidy more than triples the terminal adaptation share from 5.1% to 17.5%, while a 50% subsidy raises it to 41.3%. The welfare mitigation metric rises from 7.3% at $s = 0$ to 20.6% at $s = 25\%$ and 49.0% at $s = 50\%$ (panel a of Figure 12)—at the highest subsidy rate, nearly half of the regime-shift welfare loss is absorbed. The mitigation curve is convex, reflecting the dual-margin amplification: as ζ_1 falls, both the number of adapters and their investment intensity increase, reinforcing each other through higher adapted stock and lower equilibrium destruction.

The fiscal cost grows more than linearly with s (panel c), from 0.03% of income at $s = 25\%$

to 0.16% at $s = 50\%$. This reflects the fact that the subsidy applies to a larger investment volume (y_1 is higher) by a larger mass of adapters, so costs scale with the product of both margins. Nevertheless, even at $s = 50\%$ the fiscal burden is small in absolute terms.

Figure 13 displays transition paths for selected subsidy rates. The subsidized economies converge to substantially higher adaptation shares and higher housing aggregates, with the differences growing over time as the stock composition shifts. Period utility is higher under the subsidy despite the lump-sum tax, because the housing quality improvement more than compensates for the fiscal burden.

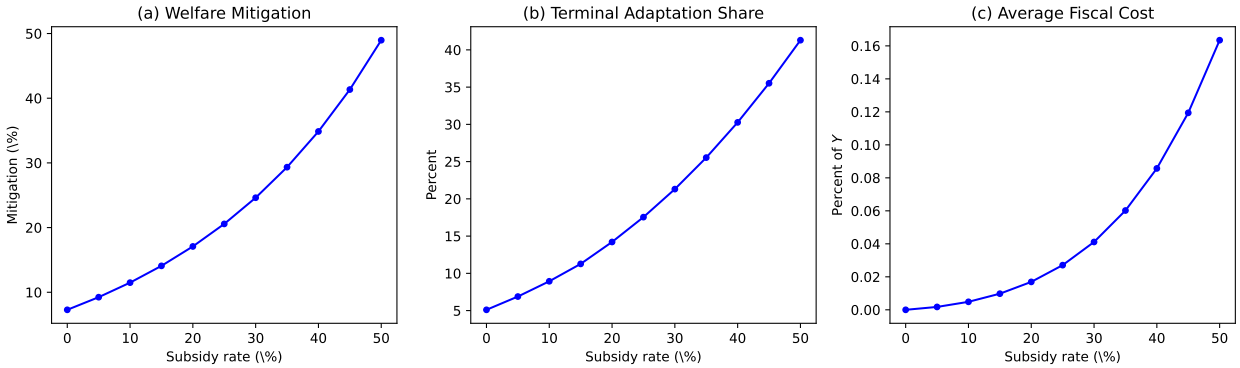


Figure 12: Adaptation subsidy analysis for $s \in [0, 50\%]$. Panel (a): mitigation of regime-shift welfare loss. Panel (b): terminal adaptation share of the housing stock. Panel (c): average fiscal cost as a fraction of income.

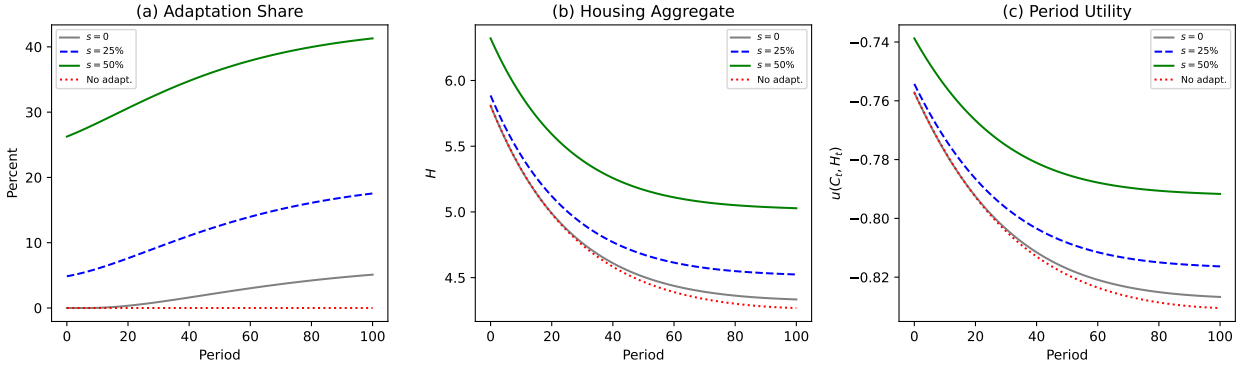


Figure 13: Transition dynamics under selected subsidy rates. All paths start from $SS(x_l)$ and converge to $SS(x_h)$ under the respective policy.

7 Conclusion

This paper studies the private adaptation of housing to rising natural disaster risk. We develop a model in which landlords choose between standard and climate-adapted renovation,

Table 8: Variable-Cost Adaptation Subsidy: Welfare and Mitigation

Subsidy s	Adapt. Share (%)	y_1	Avg. Tax (% of Y)	Mitigation (%)
No adaptation	0.0	—	—	0.0
0%	5.1	0.0651	0.0000	7.3
5%	6.9	0.0680	0.0017	9.2
10%	8.9	0.0711	0.0048	11.5
15%	11.3	0.0746	0.0098	14.1
20%	14.2	0.0783	0.0169	17.1
25%	17.5	0.0823	0.0271	20.6
30%	21.3	0.0867	0.0411	24.6
35%	25.5	0.0916	0.0602	29.3
40%	30.3	0.0970	0.0857	34.9
45%	35.5	0.1029	0.1194	41.3
50%	41.3	0.1096	0.1634	49.0

Notes: The subsidy covers fraction s of the adjustment cost $\phi_1(y_1) = (\zeta_1/\theta_c)y_1^{\theta_c}$ for adapted investment, financed by a lump-sum tax. Adaptation share is at transition horizon $t = 100$. Mitigation $= 1 - [W(x_l) - W(x_h, s)]/[W(x_l) - W(x_h, \text{no adapt})]$. Welfare includes the full dynamic cost of disaster events via the GIRF.

and calibrate it using novel property-level data on building permits and home prices that distinguish adapted from non-adapted properties. The calibrated model captures the price premia, permit dynamics, and differential disaster responses observed in the data.

Three findings stand out. First, adaptation to a permanent increase in disaster risk is slow. Shadow prices reprice immediately, but the housing stock takes over a century to approach its new composition, because adaptation depends on the gradual turnover of the existing stock. Second, the welfare value of adaptation technology is modest in laissez-faire: it mitigates only 7 percent of the welfare cost of the regime shift, reflecting the small equilibrium share of adapted housing. Third, subsidies to the variable cost of adapted investment are effective at accelerating the transition, operating through both the intensive and extensive margins simultaneously. A 50 percent subsidy absorbs nearly half of the welfare loss at a fiscal cost below 0.2 percent of income.

Several extensions deserve attention. The model assumes a representative household and abstracts from heterogeneity in income, location, or risk exposure. Introducing these features could generate distributional implications for adaptation policy that our framework does not capture. The model also lacks congestion in the construction sector, which would temper the returns to large subsidies, and treats disaster risk as known with certainty, ruling out learning dynamics that likely shape real-world adoption. Finally, the interaction between private adaptation and public infrastructure investment—seawalls, drainage systems, building

codes—is absent from our analysis but central to the policy debate. We leave these directions for future work.

Appendix A: Data Construction: Supporting Tables and Figures

Table A1: Most Frequently Mentioned N-Grams in Listings Data

N-Gram	Count	N-Gram	Count
kitchen with	7306963	move in	2630412
living room	6733968	brand new	2629754
family room	6593755	the master	2593957
close to	6340472	formal dining room	2567785
master suite	4658427	3 bedroom	2558929
floor plan	4595306	back yard	2551102
2 car	4569477	lower level	2493851
master bedroom	4458243	hardwood floors	2492958
open floor plan	4430996	great room	2459949
open floor	4310402	the main	2415697
stainless steel	3968032	bath home	2397683
access to	3789957	living room	2396774
located in	3776205	master bath	2289393
dining room	3543646	located on	2269827
car garage	3496368	2 bath	2155179
formal dining	3489161	suite with	2147957
stainless steel appliances	3451962	bath with	2136370
walk in	3413748	car garage	2120303
hardwood floors	3332960	the living	2115358
the kitchen	3291260	kitchen has	2076047
bedrooms and	3203968	yard with	2033679
kitchen and	3166061	dining room	2031900
built in	2880124	bedroom with	1971255
home features	2794246	garage with	1961782
full bath	2693820	first floor	1955113

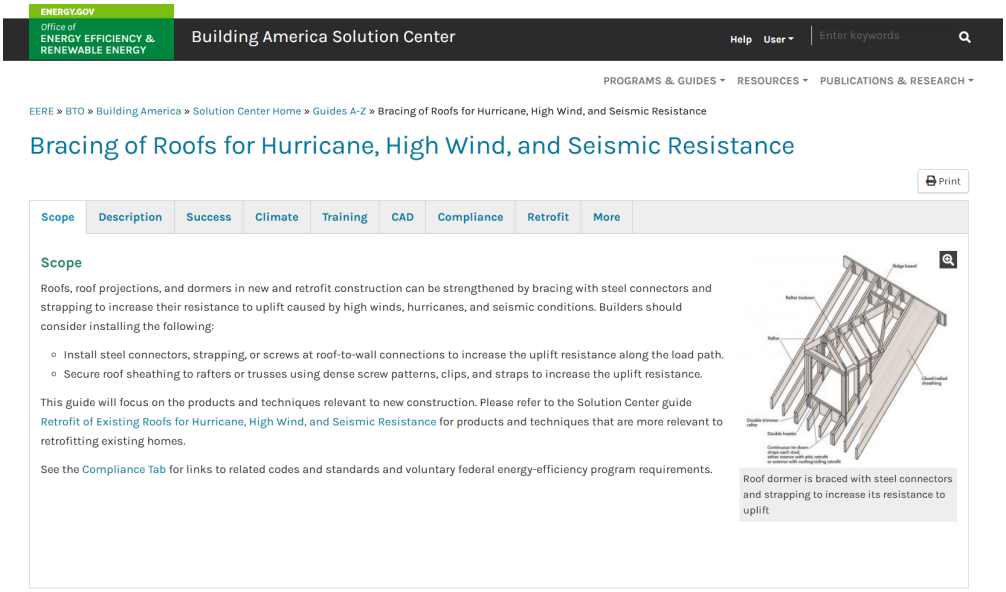
Notes: Most frequent bigrams and trigrams in CoreLogic MLS listings data. We exclude n-grams consisting solely of stop words (e.g., "the," "of," "and") or generic combinations like "this home" and "room and."

Appendix B: *

References

Bakkensen, L. and L. Barrage (2018). Climate shocks, cyclones, and economic growth: Bridging the micro-macro gap. Working Paper 24893, National Bureau of Economic Research.

Figure A1: Sample BASC Webpage



Notes: Example of expert-curated building guidance from the Department of Energy's Building America Solution Center. Complete resource guides available at `https://basc.pnnl.gov/resource-guides`.

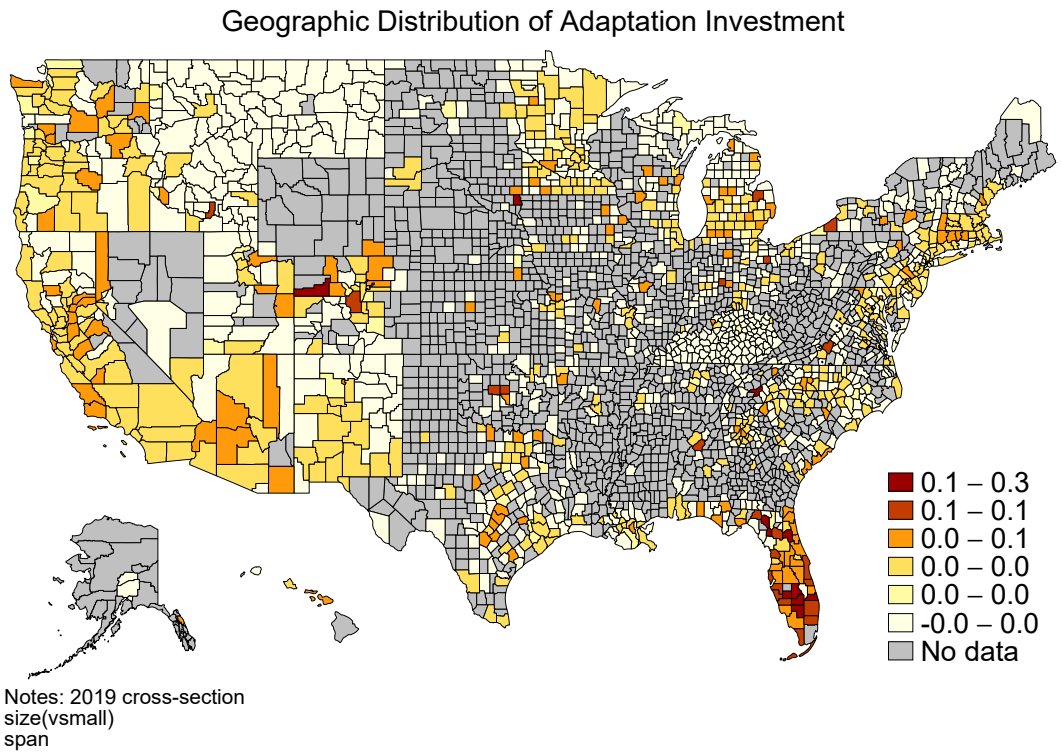
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Engle, R. F., S. Giglio, B. Kelly, H. Lee, and J. Stroebel (2020). Hedging climate change news. *The Review of Financial Studies 33*(3), 1184–1216.

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Figure A2: Geographic Distribution of Adaptation Investment



Notes: Share of renovation permits involving adaptation features, 2019 cross-section. Counties with fewer than 1,000 housing units or fewer than 10 mean quarterly permits are excluded. Darker shading indicates higher adaptation shares.

Table A2: Top N-Grams by Log-Odds of Appearing in Hurricane-Related Documents

N-Gram	Log-Odds	N-Gram	Log-Odds
hurricane rated doors	.719	installed hurricane shutters	.423
doors hurricane	.669	storm shelter right	.421
hurricane rated door	.667	storm shelter located	.417
hurricane proof doors	.63	built-in storm shelter	.417
hurricane proof windows	.587	roll-down hurricane shutters	.416
hurricane resistant windows	.551	hurricane shutters -	.412
metal roof	.55	huge storm shelter	.411
doors w storm	.535	storm shelter just	.411
hurricane proof garage	.527	safe storm shelter	.41
hurricane-rated garage door	.515	roof hurricane	.408
tornado shelter options	.51	hurricane windows doors	.407
roof metal	.508	hurricane shutters protect	.407
- hurricane shutters	.502	gutters hurricane	.405
storms doors	.501	sliding hurricane shutters	.403
hurricane doors	.498	hurricane shutter panels	.394
hurricane impact doors	.494	hurricane shutters installed	.394
tornado safe features	.479	safe storm room	.394
doors storm	.474	manual hurricane shutters	.394
metal siding roof	.467	basement storm shelter	.393
metal hurricane shutters	.457	hurricane garage doors	.392
indoor storm shelter	.452	metal seam roof	.392
siding hurricane	.451	nice storm shelter	.391
shutters hurricane	.45	fabric hurricane shutters	.388
tornado safety features	.449	hurricane panels included	.388
storm shelter storage	.449	storm shelter -	.388
hurricane impact door	.449	in-ground tornado shelter	.388
panel hurricane shutters	.448	complete hurricane shutters	.386
windows hurricane shutters	.447	patio hurricane shutters	.384
storm safe room	.44	metal shingled roof	.382
metal porch roof	.44	hurricane shutter protection	.382
storm shelter area	.437	person tornado shelter	.382
storm shelter room	.436	w tornado safety	.381
hurricane resistant garage	.436	storm shelter installed	.381
automatic hurricane shutters	.432	closet storm shelter	.38
storage storm shelter	.431	storm shelter basement	.379
doors including storm	.43	room storm shelter	.378
shutters impact glass	.427	hurricane window coverings	.376
exposed chimney	.426	plywood sheathing	.376
installed storm shelter	.425	storm shelter inside	.372

Notes: Log-odds represent the relative probability of an n-gram appearing in hurricane-related versus non-hurricane BASC webpages. We exclude redundant trigrams containing shorter bigrams (e.g., removing "metal roof siding" given "metal roof") and n-grams with ambiguous meaning (e.g., "a tornado"). Manual review ensures included terms reflect adaptation features rather than damage descriptions.

Table A3: Sample CoreLogic MLS Listing

Variable	**Value**
Public Remarks	Great Single Story family home, featuring 3 BR 2 Bath with a 2 Car Garage and covered Lanai. This open floor plan allows for ample room for your comfort and enjoyment. Neutral colors throughout. Kitchen offers stainless steel appliances, 42" Linen White cabinets, breakfast area, walk in pantry, and granite tops included throughout the home. Tile in the common areas and carpet in the bedrooms. **Elegant Glass Impact front door**, Many upgrades. Located in N Naples, Excellent schools, close to shopping, short drive to beaches, etc. A must see! Call for appointment or visit Open House on Sundays
Material Description	Concrete Block, Poured Concrete
Roof Type	Tile
Exterior Description	Stone, Stucco
Exterior Features	Room for Pool, Sprinkler Auto
Porch Description	Open
Garage Description	Attached
Flooring Description	Carpet, Tile
Interior Features	Foyer, High Speed Available, Laundry Tub, Pantry, Volume Ceiling, Walk-In Closet
Cooling Description	Ceiling Fans, Central Electric
Heat Description	Central Electric
Appliances Description	Auto Garage Door, Dishwasher, Disposal, Dryer, Microwave, Range, Refrigerator/Icemaker, Security System, Self Cleaning Oven, Smoke Detector, Washer
Green Energy Features	Ceiling Fans
Architectural Description	1 Story/Ranch
Property Style	Ranch

Notes: Representative MLS listing from Naples, Florida. The listing description mentions "Glass Impact front door" (bolded), which our algorithm identifies as an adaptation feature based on co-occurrence of door-related keywords and "impact" within the same sentence. Additional property characteristics shown when non-missing.

Table A4: Sample CoreLogic Building Permit

Variable	**Value**
City	Fort Lauderdale
State	FL
Property Usage	Single Family
Project Name	Windows and Doors Replacement
Permit Category	Residential structural application
Project Description	Doors and Windows, Residential
Permit Description	**Replacing non impact windows and doors with impact. Retrofit. 13 windows and 5 doors**
Job Value	$40,070
Permit Filing Fees	$945
Permit Effective Date	2/10/2021
Permit Status	Final
Contractor Type	General Contractor
Property Type	Single Family Residence

Notes: Representative building permit for adaptation retrofit in Fort Lauderdale, FL. The permit description (bolded) clearly indicates replacement of standard windows and doors with impact-resistant versions. Property identifiers removed for confidentiality. Additional permit details included when available.

Table A5: Disaster Response: Permits by Property Adaptation Status

	(1)	(2)	(3)	(4)
Panel A: $h = 2$ quarters after disaster				
Dep. var.: Log permits on **adapted** properties				
Disaster event	0.4633**	0.4744***	0.4127***	0.3510***
	(0.1801)	(0.1376)	(0.1378)	(0.0984)
R^2	0.447	0.693	0.724	0.806
N	73,296	73,269	72,726	69,881
Dep. var.: Log permits on **unadapted** properties				
Disaster event	0.9503***	0.8894***	0.8372***	0.7706***
	(0.1870)	(0.1576)	(0.1562)	(0.1487)
R^2	0.549	0.778	0.789	0.791
N	73,296	73,269	72,726	69,881
Panel B: $h = 4$ quarters after disaster				
Dep. var.: Log permits on **adapted** properties				
Disaster event	0.2948*	0.2103	0.1261	0.0816
	(0.1780)	(0.1427)	(0.1423)	(0.1050)
R^2	0.446	0.694	0.724	0.812
N	73,209	73,180	72,632	69,725
Dep. var.: Log permits on **unadapted** properties				
Disaster event	0.6001***	0.4169**	0.3748**	0.3264**
	(0.2010)	(0.1756)	(0.1644)	(0.1593)
R^2	0.549	0.778	0.789	0.792
N	73,209	73,180	72,632	69,725
County FE	Y	Y	Y	Y
Quarter FE		Y		
Risk-Decile × Quarter FE			Y	Y
Log Stock Control				Y

Notes: Each cell reports the coefficient on a top-100 disaster event indicator from a local projection at the specified horizon. Dependent variables are inverse hyperbolic sine of permit counts filed on adapted or unadapted properties. "Adapted" means the property had an adaptation permit filed at least 12 months prior to the current permit. Columns progressively add fixed effects. Column (4) controls for log housing stock of the corresponding type. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A6: Permit Cost Gap by Housing Feature

	Log average job value per permit						
	Win./Doors	Roof	Garage	Siding	Deck	Basement	Roof Edge
Adapted	–0.032	–0.015	–1.832***	–0.207***	0.235	–0.480***	–0.138***
	(0.041)	(0.065)	(0.117)	(0.064)	(0.151)	(0.143)	(0.030)
R^2	0.642	0.737	0.734	0.621	0.691	0.746	0.492
N	125,099	159,751	161,185	93,787	153,539	82,337	38,270
County FE	Y	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y	Y

Notes: Each column estimates the adapted-vs-general cost gap for a single housing feature. Dependent variable is log average job value per permit. County and quarter FE in all columns. Weighted by permit count with non-missing job values. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A7: Permit Cost Gap: Pre- vs. Post-2004

	Log average job value per permit						
	Pooled	Win./Doors	Roof	Garage	Siding	Deck	Basement
Adapted	–0.392***	–0.256	–0.035	–1.859***	–0.227***	0.121	–0.861***
	(0.108)	(0.163)	(0.143)	(0.321)	(0.079)	(0.183)	(0.181)
× Post-2004	–0.096	0.240	0.021	0.028	0.021	0.133	0.404**
	(0.108)	(0.152)	(0.103)	(0.334)	(0.098)	(0.169)	(0.204)
R^2	0.749	0.642	0.737	0.734	0.621	0.691	0.747
N	813,968	125,099	159,751	161,185	93,787	153,539	82,337
County FE	Y	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y	Y
Feature × County FE	Y						

Notes: "Adapted" captures the pre-2004 cost gap. "× Post-2004" captures the change after 2004. Column (1) pools all features with feature × county FE. Columns (2)–(8) estimate each feature separately with county and quarter FE. Weighted by permit count with non-missing job values. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A8: Disaster Response: Permits by Property Adaptation Status

	(1)	(2)	(3)	(4)
Panel A: $h = 2$ quarters after disaster				
Dep. var.: Log permits on **adapted** properties				
Disaster event	0.4633**	0.4744***	0.4127***	0.3510***
	(0.1801)	(0.1376)	(0.1378)	(0.0984)
R^2	0.447	0.693	0.724	0.806
N	73,296	73,269	72,726	69,881
Dep. var.: Log permits on **unadapted** properties				
Disaster event	0.9503***	0.8894***	0.8372***	0.7706***
	(0.1870)	(0.1576)	(0.1562)	(0.1487)
R^2	0.549	0.778	0.789	0.791
N	73,296	73,269	72,726	69,881
Panel B: $h = 4$ quarters after disaster				
Dep. var.: Log permits on **adapted** properties				
Disaster event	0.2948*	0.2103	0.1261	0.0816
	(0.1780)	(0.1427)	(0.1423)	(0.1050)
R^2	0.446	0.694	0.724	0.812
N	73,209	73,180	72,632	69,725
Dep. var.: Log permits on **unadapted** properties				
Disaster event	0.6001***	0.4169**	0.3748**	0.3264**
	(0.2010)	(0.1756)	(0.1644)	(0.1593)
R^2	0.549	0.778	0.789	0.792
N	73,209	73,180	72,632	69,725
County FE	Y	Y	Y	Y
Quarter FE		Y		
Risk-Decile × Quarter FE			Y	Y
Log Stock Control				Y

Notes: Each cell reports the coefficient on a top-100 disaster event indicator from a local projection at the specified horizon. Dependent variables are inverse hyperbolic sine of permit counts filed on adapted or unadapted properties. "Adapted" means the property had an adaptation permit filed at least 12 months prior. Columns progressively add fixed effects. Column (4) controls for log housing stock of the corresponding type. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table A9: Disaster Response: Adaptation vs. General Renovation Permits

	(1)	(2)	(3)	(4)
Dep. var.: Log **adaptation** permits ($h = 2$)				
Disaster event	0.5348***	0.5585***	0.4408***	0.5045***
	(0.2003)	(0.1640)	(0.1526)	(0.1619)
R^2	0.639	0.768	0.785	0.835
N	68,108	68,108	68,108	50,872
Dep. var.: Log **general renovation** permits ($h = 2$)				
Disaster event	1.1334***	1.1592***	1.0349***	1.1929***
	(0.2594)	(0.2556)	(0.2504)	(0.2128)
R^2	0.664	0.796	0.801	0.847
N	68,108	68,108	68,108	50,872
County FE	Y	Y	Y	Y
Quarter FE		Y		
Risk-Decile × Quarter FE			Y	Y
Log Stock Control				Y

Notes: Each cell reports the coefficient on a top-100 disaster event indicator from a local projection at $h = 2$ quarters. "Adaptation permits" are permits flagged as involving hurricane-adapted features. "General renovation permits" are all renovation permits. Columns progressively add fixed effects. Column (4) controls for log total housing stock. Standard errors clustered by county. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.