Who Bears the Costs of Climate Change?
Evidence from Catastrophes and Homeowners Insurance

Lin Tang*

(*Job Market Paper*)

This version: January 26, 2026

Abstract

The paper studies how the costs of climate change are borne by households through the lens of catastrophes and homeowners insurance. Combining representative U.S. household survey data with state-level catastrophe shocks and insurer-level financial and rate-filing information, I first show that, surprisingly, households in catastrophe-shocked states do not experience a significant increase in homeowners insurance costs relative to those in unshocked states. This pattern varies with the stringency of state regulations over insurance rate changes. In shocked states with light regulation, households, on average, pay 14.9% more for homeowners insurance and are more likely to drop the insurance policy relative to the control group. However, no such effects are observed in shocked states with tight regulation, potentially because homeowners insurance costs in these states are partially shared by unshocked households. Then I provide evidence for this by constructing a novel state-level loss-sharing exposure index to capture insurers' potential to shift losses from tightly regulated shocked states to unaffected states. On average, unshocked households with a one-standard-deviation increase in the exposure index pay 10.4% more for homeowners insurance, despite not being directly affected by catastrophes. The effect is stronger in states with light regulation and low market competition. Moreover, low-income households in shocked states with light regulation are disproportionately affected, being more likely to forgo the protection and facing higher homeowners insurance costs after a catastrophe. Overall, this study highlights the unequal sharing of the costs of climate change through the lens of homeowners insurance.

Keywords: Household finance, Climate change, Homeowners insurance, Insurance regulation, Inequality

---

* PhD candidate in Finance, HKU Business School, lintang@connect.hku.hk. I am grateful to my supervisor Prof. Hong Zou and co-supervisor, Prof. Mingzhu Tai for their invaluable guidance and support. I also thank Sumit Agarwal, Vikas Agarwal, Jing Cai, Ing-Haw Cheng, Andrew Ellul, Jack Xiaoyong Fu, Rawley Heimer, Theis Jensen, Wei Jiang, Yaron Levi, Giorgia Piacentino, Alberto Rossi, Zacharias Sautner, Thomas Schmid, Derek Shan, Youchang Wu, Yanjian Zhu, Yiyuan Zhou, and other participants at the MRS PhD seminar, job talks at Huazhong University of Science and Technology, Nankai University, Xiamen University and Zhongnan University of Economics and Law for their comments and suggestions. All errors are mine.

"Your homeowners' insurance bill is the canary in the climate coal mine."

- Benjamin Keys, The New York Times, 2023

"Nobody's insurance rates are safe from climate change. Even if you haven't suffered direct damage, you're paying for increasingly extreme weather."

- Dana Nuccitelli, Yale Climate Connections, 2025

1. Introduction

Homeowners insurance costs in the U.S. have risen sharply in recent years, largely driven by the increasing frequency and severity of climate-related disasters. Between 2020 and 2023, the national average homeowners insurance premium increased by 33%, from $1,902 to $2,530 (Keys and Mulder, 2024). Premium rates also vary significantly across states, depending not only on exposure to disaster hazards but also on regulatory frictions over rate changes, reinsurance costs, and rebuilding costs. In 2024, the state-level average homeowners insurance premium ranged from $1,282 in Idaho (the lowest) to $3,285 in Mississippi (the highest).[1] In some areas, homeowners insurance costs, together with property taxes, now exceed monthly mortgage payments.[2] The situation has worsened as insurers increasingly withdraw from high-risk states, leaving many homeowners, particularly the more vulnerable, unable to secure coverage from private insurers. Although several states, including California, Florida, New York, and Texas, offer Fair Access to Insurance Requirements (FAIR) plans as insurers of last resort, also referred to as the residual market, these programs typically charge higher premiums and provide more limited coverage than private policies.[3]

The regulatory institutional environment further complicates this landscape. Since the McCarran-Ferguson Act of 1945, property and casualty insurance has been regulated at the state

[1] Natalie Todoroff, "Average Homeowners Insurance Cost in January 2025", *Bankrate*, Nov. 13, 2024. https://www.bankrate.com/insurance/homeowners-insurance/homeowners-insurance-cost/

[2] Nicole Friedman, "Insurance and Taxes Now Cost More Than Mortgages for Many Homeowners", *The Wall Street Journal*, Dec. 23, 2024. https://www.wsj.com/economy/housing/home-insurance-property-tax-vs-mortgage-cost-43ab76ed?msockid=28444a0b2646697a03525ebd27586841

[3] Alex Brown, "States Beg Insurers Not to Drop Climate-Threatened Homes", *Stateline*, Jun. 5, 2024. https://stateline.org/2024/06/05/states-beg-insurers-not-to-drop-climate-threatened-homes/

level, resulting in substantial variation in the regulatory stringency across states.[4] In some states, like California and Texas where disasters happen very frequently, insurance regulators impose strict rate regulation to make the insurance affordable for local households (Cummins, 2007). When national insurers cannot easily raise rates in disaster-affected states with stringent regulations (interchangeably referred to as high-regulation states), they may pass on unrecovered losses by increasing premiums in unshocked states, especially those with light regulations over rate changes (interchangeably referred to as low-regulation states). This further creates a misalignment between insurance premiums and actual risk exposures, disproportionately burdening households in lower-risk states.[5]

Homeowners insurance serves as a critical financial tool to help households recover from natural disasters. While existing literature has primarily examined the direct impact of disaster risks and rising homeowners insurance costs on local households (Ge, Lam, and Lewis, 2022; Billings, Gallagher, and Ricketts, 2022; You, Kousky, and Atreya, 2024; Keys and Mulder, 2024; Eastman, Kim, and Zhou, 2024; Ge, Johnson, and Tzur-Ilan, 2025), less is known about how these dynamics spill over to homeowners in states experiencing little or no disaster impact, and whether these effects are unequal across different socioeconomic groups, except for one study on insurers' cross-subsidization of pricing behavior across states (Oh, Sen, and Tenekedjieva, 2025). This study seeks to fill this gap by examining how rising homeowners insurance costs from climate-driven catastrophes are unevenly borne by households, both across and within states.

Ideally, under a frictionless, forward-looking, risk-based pricing model, the occurrence of disasters should not alter insurance rates, as expected climate risks would already be fully incorporated into the pricing model. In practice, however, insurers rarely have perfect information about evolving climate risks. Following major disasters, they update their risk assessments for the

[4] Steve Koller, "The Insurance Crisis Continues to Weigh on Homeowners", *Harvard Joint Center for Housing Studies*, Dec. 9, 2024. https://www.jchs.harvard.edu/blog/insurance-crisis-continues-weigh-homeowners

[5] Christopher Flavelle, Mira Rojanasakul, "Home insurance rates in America are wildly distorted. Here's why", *The New York Times*, Jul. 9, 2024. https://www.nytimes.com/interactive/2024/07/08/climate/home-insurance-climate-change.html

affected areas, resulting in corresponding premium increases. From this perspective, households in disaster-shocked states would be expected to face significantly higher home insurance costs, leading to a greater likelihood of dropping the insurance after a catastrophe shock compared with households in unshocked states. Nonetheless, since forgoing homeowners insurance is highly risky and often infeasible under mortgage requirements, the effects at this extensive margin are likely small, with most impacts at the intensive margin through higher premiums. However, as documented by Oh et al. (2025), insurers' ability to raise insurance rates is negatively related to local insurance regulation stringency, they may shift losses not recouped in tightly regulated states to states with lenient regulations, leading to a simultaneous rise in premiums in unshocked states. Thus, the potential effects are likely to be mostly observed in states with light regulation on rate changes, while no significant rise in homeowners insurance premiums is expected in tight-regulation shocked states relative to the control group.

To answer these questions, I conduct household-level analyses using the biennial surveys from 2011 to 2023 of the US Panel Study of Income Dynamics (PSID). Utilizing blockbuster disasters with losses exceeding 10-billion dollars (hereafter referred to as catastrophes) as exogenous shocks, I adopt a cohort-based staggered difference-in-differences (DiD) design within a window of three years around the shock, where households in directly-shocked states serve as the treatment group and households in unshocked (hardly shocked) states serve as the control group. My study is structured in two main parts, with the roadmap shown in Figure 1. First, I compare homeowners insurance outcomes of households in shocked and control states. Then, I focus on households in control states and analyze how they share the rising homeowners insurance costs, even though they are not directly affected by catastrophes.

[Insert Figure 1 here]

By comparing shocked and control households, I find that, surprisingly, households in shocked states do not necessarily experience higher homeowners insurance expenditures relative to their counterparts in unshocked states following a catastrophe, although they do exhibit a slightly higher probability of dropping their homeowners insurance policies. However, this

average effect masks substantial heterogeneity across regulatory environments. Following Oh et al. (2025), I construct a measure of regulatory frictions on homeowners insurance rate changes using the average gap between insurers' target rate changes and regulators' approved rate changes in each state and year. Based on this measure, I find that in lightly regulated shocked states, where insurers have greater flexibility to adjust rates, households experience significantly larger increases in homeowners insurance expenditures, approximately $182 relative to the control group, consistent with their higher underlying risk exposure. In contrast, the increase in homeowners insurance costs for households in tight-regulation shocked states is not statistically different from that in the control group. Robustness checks using a propensity score matched sample, an alternative measure of homeowners insurance cost as a ratio of income, and a reclassification according to regulation changes give similar results.

The absence of significant treatment effects in tightly regulated states can be attributed to insurers' limited ability to raise insurance rates in these shocked states, thus, homeowners not directly shocked by catastrophes bear these rising costs passed through insurers' cross-subsidization across states. To provide corresponding evidence, I focus on households in unshocked states to examine the changes in their homeowners insurance outcomes following catastrophe shocks. I construct a novel index to measure loss-sharing exposure for unshocked states, capturing the extent to which common insurers can pass through losses from high-regulation, shocked states to the unshocked focal state. I find that, although there is no significant effect on the likelihood of dropping homeowners insurance among unshocked households, those with greater exposure to loss-sharing face higher homeowners insurance costs. Economically, a one-standard-deviation increase in the exposure index implies an additional $120.5, an increase of 10.4% according to the sample mean. This effect is more pronounced in unshocked states with light regulation on homeowners insurance rates. Additionally, market competition plays a role, with the strongest effects in unshocked states with both light regulation and low competition in homeowners insurance, and the weakest effects in states with tight regulation and high competition.

Heterogeneity tests suggest that the increase in homeowners insurance burden in low-regulation shocked states is significantly larger for low-income households. This phenomenon can be attributed to two factors across shocked and unshocked states. In shocked states with light regulation, low-income households bear a disproportionate burden by paying higher premiums than their high-income counterparts. This income-based inequality, however, is not observed in unshocked states. These results align with broader observations that the most severe impacts of climate change tend to disproportionately affect socially vulnerable populations, with economically disadvantaged households shouldering a larger share of the burden.[6] This might be explained by several potential channels, such as lower credit scores, a greater likelihood of residing in higher-risk areas, and a higher probability of filing claims, that are capitalized into insurers' pricing models.

The study sits at the intersection of household finance and climate risk, contributing to several strands of literature. First, it documents a phenomenon out of the common perception that higher disaster risks equal higher homeowner insurance costs. To the best of my knowledge, this study is the first one to use representative national household data to examine the distribution of homeowners insurance costs caused by climate-caused disasters, across disaster-shocked and unshocked states, across states with different regulation and across different households. Existing literature have mainly investigated the effects of rising homeowners insurance premiums on various household outcomes, like declines in house values (Ge et al., 2022; Keys and Mulder, 2024; Eastman, Kim, and Zhou, 2024), higher probability of credit default (Ge et al., 2025), relocation to lower-risk areas (You et al., 2024; Ge et al., 2025; Collier, Huber, Jaspersen, and Richter, 2023), and home insurance unavailability or under-insurance (You et al., 2024; Sastry, Sen, Tenekedjieva, and Scharlemann, 2024; Collier et al., 2023). While the primary driver of the sharp increase in homeowners insurance premiums is rising local climate risks (Ge et al., 2022; Boomhower, Fowlie,

[6] Lucy Sherriff, "Climate change is fuelling the US insurance problem", *BBC News*, Mar. 18, 2024. https://www.bbc.com/future/article/20240318-climate-change-is-fuelling-the-us-insurance-problem

Gellman, and Plantinga, 2024), other factors, such as regulatory frictions on insurance rate changes (Oh et al., 2025) and reinsurance costs (Cummins, 2007; Keys and Mulder, 2024) also play a role.

Among the above literature on climate risk and homeowners insurance costs, this study is mostly close to Ge et al. (2025) and Oh et al. (2025). Compared with Ge et al. (2025) who investigate the effect of rising homeowners insurance costs on household outcomes, the most important gap between ours is that I study where the rising costs come from and the distribution of raising homeowners insurance costs.[7] Compared with Oh et al. (2025), who focus on insurers' pricing responses to out-of-state losses, this study analyzes households directly to document how homeowners insurance costs are ultimately borne unevenly across and within states. Whether and how the rate changes of insurers as documented in Oh et al. (2025) are transferred to households could depend on their relative bargaining power in the market. Therefore, I examine the role of local insurance market competition and show stronger effects in unshocked states with low competition. Beyond differentiating rate regulation at the state level, I emphasize the within-state heterogeneity across different household income groups and show that low-income households are disproportionately affected, indicating widening inequality in climate-related costs after disaster shocks.[8]

Second, the study contributes to the broader household finance literature that examines the effects of climate risk on household behavioral and financial outcomes. A large number of studies exploit acute and sudden disaster shocks and document substantial declines in household wealth and assets (Daverman, Kazdin, Pensky, and Sloof, 2023; Sachdeva, Xu, and Ando, 2024), reductions in college enrollment and student loans after natural disasters (Gallagher, Billings, and Ricketts, 2023), and increases in household debt (Sachdeva et al., 2024). However, Gallagher and Hartley (2017) only document modest and short-lived deterioration in credit outcomes because

[7] In addition, while Ge et al. (2025) focus on mortgage takers who consistently hold homeowners insurance, I add to the extensive margin by using a more representative household sample.

[8] Third, while existing literature following Oh et al. (2025) relies on time-invariant state regulation classifications over a long period (Sun, 2025; Kim, Mahajan, and Wang, 2025), this study adopts a cohort-specific classification, that better captures the contemporaneous regulatory environment and avoids look-ahead biases

households use insurance payouts to pay down these debts. Others show that households adapt by relocating to lower-risk areas (Wrenn, 2024) or a trade-off between rebuilding and relocation (See more discussions on the effects of climate change on household housing decisions in Schuetz (2023)).

Another line of work examines how households and financial institutions update their beliefs under less-acute and chronic climate changes and subsequently change their behaviors. For example, sea level rise risks could be viewed as a long-term risk and priced into mortgage pricing models, thus leading to higher interest rates (Nguyen, Ongena, Qi, and Sila, 2022). Households exposed to extreme weather exhibit greater environmental concerns and shift their investment portfolios toward greener firms and reduce holdings of carbon-intensive firms (Anderson and Robinson, 2019; Choi, Gao, and Jiang, 2020). Warm temperatures lead to net out-migration of populations in the medium- to long- run (Baylis, Bharadwaj, Mullins, and Obradovich, 2025). Other studies identify a risk attitude change channel through which climate changes affect households, showing that stricter climate regulation increases labor income risk for workers in high-emission industries, which in turn dampens their financial risk-taking (Gao, Jo, and Lam, 2022) and sea level rise serves as a background risk thus leading to a decrease in household risky investments (Ilhan, 2020). Our study adds to this growing body of literature by focusing on the homeowners insurance channel, together with Ge et al. (2022, 2024). Compared with their work, we highlight the critical role of cross-state variation in insurance rate regulation and emphasize how increasing premium costs after disasters are unevenly shared from shocked to unshocked households depending on regulatory environments and competition conditions.

Finally, the study also adds to the literature on growing inequality among households following disaster shocks. Existing research has documented several dimensions of post-disaster inequality, including heightened household bankruptcy and debt delinquency driven by pre-existing credit disparities (Billings et al., 2022), unequal access to credit assistance for recovery from disasters (Begley, Gurun, Purnanandam, and Weagley, 2024), and widespread under-insurance among vulnerable households (Sastry et al., 2024). Financial inclusion, proxied by bank

expansions, can help mitigate the post-disaster inequality in household consumption growth, children schooling, credit accessibility, as well as employment caused by disasters (Gupta and Sedai, 2024). This study adds a new channel to this literature by focusing on homeowners insurance costs and showing that low-income households shocked by catastrophes face significantly larger increases in homeowners insurance premiums compared with their high-income counterparts.

The rest of the paper proceeds as follows. Section 2 describes the research design and sample construction, including the definition of shocked versus control states, the construction of the household sample and empirical model specifications. Section 3 presents the main empirical results of comparing shocked and control households. Section 4 focuses on households in unshocked states and examines whether and how they share the rising costs of homeowners insurance from catastrophe shocks in other states. Section 5 investigates the heterogeneity across income groups. Section 6 provides a mechanism test at the state level. Section 7 concludes.

2. Research Design and Sample Construction

2.1 Identifying Catastrophe Shocked States and Control States

To investigate the effects of climate risks on homeowners insurance costs and their spillover effects on unshocked households, I focus on unexpected and catastrophic climate disasters. Small or routine disasters can typically be absorbed by insurers or incorporated ex ante into actuarial pricing models, allowing them to smooth losses across portfolios and maintain stable product prices following these events. As a result, such events are unlikely to generate significant changes in homeowners insurance costs at the household level in the short term. In contrast, rare blockbuster disasters can trigger substantial and abrupt increases in insurance costs that are ultimately passed on to households. While some existing studies define blockbuster disasters as the top 20 most severe natural disasters within a given sample period (Born and Viscusi, 2006), I follow Telljohann, Born, and Karl (2025) and define blockbuster disasters as state-level events with property losses exceeding 10 billion dollars in CPI-adjusted terms.

I obtain disaster loss data from NOAA National Centers for Environmental Information (NCEI) - *U.S. Billion-Dollar Weather and Climate Disasters*, which reports disaster events causing costs or damages for at least one billion dollars across seven categories: tropical cyclones, severe storms, wildfires, freezes, winter storms, flooding, and drought. As flood risk is primarily covered by the National Flood Insurance Program rather than private insurers, and drought risk is generally not covered by homeowners insurance, I exclude these two categories when defining the shocked and control state groups. Earthquakes are also excluded because they are not climate-related hazards and are outside the scope of my study. My analysis therefore focuses on the remaining five climate-related disaster types covered by the HO-3 type homeowners insurance policy.[9] As the household sample includes PSID survey waves from 2011 to 2023, I focus on "blockbuster" disaster events occurring between 2012 and 2022 to ensure at least one survey wave before and after each shock. I identify 18 blockbuster disaster events across eight states and 10 cohort years.

2.2 Construction of Cohort-Based Stacked Sample

My analysis is based on a short window of three years around each blockbuster disaster event. Over a longer horizon, insurers' market shares and state-level regulatory environments may change substantially, which could introduce confounding factors. Moreover, Oh et al. (2025) document an immediate cross-subsidization response by insurers, showing that lagged-year loss ratios are linked to rate adjustments in the current year, indicating any effect (if existing) could happen in the short run. Therefore, I follow Kalda, Sharma, Soni, and Wenning (2025) and adopt a window of [-3, +3] years around each event to construct the sample. In each cohort, directly shocked states serve as the treatment group. Control states are unshocked or less-shocked states, defined as having annual disaster losses below one billion dollars throughout the seven-year window surrounding the event.

[9] There are eight standard types of homeowners insurance policies (HO-1 through HO-8), which differ in coverage scope and policyholder eligibility. Among them, the HO-3 policy, also known as the "Special Form", is the most widely purchased. It provides coverage for damages to owner-occupied homes and personal belongings, including losses from events such as broken pipes, many types of natural disasters, and fires (National Association of Insurance Commissioners, 2022). HO-3 policies account for more than 85% of all homeowners insurance contracts sold in the private market (Oh et al., 2025).

As some states experience blockbuster disasters in consecutive years, leading to overlapping analysis windows, I retain only the first shock year for each shocked state in the [-3, +3] year window to construct a cleaner sample.[10] After applying this restriction, the final sample includes 10 disaster events across eight states and six cohort years.

In each cohort, households in shocked and selected unshocked (control) states from survey years within the [-3, +3] year window are included. All cohorts are then stacked together to construct the cohort-based stacked household sample for analyses. The list of shocked states, analysis window, control states, and household survey waves to be used are listed in Table 1.

[Insert Table 1 here]

2.3 Measuring Homeowners Insurance Costs for Households

As the household survey provides data on household expenses on homeowners insurance without the information on coverage, I cannot accurately measure the homeowners insurance rate for each household. Bearing this data limitation in mind, I use annual homeowners insurance expenditures as a proxy for homeowners insurance cost (rate), which is justified under the assumption that the insurance coverage remains unchanged within the short analysis window. In a standard homeowners insurance policy, the coverage is typically determined by the replacement costs of the house in the event of a total loss and the value of personal property. Therefore, in the short run, the coverage value is unlikely to change because I limit the sample to houseowners who do not relocate. In addition, time-invariant household fixed effects are included in the model, so changes in homeowners insurance expenditure largely reflect changes in homeowners insurance rates in this setting.

[10] For example, Texas experienced blockbuster disasters in 2016, 2017, 2019, and 2021. I keep only the 2016 event for Texas because the analysis windows for the later events would overlap with the first event's window [2013, 2019]. In contrast, New Jersey and New York experienced blockbuster disasters in 2012 and 2021. Since the corresponding year windows [2009, 2015] and [2018, 2023] do not overlap, both cohorts are retained.

2.4 Model Specification

I leverage these staggered blockbuster disaster events to examine their effects on household homeowners insurance outcomes. As noted by Sun and Abraham (2021) and Baker, Larcker, and Wang (2022), the traditional staggered difference-in-difference (DiD) method using already-treated observations as the comparison units for newly treated observations can lead to biased inference when treatment effects are heterogeneous. Following the literature (Cengiz, Dube, Lindner, and Zipperer, 2019; Barrios, 2022; Sun and Abraham, 2021), I adopt a cohort-based staggered DiD model using the stacked sample described in Section 2.2.

Specifically, I compare changes in homeowners insurance take-up and expenditure between households in shocked states and unshocked states using available surveys within the [-3, +3] year window around each event, as illustrated in Equation (1).

$$HH_HOI_{c,i,s,t} = \beta_0 + \beta_1 Shock_{c,s} * Post_{c,t} + HHControl_{c,i,s,t} + StateControl_{c,s,t-1} + \gamma_{c,i} + \delta_{c,t} + \varepsilon_{c,i,s,t} \quad (1)$$

where $HH_HOI_{c,i,s,t}$ denotes the outcome variable for household *i* in state *s* and survey year *t* in cohort *c*. The outcomes of interest in the baseline analysis include two measures, homeowners insurance take-up (*Insured*) and annual homeowners insurance expenditure (*lnHOIns*), conditional on holding a policy. $Shocked_{c,s}$ is the treatment indicator set to one for state *s* that experienced a blockbuster disaster in cohort year *c*, and zero for control states with annual disaster losses below one billion dollars throughout the seven-year window. $Post_{c,t}$ is the relative time indicator, which equals one for surveys in the cohort year or later, and zero otherwise. β_1 captures the average treatment effect of blockbuster disaster shocks on homeowners insurance outcomes for households in shocked states, relative to households in control states.

I control for household-level characteristics in the survey year that may be correlated with households' decision to take up homeowners insurance and the expenditure. Family income (*lnFamInc*) is a key determinant, influencing both the decision to purchase insurance and the chosen coverage or deductible. Risk preferences also affect insurance decisions. Accordingly, I

control for the age (*lnAge*), marital status (*Married*), education level (*College*), and presence of children (*Child*) for the household head, which are closely linked to risk attitudes (Gao et al., 2022). Since mortgage takers are typically required by lenders to maintain homeowners insurance, mortgage status (*Mortgage*) is an important factor in homeowners insurance decisions. Finally, the replacement value of the insured home is closely related to homeowners insurance coverage and thus the expenditure, so I control for the house value (*lnHouseValue*). Some state-level basic factors that may influence homeowners insurance costs, including lagged disaster losses (*lnDisaLoss*), GDP per capita (*lnPerGDP*), yearly change in the house price index (*HPI_Chg*), population (*lnPopu*) are also controlled for. Additionally, I control for the democratic inclination in a state(*Democracy*), as significant partisan divide in climate change may influence households' preference of resident locations and insurance demand (Bernstein, Billings, Gustafson, and Lewis, 2022). The definition of these variables can be seen in Appendix Table A1.

In the stacked sample, since a household can serve as a control unit in multiple cohorts, I include high-order Cohort-by-Household fixed effect ($\gamma_{c,i}$) and Cohort-by-Year fixed effect ($\delta_{c,t}$) to differentiate households and years across different cohorts. Standard errors are clustered at the state level to account for unobservable common factors in a given state, such as climate risks, regulatory environment, and economic conditions (Oh et al., 2025). For analyses restricted to shocked states, the small number of clusters (fewer than ten) may yield unreliable estimates. Therefore, following Gao et al. (2022), standard errors are clustered at the State-by-Year level to account for common factors in a given state and year.

2.5 Main Data Sources

2.5.1 Household-level Data

To conduct the stacked DiD analysis at the household level, I use the Panel Study of Income Dynamics (PSID), a dataset that has been widely used in research on U.S. household finance and economics (Blundell, Pistaferri, and Preston, 2008; Attanasio and Pistaferri, 2014; Bonaparte, Korniotis, Kumar, and Vosse, 2024; Hu, Lin, and Liu, 2024; Sarada, 2024). The PSID is a

longitudinal, nationally representative survey of over 18,000 individuals living in approximately 5,000 U.S. families, tracking households and individuals biennially from 1968 to 2023. In addition to common demographic and financial information, the survey provides key variables for this study, including geographic identifiers, homeowners insurance take-up and expenditure, and house-related information such as ownership status, house characteristics, house value, and mortgage status. To avoid confounding effects from the 2007-2009 Global Financial Crisis, which significantly affected the housing and mortgage markets, I use survey waves from 2011 to 2023.

To prepare the household sample for the empirical analysis, I apply a series of screening procedures as described below. First, I keep households whose head is between 20 and 90 years old, which removes very young and extreme elderly outliers (Ales, Hosseini, and Jones, 2012; Yu, 2024). Second, I focus on homeowners, excluding households that are renters in all survey waves. For households that switch between homeownership and renting across waves, I retain only the observations corresponding to periods when they are homeowners. Third, to ensure households remain in the same state, I restrict the main sample to households that do not relocate within the analysis window. Fourth, I exclude states with fewer than five households in the stacked sample, as they may not be representative of local populations. This results in dropping three observations from Hawaii (corresponding to one household) and nine observations from Montana (corresponding to four households). Lastly, I require each household to have at least one observation before and one after the shock in each cohort, in addition to the survey wave in the shock year.

The final sample consists of 2,746 unique households from 35 states, with an average of 126 households per state. Within each cohort, a household has three observations on average. All non-logged continuous variables are winsorized at the 1st and 99th percentiles in the stacked sample. Summary statistics for the key variables are presented in Table 2. A very high proportion of households (97%) hold homeowners insurance, which is reasonable given that 68% of them have a mortgage. Conditional on holding homeowners insurance, the average annual expenditure is $1,209, which is very similar to the magnitude in related literature using other data sources

(Eastman and Kim, 2023; Ge et al., 2025). In relative terms, this expenditure represents approximately 1.7% of family income for insured households.

2.5.2 State-level Data

The disaster events and loss data come from the NOAA National Centers for Environmental Information (NCEI) - *U.S. Billion-Dollar Weather and Climate Disasters*, as mentioned in Section 2.1. Data for state-level control variables are obtained from multiple sources, including the Bureau of Economic Analysis' Regional Economic Accounts for GDP and population, the Federal Housing Finance Agency (FHFA) for the house price index, and the National Conference of State Legislatures (NCSL) for partisan inclination data. Table 2 reports on the summary statistics for these state-level variables.

In addition, from the Insurance Information Institute, I obtain state-level average homeowners insurance premiums from 2009 to 2022, originally sourced from the National Association of Insurance Commissioners (NAIC). This data will be used in the state-level mechanism test presented in Section 5.

2.5.3 Insurer-level Data

SNL Insurance Regulatory Data (later merged with S&P Capital IQ into S&P Global Market intelligence in 2015) provides statutory financial information disclosed by insurance companies across regions and countries as required by local regulators. From the Insurance Statutory Market Share Report, I obtain insurer-state-year level data on losses paid, premiums written, and market shares for the homeowners insurance business line, along with insurer-year level financial characteristics. This data will be used to construct the loss-sharing exposure index for unshocked states in Section 4.1.

[Insert Table 2 here]

3. Effect of Catastrophe Shocks on Homeowners Insurance Take-up and Costs

3.1 Baseline Results

Table 3 reports the results from the stacked DiD model in Equation (1). To examine whether treated households become more likely to forgo homeowners insurance following the shock (potentially due to rising insurance costs), I restrict the sample in Columns (1) to (3) to households that already held homeowners insurance in the pre-shock survey year. The outcome variable is a dummy for homeowners insurance take-up. Household-level and lagged state-level control variables are added stepwise. The coefficient estimate in Column (3) indicates that the treated households have significantly higher probability of dropping homeowners insurance after the shock relative to the control group. This might reflect the combined effects of increased insurance premiums and financial difficulties for the shocked households following a disaster. However, the economic magnitude, 0.8 percentage points, is understandably trivial relative to the mean coverage rate of 99%. Homeowners are generally very cautious about forgoing homeowners insurance, especially because most of them have outstanding mortgages for which maintaining homeowners insurance is a prerequisite.

In Columns (4) to (6), I examine changes in homeowners insurance spending, conditional on households maintaining coverage throughout the [-3, +3] window. The results are somewhat surprising. The coefficient is positive but not statistically significant, indicating that, on average, households in directly shocked states do not pay significantly higher homeowners insurance premiums than those in control states following the shock. This does not imply that premiums in shocked states do not increase. Rather, it reflects that homeowners insurance expenditures rise in both shocked and unshocked states, which attenuates the observed differential, as shown by the pre-to-post tests for shocked and unshocked households in Appendix Table A2. This pattern is consistent with the finding of cost subsidization from shocked to unshocked states (Oh et al., 2025).

I decompose *Post* into relative survey-wave indicators (*Pre2*, *Pre1*, *Post0*, *Post1*, *Post2*), which are interacted with the treatment indicator, *Shocked*. *Pre2 (Post2)* corresponds to the second survey wave before (after) the shock, with the other indicators defined analogously. The survey

wave right before the shock (*Pre1*) is omitted as the reference period. Figure 2 presents the dynamic effects up to two survey waves around the shock using these relative-time interactions. The estimates show no pre-trend within two survey waves (roughly three calendar years) prior to the shock. In the survey year following the shock, however, treated households experience a significant decline in the probability of holding homeowners insurance, and an upward (though statistically insignificant) trend in homeowners insurance expenditure relative to the control group.

[Insert Table 3 and Figure 2 here]

3.2 Does Homeowners Insurance Rate Regulation Matter?

The U.S. insurance industry is primarily regulated at the state level, and there is substantial heterogeneity across states in the stringency of homeowners insurance rate regulation. Although there are three common principles that guide every state's rate regulation, including adequate rates, rates not excessive and rates not unfairly discriminatory, state insurance regulators have considerable discretion when proceeding with insurers' rate change requests. When insurers face binding rate-increase constraints in highly regulated states following major disasters, they may offset these losses by raising premiums in other, non-shocked states, particularly those with more flexible regulatory environments. This behavior, often referred to as *cross-subsidization*, effectively shifts part of the homeowners insurance burden from households in high-risk, tightly regulated areas to those in low-risk but lightly regulated states, creating a misalignment between premiums and underlying risks (Oh et al, 2025; Kim et al., 2025). This phenomenon has also been widely documented in media reports, for example, "*After big losses in those tightly regulated states, such as California, national insurers tend to raise rates in more loosely regulated states.*"[11]

This regulatory discrepancy may help explain the results in the baseline model. In states with strict insurance rate regulation, premiums in shocked states may not rise significantly relative to unshocked states, which would attenuate any observable treatment effects at the household level.

[11] Flavelle, Christopher. "Home Insurance Rates in America Are Wildly Distorted. Here's Why." *The New York Times*, Jul. 8, 2024. https://www.nytimes.com/interactive/2024/07/08/climate/home-insurance-climate-change.html.

In shocked states with lax rate regulation, insurers should be able to adjust premiums more freely, and significant treatment effects are therefore expected. To investigate this, I examine homeowners insurance rate regulation in shocked states and assess whether the baseline effects differ between high-regulation and low-regulation states.

3.2.1 Construction of Regulation Index for Homeowners Insurance Rate

Existing literature primarily uses two approaches to measure state-level insurance rate regulation. The first method classifies states into two broad categories, "*prior approval*" and "*competitive rating*", based on the pre-determined system of rate regulation. Under the "*prior approval*" system, insurers must file new rates and obtain regulatory approval before implementation, making it less likely that they can achieve their desired rates. In contrast, a "*competitive*" system allows insurers to use new rates immediately and either file afterward ("*use and file*") or not file at all.[12] Although this approach has been used in some studies (Harrington, 1984; Cummins and Harrington, 1987; Born and Klimaszewski-Blettner, 2013; Born, Karl, and Klein, 2018), it is a very coarse classification that fails to capture the enforcement intensity of these rules or the variation in regulatory stringency across states with the same system. A second approach is to use the gap between insurers' requested rate changes and the rates approved by regulators based on actual rate filings, providing a more precise reflection of regulatory friction (Oh et al., 2025; Keys and Mulder, 2024).

This study adopts the second approach to measure regulatory stringency more accurately. Following Oh et al. (2025), I obtain insurers' rate change filings for homeowners insurance products from 2009 to 2023 using the U.S. Insurance Product Filing Search Engine (RateFilings.com) in S&P Capital IQ Pro Dataset. Specifically, I restrict the search to filings with the *Filing Type* set to "*Rate*" and the *Line of Business* set to "*Homeowners*". For each rate-change filing, key information is collected, including the filing state, insurance company name, filing date, filing status, status date, the rate change indicated by the insurer, and the rate change approved by

[12] Insurance Information Institute: https://www.iii.org/publications/commercial-insurance/how-it-functions/regulation

the regulator. For each rate filing by insurer *i* in state *s* and year *t*, I calculate the rate gap ratio (*RateGap*) as shown in Equation (2), where $Rate\Delta Received$ denotes the rate change approved by the regulator, and $Rate\Delta Target$ denotes the rate change requested by the insurer based on actuarial models.

After the screening procedures described in Appendix A1, I obtain 16,830 rate filings from 421 unique insurance companies between 2009 and 2023 across all states. The rate gap ratios are then winsorized at the 1st and 99th percentiles in the pooled sample to mitigate the influence of outliers potentially caused by data errors. I then average all winsorized *RateGap* in a state-year (where *N* represents the total number of filings in state *s* and year *t*) to construct the state-year *Regulation Index*, as illustrated in Equations (2) and (3).

$$RateGap_{ist} = 1 - \frac{Rate\Delta Received_{ist}}{Rate\Delta Target_{ist}} \tag{2}$$

$$Regulation\ Index_{st} = \frac{\sum_{i=1}^{N} RateGap_{ist}}{N} \tag{3}$$

3.2.2 Classification of States into *Low-* and *High-* Regulation Groups

The regulation groups used in existing literature, such as Oh et al. (2025), Keys and Mulder (2024), and Sun (2025), are all time-invariant. These studies define the groups based on the average regulation index over their entire sample period, rather than using a year-by-year classification. Although the regulatory environment is generally argued to be relatively stable over time, and Oh et al. (2025) provide evidence of high correlation in group classifications across different periods, a look-ahead bias could exist for the early years, particularly because this *Regulation Index* can be volatile following major disasters. Therefore, using a single-year *Regulation Index*, particularly that of the shock year may provide an inaccurate proxy for the overall regulatory friction environment over the analysis window. Moreover, to avoid look-ahead bias arising from insurers' rate filing behavior and regulators' strategic adjustments to stringency after a big disaster shock, I do not use regulation measures in the post-shock periods. Instead, I calculate each state's average *Regulation Index* across pre-shock years within the [-3, -1] window. States are then classified into *Low-* (bottom tercile) and *High-* (middle and top terciles) regulation groups among the 50 states

and DC in each cohort. The tercile cutoff is chosen because evidence shows that insurers primarily cross-subsidize their losses to low-regulation states, rather than to middle- or high-regulation states (Oh et al., 2025).

3.2.3 Effect of Catastrophe Shocks on Homeowners Insurance Take-up and Costs, Moderated by Shocked States' Regulation

Before conducting the DiD tests differentiating shocked states' regulations, I first examine the pre-to-post changes in homeowners insurance-related outcomes for shocked states in different regulation groups. The results are reported in Table 4 Panel A. The estimates on the *Post* dummy in Columns (2) and (4) indicate a significant decrease in the probability of homeowners insurance take-up and a significant increase in homeowners insurance expenditure (conditional on taking the insurance) for households in low-regulation shocked states. In economic terms, this expenditure for households in low-regulation shocked states increases by 25.1% after the shock, corresponding to an additional $382 at the sample mean. In contrast, no significant effects are observed in high-regulation states. The Chow-test statistics reported in rows after the coefficients confirm that the difference in effects between high- and low-regulation groups is substantial.

To assess how homeowners insurance outcomes change for shocked households across different regulatory groups relative to unshocked control households, I interact the treatment indicator, *Shock*, with the high- and low-regulation indicators based on the specification in Equation (1).

$$HH_HOI_{c,i,s,t} = \beta_0 + \beta_1\, LowReg_{c,s} * Shock_{c,s} * Post_{c,t} + \beta_2\, HighReg_{c,s} * Shock_{c,s} * Post_{c,t} + HHControl_{c,i,s,t} + StateControl_{c,s,t-1} + \gamma_{c,i} + \delta_{c,t} + \varepsilon_{c,i,s,t} \quad (4)$$

Where $LowReg_{c,s}$ ($HighReg_{c,s}$) is the moderating variable indicating low (high) regulatory friction for state *s* in cohort *c*. It is defined based on the terciles of the average regulation index over the pre-shock year window [-3, -1]. States in the bottom tercile are classified as low regulation, while all others are classified as high regulation. All other settings remain the same as in Equation (1).

Table 4 Panel B presents the estimation results from Equation (4). The treatment effects are only observed for low-regulation shocked states. When comparing shocked households in low-regulation states with control households, the former exhibit a significantly lower take-up rate and higher homeowners insurance expenditure after the shock. These results hold regardless of whether household- and state-level control variables are included. Economically, in low-regulation shocked states, the catastrophe shock leads to a 1.9-percentage-point increase in the likelihood that households will forgo homeowners insurance, which leaves them more financially vulnerable if a disaster strikes (Cookson, Gallagher, and Mulder, 2025). When continuing to hold the insurance policy, households in low-regulation shocked states pay 14.9% more (equivalent to an additional $182) relative to the control group, as implied by the coefficient in Column (6). However, there is no significant effect among shocked states with high regulation. Moreover, the negative (though insignificant) coefficient b_2 in Columns (4) to (6) likely reflects an equal (or slightly higher) increase in the expenditure for control households compared with those in high-regulation shocked states.

[Insert Table 4 here]

3.3 Robustness Checks

3.3.1 Propensity Score Matching for Shocked and Control Households

Natural disasters can be viewed as exogenous and plausibly random shocks. Therefore, apart from underlying differences in disaster risk, there should be no systematic differences in household characteristics between shocked and unshocked states that could influence households' homeowners insurance decisions. Table A3 Panel A presents comparisons of key household-level covariates between the treatment and control groups in the survey year prior to the shock. Across most dimensions, such as marital status, presence of children, family income, house value, and mortgage status, there are no statistically significant differences, although households in shocked states are less likely to hold homeowners insurance and spend significantly more on it even before the catastrophe shock.

To mitigate concerns that the results may be driven by differential pre-trends in homeowners insurance take-up and expenditure between the treatment and control groups, I conduct a propensity score matching procedure. Specifically, each shocked household is matched to one control household within the same cohort based on observables from the pre-shock survey wave, using a caliper of 0.05 and allowing replacement. Covariates used for matching include the age of the household head, marital status, education level, house value, mortgage status, and state-level GDP per capita. In addition, I match pre-shock homeowners insurance expenditure and its ratio to family income to ensure comparability in baseline insurance spending. Table A3 Panel B presents the mean-difference *t*-test results after matching, showing that there are no significant differences in key household characteristics between the treatment and control groups before the shock.

Using the matched sample, I repeat the DiD regressions in Equations (1) and (4), with results report in Table 5.[13] When the homeowners insurance rate regulation is not considered, there are no significant treatment effects for the shocked states, as shown in Columns (1) and (3). However, once shocked states are separated into low- and high-regulation groups in Columns (2) and (4), the effects in high- and low-regulation groups are significantly different, consistent with the baseline results. Although the change in homeowners insurance take-up is relatively small, homeowners insurance expenditure for shocked households in low-regulation states increases by 27% after the shock compared with their matched unshocked counterparts. The magnitude is much larger than the effect before matching.

[Insert Table 5 here]

3.3.2 Alternative Outcome: Relative Burden of Homeowners Insurance Costs

So far, the analysis has focused on changes in homeowners insurance expenditure in absolute terms. To assess households' financial strain from rising home insurance costs, I also examine the ratio

[13] Although I have matched on household characteristics before the shock, I still include household-level controls in the test. If I do not include household controls, results are also similar.

of homeowners insurance expenditure to household income as an alternative outcome measure. Table 6 reports the results for this alternative outcome. Column (4) shows that, on average, there is no significant treatment effect on household homeowners insurance burden, possibly because the burden increased in both shocked and control states, as shown by the pre-to-post tests in Columns (1) to (3). Column (5) indicates that households in low-regulation shocked states experience a significantly higher cost burden after the shock relative to the control group. On average, this increase amounts to 0.2 percentage points, representing a 12% growth relative to the sample mean of 1.7 percentage points. However, this effect is not observed for high-regulation shocked states.

Overall, the results suggest that the disaster shock raises homeowners insurance costs not only in absolute terms but also relative to household income, and this effect arises only in low-regulation states.

[Insert Table 6 here]

3.3.3 Is State Regulation Stable around the Catastrophe Shock?

Although prior literature argues that state rate regulation is slow-moving with few reclassifications when comparing regulation groups defined over 2009-2013 and 2014-2019 (Oh et al., 2025), I conduct an additional test to examine the changes in *Regulation Index* around catastrophe shocks. The test is based on the cohort-based stacked sample within the [-3, +3] year window at the state level and the results are reported in Appendix Table A4 Panel A.

The findings indicate a modest decline in the regulation index for shocked states, whereas no such change is observed for unshocked states. This decrease is concentrated in the shock year relative to surrounding years and is particularly pronounced among states that were classified as high-regulation ex ante.[14] This decline is likely driven by the surge in rate-filing activity by insurers following large catastrophes (Telljohann et al., 2025). These rate-change requests tend to

[14] For brevity, these results for high- and low-regulation groups and dynamic DiD tests are not reported.

receive higher approval rates than in non-catastrophe years, potentially reflecting regulators' efforts to retain insurers in the market after major disaster events.[15] For example, Texas ranks in the top tercile of the regulation index prior to 2016, but in disaster years such as 2016, 2017, 2019, and 2021, its regulation index drops to the middle or even lower terciles. Such ad hoc reductions in rate-setting stringency in response to catastrophe shocks suggest that regulators may temporarily grant insurers greater pricing flexibility. If this occurs, one might expect to observe corresponding short-term increases in households' homeowners insurance costs in those states.

To address this question, I compare shocked states' regulation classifications in the pre-shock period with those in the shock year. Among the shocked states originally classified as low-regulation, their regulatory status remains stable. In contrast, among the eight ex-ante high-regulation states, four exhibit a relaxation in the rate stringency during the shock year and shift into the low-regulation group. Accordingly, I further decompose shocked states into three categories: consistently low-regulation, ex-ante high-regulation that switch to low-regulation in the shock year, and ex-ante high-regulation that remain high-regulation. I repeat the baseline analysis by adding interaction terms of the three regulation indicators with *Post*, with results reported in Appendix Table A4 Panel B. While the change in regulation does not significantly affect households' likelihood of dropping homeowners insurance, Column (2) shows that for ex-ante high-regulation states that relax their regulatory constraints, households also experience significantly higher homeowners insurance costs relative to the control states after the shock. Although the magnitude is smaller, the effect is not statistically different from that of consistently low-regulation states. By contrast, ex-ante high-regulation states that remain tightly regulated exhibit no significant increase in their homeowners insurance costs, compared with the control group.

[15] Unreported tests on the number of rate filings and average approval rate at the state level indicate significant increases in insurers' rate filing activities and approval rates for shocked states following the catastrophe, relative to the control states.

3.4 Testing Other Household Outcomes

In addition to homeowners insurance outcomes, this section examines changes in other household-level consequences, including home repair expenses, mortgage and credit cards balances, based on the sample of households that always hold homeowners insurance. As many households do not incur these expenditures or use credit, Poisson regression is employed to account for the large number of zero values. Results reported in Table 7 suggest that households adjust their behavior in response to disaster shocks in ways beyond homeowners insurance.

For households in shocked states with light regulation, they significantly increase their home repair expenditure, with a coefficient of 0.368, corresponding to a 44.5% increase ($= e^{0.368} - 1$) and an additional $1,370 at the sample mean of $3,380. Why does this occur only in shocked states with light regulation and not in tight-regulated ones? One possible explanation is that houses in disrepair may face higher insurance rates, particularly in states where insurers can adjust premiums more flexibly following major disaster shocks. In response, households in these states take immediate actions to improve their home conditions, thereby gaining greater bargaining power and potentially securing more favorable insurance terms.[16] On average, shocked households exhibit higher credit card balances relative to households in control states, although the effect is only marginally significant, consistent with Ge et al. (2025), who find that larger homeowners insurance premium increases lead to greater credit card utilization and delinquency. This effect does not essentially differ between low- and high-regulation states. No significant treatment effects are observed on household mortgage balances.

[Insert Table 7 here]

4. The Cost Sharing of Unshocked Households after Catastrophe Shocks

So far, I find that, on average, households in shocked states do not experience significantly higher homeowners insurance expenditures after catastrophes relative to households in control states,

[16] Additional tests in low-income and high-income groups separately indicate this result is mainly driven by high-incomes households.

based on the cohort-based stacked household sample. Significant increases are observed only in shocked states with light regulations, where insurers can adjust rates more flexibly, but not in tight-regulation shocked states. Moreover, these increases disproportionately burden low-income households. These findings are consistent with existing literature that finds a disconnect between homeowners insurance premiums and underlying physical disaster risks at the insurer level (Oh et al., 2025).

This raises an important question: Who ultimately bears the costs of rising climate risks for households in shocked but high-regulation states? Preliminary evidence from the pre-to-post tests in Appendix Table A2 suggests that households in unshocked states are also experiencing rising homeowners insurance premiums. To further investigate whether and how households in unshocked states are unequally sharing the costs originating from shocked states, the analysis then focuses on the unshocked households in control states and examines their homeowners insurance outcomes.

The primary channel through which homeowners insurance costs in high-risk, high-regulation states are shared with households in unshocked states is the presence of national insurers operating across multiple states. Consistent with the main analysis, I use the same event cohorts defined in Table 1 to examine whether households in unshocked (or minimally shocked) states with varying exposure to insurers' losses from these disasters experience differential changes in homeowners insurance take-up rates and expenditures.

4.1 Measuring the Losses Sharing Exposure to Shocked States with High Regulation

Existing literature finds that cross-subsidization by insurers occurs primarily from high-regulation states to low-regulation states (Oh et al., 2025). Based on this insight, I construct a novel index for each unshocked state to measure its exposure to sharing losses from high-regulation shocked states, as described below.

First, I compute a loss-sharing index for each insurer operating in the focal states during the shock year. The index is defined as an insurer's direct losses paid (DLP) in all high-regulation

shocked states divided by its direct premiums written (DPW) in all control states in the same year, as shown in Equation (5).[17] Intuitively, this measure captures how many dollars of losses in high-regulation shocked states are effectively shared by every one dollar of DPW collected in the control states. Next, I aggregate the insurers' loss-sharing indices to the state level, weighted by each insurer's market share as a proxy for its pricing power within the state. As shown in Equation (6), $N_{c,s}$ denotes the number of homeowners insurers operating in the focal state *s* in cohort year *c*. $MarketShare_{c,s,i}$ represents insurer *i*'s market share in homeowners insurance, calculated as the ratio of its DPW to the total DPW in homeowners insurance in the focal state *s* in cohort year *c*.

$$LossShr_{c,s,i} = \frac{\text{Insurer } i\text{'s } DLP \text{ in shocked states with tight regualtion in year } c}{\text{Insurer } i\text{'s } DPW \text{ in all control states in year } c} \tag{5}$$

$$LossShrExp_{c,s} = \sum_{i=1}^{N_{c,s}} MarketShare_{c,s,i} * LossShr_{c,s,i} \tag{6}$$

Table 8 reports summary statistics for the loss-sharing exposure index and other key variables in the unshocked household sample. On average, every one-dollar DPW in unshocked states is exposed to around $1.5 of insurers' loss from disasters in high-regulation states (with mean of *LossShrExp* being 1.474). This exposure displays substantial variation, ranging from less than $0.1 to more than $3.

[Insert Table 8 here]

4.2 Effect of Catastrophe Shocks on Unshocked Households

The model specification is similar to Equation (1), except that the *Shock* indicator is replaced by the continuous treatment variable, *LossShrExp*, as follows.

$$HH_HOI_{c,i,s,t} = \beta_0 + \beta_1 LossShrExp_{c,s} * Post_{c,t} + HHControl_{c,i,s,t} + StateControl_{c,s,t-1} + \gamma_{c,i} + \delta_{c,t} + \varepsilon_{c,i,s,t} \tag{7}$$

[17] As this test focuses on households in unshocked states, I account for all blockbuster disaster events, not only the first disaster shock in each state, to fully capture their exposure to loss sharing. For example, for the 2018 cohort, the exposure index incorporates all three disasters that occurred in North Carolina, Florida, and California.

Table 9 reports the results. The coefficients on the interaction term from Columns (1) to (3) indicate that there are no significant effects on the probability of holding homeowners insurance. Conditional on holding homeowners insurance, households with greater exposure to insurers' loss-sharing incentives pay significantly higher insurance expenditures, both in absolute terms and relative to family income. From Column (6), the estimate for β_1 can be interpreted into a 10.14% increase ($= e\text{^}(0.069 * 1.40) - 1$) at the average exposure index, corresponding to an additional \$118 based on the sample mean of \$1,164. Similarly, a one-standard-deviation increase in the exposure index implies an effect of 10.4%, equivalent to \$120.5. Regarding the effects on homeowners insurance burden, a one-standard-deviation increase in the exposure index leads to a 0.13-percentage-point increase ($= e\text{^}(0.087 * 1.43) - 1$) in the burden ratio, which is substantial relative to the sample mean of 1.63 percentage points. Figure 3 depicts the dynamic effects of the loss share exposure on homeowners insurance expenditure and burden for households in unshocked states.

[Insert Table 9 and Figure 3 here]

The literature suggests that the cross-subsidization mostly occurs from high-regulation states to low-regulation states. Therefore, the loss-sharing effects are expected to be more pronounced in low-regulation groups. To examine this, I differentiate the effects by interacting $LossShrExp$ in Equation (7) with indicators for high- and low-regulation states. A high- (low-) regulation state is defined as one whose average regulation index in the pre-shock years falls in the middle-to-top (bottom) tercile among the 50 states and DC (see Section 3.2.2 for details).

Table 10 reports the results, where b_1 captures the effects for low-regulation states and b_2 for high-regulation states. For the probability of holding homeowners insurance, there is no significant effect in either low- or high-regulation states. This is understandable, as the increase in homeowners insurance costs in these unshocked states is not large enough to induce households to forgo coverage. For conditional homeowners insurance expenditure, there is a significant increase with higher loss-sharing exposure in both low- and high-regulation unshocked states. This is plausible because the defined high-regulation category encompasses both the middle and top

terciles of regulatory stringency. In low-regulation states, a one-standard-deviation increase in the exposure index leads to a 13% rise in homeowners insurance expenditure (equivalent to $151), which is larger than the effect reported for the full sample in Table 9 Column (6). In contrast, in high-regulation states, the effect is smaller at 8.65% (equivalent to $101). The effect on insurance burden is observed only in low-regulation states, with an increase of 0.2-percentage-point following a one-standard-deviation rise in the exposure index.

[Insert Table 10 here]

4.3 Robustness Check for the Loss-Sharing Exposure Index

Some concerns may arise regarding the extent to which the loss-sharing exposure index accurately captures both the probability and intensity of cost sharing from shocked to unshocked states.

One may argue that, rather than compensating their losses in high-regulation shocked states solely by raising premiums elsewhere, insurance companies may also reject more claims or reduce payouts in unaffected states. Kalda et al. (2025) provide some evidence of this mechanism in their study of Florida, documenting that insurers redistribute cost by increasing claim rejections for low-income households who are more price-sensitive. However, this possibility would bias my findings downward, making it more difficult to detect significant effects. Moreover, my analysis focuses on a short three-year window around the shock and restricts the control states to those experiencing no or only minimal disasters. Under this design, the alternative mechanism is less concerning, as relatively few claims are likely to have occurred in the unshocked states during this period. Even if some idiosyncratic risks generate homeowners insurance claims in unshocked states, insurers are likely to be cautious about rejecting such claims without reasonable justification, given potential reputational concerns.

Another concern is whether the insurer remains in a state to provide homeowners insurance after the shock. The stability of insurers is reasonably expected within the short analysis window, as insurers are generally slow to exit one state market for several reasons, such as geographic diversification needs and bundling with other business lines (Oh et al., 2025). If anything, such

market withdrawals are more likely to occur in high-regulation and high-risk states (Sastry et al., 2024; Hemmati, Gray, and Bowen, 2025), which might not affect my findings that are primarily documented in low-regulation states. Nevertheless, I still perform two tests to mitigate this concern. I first examine whether there are significant insurers' exits in the shocked states compared with the control states and whether the number of homeowners insurance provides is affected by the loss-sharing exposure following a catastrophe, with results reported in Appendix Table A6. There are no significant effects, indicating relatively stable market composition of insurers over my sample period. Then, I perform another robustness check by considering only large insurers (with a market share over 1%) in the focal state in the shock year when constructing the state-level exposure index, following Oh et al. (2025). These sizable insurers have dominant market share and pricing power in the states and are typically more stably operating in one state. Results based on the alternative measure are reported in Panels A of Table A6, which is quite robust, with more significant effects in the low-regulation states.[18]

Finally, insurers might also offset losses in other unshocked states that are not included in the control group. Similar to the first concern, any such spillover of loss-sharing to unselected states would work against the detection of significant effects in my setting. To alleviate this concern, I employ an alternative loss-sharing exposure index that accounts for the relative market importance of a focal state for each insurer's homeowners insurance business. Specifically, based on the aggregation method in Equation (6), I introduce the ratio of an insurer's premium written in the focal state to its total nationwide homeowners insurance premium as an additional multiplier, which measures the insurer's reliance on a focal state. The results using this alternative measure are highly similar and robust, as reported in Panel B of Table A6.

[18] I also use the top 50 insurers in the focal state to construct the loss-sharing exposure index. Results are quite robust and not reported.

4.4 The Role of Insurance Market Competition

The intensity of competition in local insurance markets may influence both the extent of insurers' cross-subsidization and households' responses. In more competitive markets, insurers may be less likely to raise rates when they suffer losses from high-regulation shocked states or do so to a smaller degree to retain customers. Similarly, when homeowners face an increase in the insurance costs at the current insurer, they can shop around for better prices in a more competitive market. As the survey does not provide information on insurance companies from which households purchase their insurance, I cannot conduct a direct test on whether households change their insurers. Therefore, I hypothesize that the effects of the loss-sharing index are weaker in states with high competition, as an alternative piece of evidence.

Similar to the heterogeneity analysis by household income, I divide the sample states into low- and high-competition groups and interact the income group indicators with *LossShrExp*Post* to re-estimate the regressions. Within each cohort, an unshocked state is classified as low competition if its average Herfindahl-Hirschman Index (HHI) for the homeowners insurance market over the [-3, -1] year window is higher than the median among all 50 states and DC; otherwise, it is classified as high competition.

Table 11 reports the heterogeneous effects of loss-sharing exposure by local insurance market competition, separately for low- and high-regulation states. Results in Columns (1)-(3) show households with greater exposure to loss sharing experience significant increases in both homeowners insurance expenditure and the burden ratio across high- and low-competition states. This effect is significantly stronger in less-competitive states, as indicated by the statistically significant test of $b_1 - b_2 = 0$. Economically, a one-standard-deviation increase in the exposure index is associated with a 28% (equivalent to $325) increase in homeowners insurance expenditure in low-competition states, which is 10 percentage points higher than the increase in high-competition states (18%, equivalent to $209), corresponding to a gap of $116 as reported in Column (2).

Furthermore, I classify the states into four groups based on regulation and competition and differentiate the effects across these groups by adding interaction terms in the pooled specification. The results are reported in Appendix Table A7. Consistent with the results in Table 11, the effects are strongest in low-competition, low-regulation states (b_1) and weakest in high-competition, high-regulation states (b_2). The difference between the low-competition, low-regulation group and the other three groups is statistically significant.

[Insert Table 11 here]

4.5 Testing Other Household Outcomes

Consistent with the analyses in Section 3.4, this part examines additional household outcomes in the unshocked states, including home repair expenses, mortgage balances, and credit usage.

The results, reported in Table 12, show that these household outcomes are largely unaffected. This is unsurprising, as the increase in homeowners insurance expenditures attributable to loss-sharing, $100 to $150 annually, is relatively modest and unlikely to meaningfully influence households' credit usage. Also, because households in unshocked states do not experience physical damage to their homes, they have little incentive to undertake repairs or upgrades. One exception is the observed change in mortgage balances for unshocked households, which may reflect their incentives to accelerate mortgage repayment when facing higher insurance costs, thereby enabling them to subsequently forgo homeowners insurance or relocate.

While these results are based on a short-term window, over the long run, the disconnect between physical risk and premiums may accumulate, potentially affecting households' access to homeowners insurance and increasing premiums more in low-risk areas. Further, this could lead to adverse effects on other household outcomes.

[Insert Table 12 here]

5. Unequal Effects across Income Groups

The study has documented the effects of catastrophes on household homeowners insurance costs only in states with light regulation and households in the unshocked states are sharing these costs of shocked states with tight regulation. As the social inequality is a hot debate in front of climate risks, a further question is whether these effects are uneven across different households within the same state. Specifically, I investigate whether more financially vulnerable households are disproportionately affected by the shock through examining heterogeneity across household income.

5.1 Hypotheses on the Unequal Effects across Income Groups

Ex-ante, there is no clear prediction on which household group is more affected, regarding both the likelihood of holding homeowners insurance and the costs. I expect not to observe significant changes in the homeowners insurance ownership among high-income groups, as they have the financial ability to afford the insurance and are very cautious to forgo the protection. For the low-income households, on the one hand, they tend to forgo homeowners insurance when faced with rising insurance costs as they are more financially constraint. On the other hand, low-income households are more likely to carry outstanding mortgages, and it is hard for them to pay down the mortgage in the short run, making it mandatory for them to maintain the homeowners insurance. Therefore, there might be no significant difference for the changes of homeowners insurance ownership between high- and low-income groups.

Regarding the insurance costs conditional on holding the policy, there is little possibility that low-income households can reduce the coverage or increase deductibles to maintain a lower cost. This is because homeowners insurance policies are quite standard ("super contracts of adhesion") and most customers are in a position of "take-it-or-leave-it" in front of sophisticated insurers (Schwarcz, 2011). In contrast, low-income households could be charged higher due to several reasons, such as worse house conditions, lower credit scores and higher physical risks.

In many states like North Carolina, Florida, Louisiana, New Jersey, New York, Texas, insurers are required to offer premium discounts to property owners who undertake mitigation

measures to strengthen their homes.[19] High-income families are more likely to retrofit their homes and qualify for discounts. However, low-income households have less financial capability to elevate their housing conditions especially after a disaster hit, thus facing higher premium charges (Billings, Ryan, and Yan, 2025). Additionally, low-income groups might be correlated with lower credit scores and higher likelihood of filing a claim when a disaster hits, which matters for pricing under the credit-based insurance score model used in many states (Morris, Schwarcz, and Teitelbaum, 2017).[20] Worse credit can lead to substantially higher insurance prices for disaster risks (Blonz, Hossain, and Weill, 2024). [21] Finally, even within a state, low-income or rural households are more likely to stay in riskier regions, as they are usually mortgage holders with less mobility in the short run than high-income households (Boustan, Kahn, Rhode, and Yanguas, 2020; Wylie, Amornsiripanitch, Heilbron, and Zhao, 2025).

Overall, the aforementioned arguments suggest that low-incomes households are likely to be more affected when the homeowners insurance rises, Still, the effects could differ in shocked and unshocked states and states with different regulations, depending on the extent of homeowners insurance cost increase, the actual physical risk exposure and insurance market conditions. If there were indeed any effect, they were expected to be observed in states with light regulation, instead of tightly-regulated ones where insurers are difficult to adjust their rates for all groups of households.

5.2 Empirical Results on the Unequal Effects across Income Groups

To examine the heterogeneity of the treatment effects across incomes groups, I use the full sample of both shocked and control states. Households with annual family income below (above)

[19] FORTIFIED – A program of the Insurance Institute for Business & Home Safety: Financial Incentives. https://fortifiedhome.org/incentives/#:~:text=Other%20states%20that%20may%20offer%20incentives%20for,with%20the%20Louisiana%20State%20Uniform%20Construction%20Code.

[20] Insurance Information Institute - Insurance Handbook: "Insurance scores, which are also referred to as credit-based insurance scores, are ratings based fully or partially on a consumer's credit information. Insurers use credit information with other factors to help underwrite and price policies. These confidential ratings are typically used for personal lines such as homeowners and personal automobile insurance." https://www.iii.org/publications/insurance-handbook/regulatory-and-financial-environment/background-on-insurance-scoring

[21] Credit-based insurance scores are ratings based fully or partially on a consumer's credit information. Insurers use credit information with other factors to help underwrite and price policies. These confidential ratings are typically used for personal lines such as homeowners and personal automobile insurance.

the state median in the survey wave that was immediately before the shock are classified as low-income (high-income) groups. To avoid a too complicated interaction term of many indicators in the model, I first repeat the baseline DiD test in high- and low- income samples separately.

Table 13 reports the estimation results for the two subsamples. On average, low-income households are significantly more likely to drop homeowners insurance protection after the shock. This is consistent with the argument that the issue of under-insurance and affordability is concentrated among vulnerable households in high-risk states (Sastry et al., 2024), which may drive the low-income households into long-term insecurity without insurance protection. Conditional on holding the insurance, low-income households in shocked states experience a significant increase in insurance expenditure (burden) relative to their counterparts in control states, and this effect appears only in low-regulation states. According to Column (2), low-income households in low-regulation shocked states pay 22% more, corresponding to an additional $230, relative to their counterparts in control states. For high-income households, the effects are smaller in magnitude.

[Insert Table 13 here]

The observed effects on homeowners insurance expenditure are likely shaped by interacting forces from both shocked and unshocked states. In shocked states with low regulation, low-income households experience disproportionately larger premium increases following a catastrophe shock.[22] This could be explained by aforementioned reasons such as worse house conditions, lower credit quality and higher residence risk, which only function in states with actually higher hazard and light regulation. In contrast, in unshocked states, low-income households are not penalized as severely because the underlying disaster risk is low, and most premium increases stem from insurers' cross-subsidization behavior rather than local risk

[22] An unreported test examining changes in homeowners insurance take-up probability and expenditure within shocked states, by adding a three-term interaction of *Post* with low-regulation and low-income indicators, supports this argument in my setting. The results show that low-income households in low-regulation shocked states are more likely to forgo homeowners insurance and, conditional on maintaining the policy, experience significantly larger increases in expenditure than their high-income counterparts.

conditions. Being more price-sensitive, low-income households can more effectively shop around to maintain their insurance rates in markets with sufficient competition and financially stable insurers. High-income households, by contrast, may bear a larger share of the cross-subsidization originating from tightly regulated, shocked states, as their lower price sensitivity makes them less likely to seek better prices in response to premium increases (Kalda et al., 2025).

To investigate whether low- and high-income households within a state are unequally affected by the loss-sharing exposure from disasters elsewhere, I interact *LossShrExp*Post* with indicators for low-income and high-income households respectively, based on the model in Equation (7). As I have found the treatment effects only for the low-regulation group, to better whether the effects for two income groups are significantly different, I mainly focus the test on low-regulation states by adding the interaction term with income indicators. The results are reported in Table 14. Columns (1) to (3) present the estimates for the low-regulation group. They suggest that low- and high-income households are almost equally affected by the cost-sharing for losses from high-regulation shocked states, as evidenced by the similar magnitudes of b_1 and b_2 as well as the insignificance of b_1-b_2. In contrast, for high-regulation states, the effects on homeowners insurance take-up and expenditures are minimal and largely insignificant.[23]

[Insert Table 14 here]

Overall, catastrophe shocks combined with light regulation can lead to disproportionately higher homeowners insurance costs for lower-income households. But this disparity does not appear in unshocked states where the rising costs are from insurers' cross-subsidization instead of physical risks. This kind of unequal burden may further exacerbate underinsurance among financially vulnerable households and potentially widen homeownership disparities between low- and high-income groups (Sastry et al., 2024).

[23] One unexpected finding from Column (6) is that low-income households also have significantly higher home insurance expenditure burden, even in high friction states. This is possibly because in high-friction states, households are more likely to turn to the state-sponsored insurance plans when they cannot find a commercial insurer willing to cover them. These state-sponsored insurance plans usually have higher prices.

6. Mechanism: The Change of Homeowners Insurance Premium Growth at the State Level

The study has documented how the increases in homeowners insurance costs of climate risks after catastrophes are shared across households in shocked and unshocked states with different homeowners insurance regulation stringency, as well as across income groups within a state. On average, households in shocked states with light regulation pay significantly higher homeowners insurance premiums relative to their counterparts in unshocked states after catastrophe shocks. This effect is particularly pronounced for low-income households. In contrast, households in shocked states with tight regulation do not exhibit a significant increase in insurance expenditure compared with the control group. This pattern is driven by concurrent premium increases in unshocked states. The underlying mechanism is that multi-state insurers compensate their losses in high-regulation shocked states by increasing rates in unshocked states, especially those with light regulation. To further corroborate this mechanism, the following section presents evidence at the state level.

Insurance Information Institute provides the data on average homeowners insurance premiums by state and year, from which I calculate the annual growth rate as (average premium - lagged average premium) / lagged average premium × 100.[24] DiD analyses of the relative change in the growth rate of state-level premium are conducted using the cohort-based stacked sample over the time window of [-3, +3] years around the shock. The model specifications are similar to those for household-level tests in Equations (1) and (7), with Cohort-by-Household fixed effects replaced by Cohort-by-State fixed effects. Additionally, the pre-shock average homeowners insurance premium interacted with the *Post* indicator is included to control for the baseline premium level in each state.

Table 15 presents the state-level DiD results, with Panel A reporting outcomes for both shocked and control states. Following a catastrophe shock, the growth in homeowners insurance premiums is significantly higher in shocked states relative to control states, with significantly

[24] The definition of average premium from Insurance Information Institute: Average premium = Premiums/exposure per house years. A house year is equal to 365 days of insured coverage for a single dwelling.

larger effects in low-regulation shocked states than in high-regulation shocked states. Columns (1) to (2) show that the premium growth rate is 2.7 percentage points higher in shocked states, a substantial increase given the sample mean of 3.9%. This gap widens to 5.2 percentage points when focusing on low-regulation shocked states. The results remain robust, and the estimated coefficients become slightly larger after controlling for state-level covariates and the pre-shock homeowners insurance premium level.

Panel B reports results for the unshocked control states, showing that homeowners insurance premium growth is also positively affected by the disaster shock through cross-subsidization of multi-state operating insurers. Results in Column (1) suggest that a one-standard-deviation increase in an unshocked state's exposure to loss sharing leads to a 0.8-percentage-point increase in its average homeowners insurance premium growth. This effect is not homogeneous across unshocked states, with the magnitude substantially larger in unshocked states with light regulation, reaching 4.9 percentage points as shown in Column (2). The difference in effects between the two groups is statistically significant. Figure 4 presents the dynamic DiD estimates corresponding to Column (3) in the two panels, showing no evidence of pre-trend.

[Insert Table 15 and Figure 4 here]

7. Conclusion

This paper examines how rising homeowners insurance costs following catastrophes are shared across households in both disaster-shocked and unshocked states, how these effects vary with the stringency of state insurance regulation, and how different income groups are affected.

Using household-level data from the U.S. Panel Study of Income Dynamics (PSID), I show that, on average, catastrophe shocks do not significantly increase insurance expenditures for households in shocked states relative to those in unshocked states. This does not imply that premiums do not rise in shocked areas; rather, premiums increase in both affected and unaffected states. The mechanism underlying this pattern is that national insurers partially shift catastrophe losses from tightly regulated, disaster-affected states onto homeowners in unshocked states. To

capture the extent to which insurers can pass through their losses across state lines, I construct a novel loss-sharing exposure index and find that unshocked households with higher exposure experience significantly greater increases in homeowners insurance expenditures. The magnitude of these spillover effects depends critically on state regulation on insurance rate changes. Both shocked and unshocked states with light regulations face substantially larger premium increases compared with tightly regulated counterparts. At the extensive margin, I document that households in low-regulation shocked states are more likely to be uninsured following a catastrophe, although the magnitude of this effect is small. For households in unshocked states, their probability of holding insurance remains largely unchanged. Other household outcomes exhibit limited responses, with the exception of increased home repair spending in shocked states with light regulation.

This study also highlights widening inequalities in home insurance burdens across socioeconomic groups. Within catastrophe-shocked states with light regulation, low-income households face disproportionately higher premiums than high-income households and are more likely to go without insurance, leaving them particularly financially vulnerable after disasters.

Overall, my findings reveals the significant impact of climate-driven disasters on households through the homeowners insurance channel. This pattern is not unique to the United States. Similar pressures are evident in other countries, including Australia,[25] Canada,[26] and New Zealand.[27] This study provides broader insights into the global challenges posed by rising climate risks and the affordability of home insurance, highlighting the crucial role of insurance regulation while also cautioning against the potential widening financial inequality resulting from these risks.

[25] Sharanjit Paddam, "Rising climate risks: Why accessible, affordable home insurance is under threat", *AdaptNSW*. https://www.climatechange.environment.nsw.gov.au/news/rising-climate-risks-why-accessible-affordable-home-insurance-under-threat

[26] "How much home insurance rates are up in 2025", *The Insurance Institute of Canada, Insights & Publications*. https://www.insuranceinstitute.ca/en/insights-and-publications/canadianunderwriterarticles/items/2025/03/04/how-much-home-insurance-rates-are-up-in-2025

[27] Emma Thomasson, "Australia and NZ face home insurance crisis due to climate, experts warn", *Green Central Banking*, Mar. 26, 2025. https://greencentralbanking.com/2025/03/26/australia-and-nz-face-home-insurance-crisis-due-to-climate-experts-warn/

References

Ales, L., Hosseini, R., & Jones, L. E. (2012). Is there "too much" inequality in health spending across income groups? (No. w17937). *National Bureau of Economic Research*.

Anderson, A., & Robinson, D. T. (2019). Climate fears and the demand for green investment. *Swedish House of Finance Research Paper*, (19-14).

Attanasio, O., & Pistaferri, L. (2014). Consumption inequality over the last half century: some evidence using the new PSID consumption measure. *American Economic Review*, 104(5), 122-126.

Baker, A. C., Larcker, D. F., & Wang, C. C. (2022). How much should we trust staggered difference-in-differences estimates?. *Journal of Financial Economics*, 144(2), 370-395.

Barrios, J. M. (2022). Staggeringly problematic: A primer on staggered DiD for accounting researchers. *Available at SSRN 3794859*.

Begley, T. A., Gurun, U. G., Purnanandam, A., & Weagley, D. (2024). Disaster lending: "fair" prices but "unfair" access. *Management Science*, 70(12), 8484-8505.

Bernstein, A., Billings, S. B., Gustafson, M. T., & Lewis, R. (2022). Partisan residential sorting on climate change risk. *Journal of Financial Economics*, 146(3), 989-1015.

Billings, M. B., Ryan, S. G., & Yan, H. (2025). Climate risk, population migration, and banks' lending and deposit-taking activities. *Available at SSRN 4244372*.

Billings, S. B., Gallagher, E. A., & Ricketts, L. (2022). Let the rich be flooded: The distribution of financial aid and distress after hurricane Harvey. *Journal of Financial Economics*, 146(2), 797-819.

Blonz, J. A., Hossain, M., & Weill, J. (2024). Pricing protection: Credit scores, disaster risk, and home insurance affordability. *Available at SSRN 5026600*.

Blundell, R., Pistaferri, L., & Preston, I. (2008). Consumption inequality and partial insurance. *American Economic Review*, 98(5), 1887-1921.

Bonaparte, Y., Korniotis, G. M., Kumar, A., & Vosse, M. (2024). Inflation, monetary policy, and portfolio decisions of US households. *Management Science*, 70(9), 6438-6460.

Boomhower, J., Fowlie, M., Gellman, J., & Plantinga, A. (2024). How are insurance markets adapting to climate change? Risk selection and regulation in the market for homeowners insurance (No. w32625). National Bureau of Economic Research.

Born, P. H., & Klimaszewski‐Blettner, B. (2013). Should I stay or should I go? The impact of natural disasters and regulation on US property insurers' supply decisions. *Journal of Risk and Insurance*, 80(1), 1-36.

Born, P., & Viscusi, W. K. (2006). The catastrophic effects of natural disasters on insurance markets. *Journal of Risk and Uncertainty*, 33(1), 55-72.

Born, P., Karl, J. B., & Klein, R. W. (2018). Does state rate regulation matter? An assessment of the effects of more stringent regulation on insurers' performance in homeowners insurance. *Available at SSRN 3288760*.

Boustan, L. P., Kahn, M. E., Rhode, P. W., & Yanguas, M. L. (2020). The effect of natural disasters on economic activity in US counties: A century of data. *Journal of Urban Economics*, 118, 103257.

Baylis, P., Bharadwaj, P., Mullins, J. T., & Obradovich, N. (2025). Climate and Migration in the United States. *Journal of Public Economics*, 249, 105446.

Cengiz, D., Dube, A., Lindner, A., & Zipperer, B. (2019). The effect of minimum wages on low-wage jobs. *The Quarterly Journal of Economics*, 134(3), 1405-1454.

Choi, D., Gao, Z., & Jiang, W. (2020). Attention to global warming. *The Review of Financial Studies*, 33(3), 1112-1145.

Cookson, J. A., Gallagher, E., & Mulder, P. (2025). Coverage neglect in homeowners insurance. *Available at SSRN 5176504*.

Cummins, J. D. (2007). Reinsurance for Natural and Man‐Made Catastrophes in the United States: Current State of the Market and Regulatory Reforms. *Risk Management and Insurance Review*, 10(2), 179-220.

Cummins, J. D., & Harrington, S. E. (1987). The impact of rate regulation in US property-liability insurance markets: A cross-sectional analysis of individual firm loss ratios. *Geneva Papers on Risk and insurance*, 50-62.

Daverman, T., Kazdin, J., Pensky, M., & Sloof, F. (2023). Extreme weather and retirement savings. *Available at SSRN 4628702*.

Eastman, E., & Kim, K. (2023). Regulatory capital and catastrophe risk. *Available at SSRN 4468543*.

Eastman, E., Kim, K., & Zhou, T. (2024). Homeowners insurance and housing prices. *Available at SSRN 4852702*.

Gallagher, E. A., Billings, S. B., & Ricketts, L. R. (2023). Human capital investment after the storm. *The Review of Financial Studies*, 36(7), 2651-2684.

Gallagher, J., & Hartley, D. (2017). Household finance after a natural disaster: The case of Hurricane Katrina. *American Economic Journal: Economic Policy*, 9(3), 199-228.

Gao, Z., Jo, C., & Lam, S. S. (2022). Climate change and households' risk-taking. *Available at SSRN 4056360*.

Ge, S., Johnson, S., & Tzur-Ilan, N. (2025). Climate risk, insurance premiums and the effects on mortgage and credit outcomes. *Available at SSRN 5101775*.

Ge, S., Lam, A., & Lewis, R. (2022). The costs of hedging disaster risk and home prices in the face of climate change. *Available at SSRN 4192699*.

Gupta, N., & Sedai, A. (2024). Can financial inclusion increase household resilience to natural disasters?. *Available at SSRN 4946080*.

Harrington, S. (1984). The impact of rate regulation on prices and underwriting results in the property-liability insurance industry: A survey. *Journal of Risk and Insurance*, 577-623.

Hemmati, M., Gray, I. P., & Bowen, S. G. (2025). The growing void in the US homeowners insurance market: Who should bear the rising cost of climate change?. *npj Climate Action*, 4(1), 35.

Hu, M., Lin, Z., & Liu, Y. (2024). Financial literacy and mortgage stress. *Journal of Banking & Finance*, 163, 107170.

Kalda, A., Sharma, V., Soni, V., & Wenning, D. (2025). Beyond the storm: climate risk and homeowners' insurance. *Available at SSRN 5138641*.

Keys, B. J., & Mulder, P. (2024). Property insurance and disaster risk: New evidence from mortgage escrow data (No. w32579). *National Bureau of Economic Research*.

Kim, M., Mahajan, P., & Wang, Z. (2025). The rise in insurance costs for commercial properties: Causes, effects on rents, and the role of owners. *Available at SSRN 5175451*.

Ilhan, E. (2020). Sea level rise and portfolio choice. *Available at SSRN 3743046*.

Morris, D. S., Schwarcz, D., & Teitelbaum, J. C. (2017). Do credit‐based insurance scores proxy for income in predicting auto claim risk?. *Journal of Empirical Legal Studies*, 14(2), 397-423.

Nguyen, D. D., Ongena, S., Qi, S., & Sila, V. (2022). Climate change risk and the cost of mortgage credit. *Review of Finance*, 26(6), 1509-1549.

NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2025). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73.

Oh, S., Sen, I., & Tenekedjieva, A. M. (2025). Pricing of climate risk insurance: Regulation and cross-subsidies. *Journal of Finance*, Forthcoming.

Sachdeva, P., Xu, Y., & Ando, A. W. (2024). Household finance in the aftermath of floods and wildfires. *Available at SSRN 4720007*.

Sarada. (2024). The unobserved returns to entrepreneurship. *Review of Economics and Statistics*, 1-45.

Sastry, P., Sen, I., Tenekedjieva, A. M., & Scharlemann, T. C. (2024). Climate risk and the US insurance gap: Measurement, drivers and implications. *Available at SSRN 4909444*.

Schuetz, J. (2023). How will climate change alter household-level housing decisions?. *Available at SSRN 4340610*.

Schwarcz, D. (2011). Reevaluating standardized insurance policies. *The University of Chicago Law Review*, 78, 1263.

Sun, L., & Abraham, S. (2021). Estimating dynamic treatment effects in event studies with heterogeneous treatment effects. *Journal of Econometrics*, 225(2), 175-199.

Sun, T. (2025). Climate change risk perception, media climate change concern and pricing of U.S. homeowners insurance. *Working Paper*.

Telljohann, D., Born, P. H., & Karl, J. B. (2025). Natural disasters and regulatory constraints: US homeowners insurer market responses. *North American Actuarial Journal*, 1-23.

Wrenn, D. H. (2024). The effect of natural disasters and extreme weather on household location choice and economic welfare. *Journal of the Association of Environmental and Resource Economists*, 11(5), 1101-1134.

Wylie, D., Amornsiripanitch, N., Heilbron, J., & Zhao, K. (2025). JUE Insights: Who bears climate-related physical risk?. *Journal of Urban Economics*, 149, 103791.

Yu, Z. (2024). Why are older men working more? The role of social security. *Journal of Public Economics*, 231, 105071.

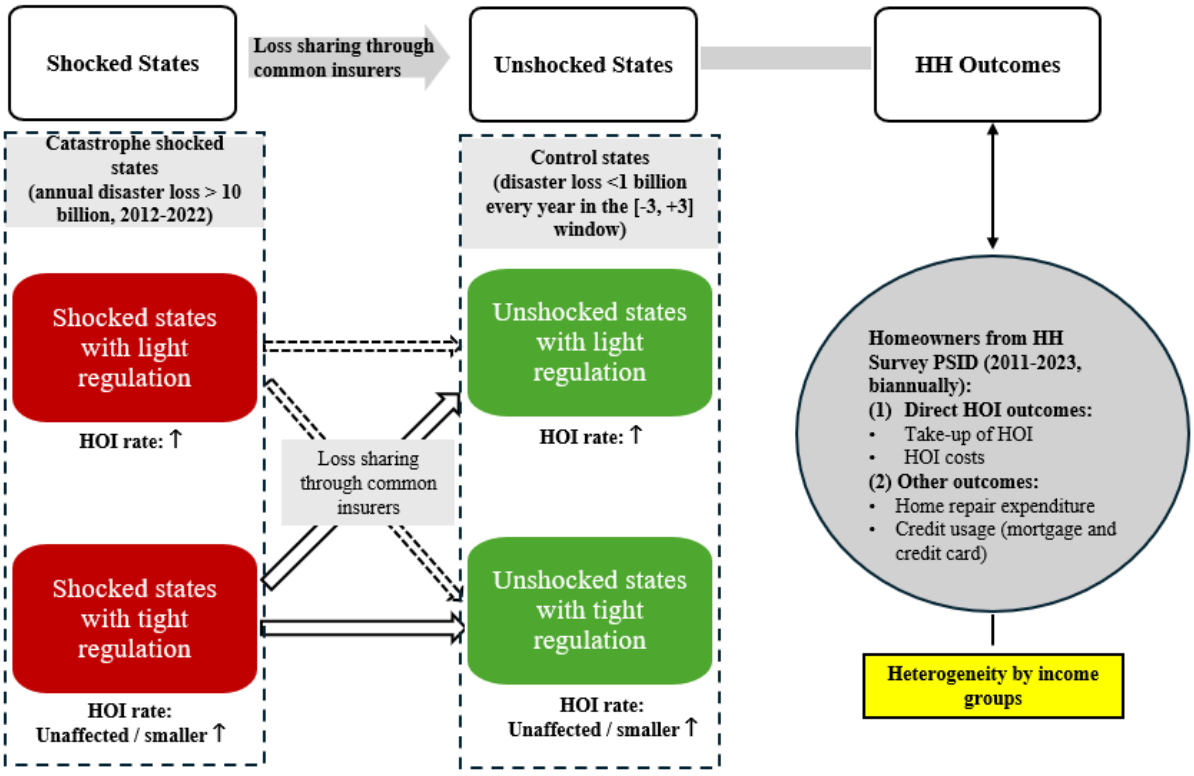


Figure 1. Roadmap of the study

The figure presents the roadmap of the study. The red rectangles on the left represent the shocked states, defined as states experiencing at least one disaster causing more than ten billion (bn) dollars in losses. The green rectangles on the right represent the selected unshocked states, defined as states whose annual disaster losses remain below one bn dollars throughout the [-3,+3] year window surrounding each catastrophe shock. The gray circle shows the household-level outcomes examined in the analysis.

Table 1. Blockbuster disaster events from 2012 to 2022

The table lists 18 blockbuster disaster (catastrophe) events identified from 2012 to 2022. A blockbuster disaster is defined as a state-year in which annual disaster losses (excluding flooding, droughts and earthquakes) exceed 10 billion (bn) dollars in CPI-adjusted terms. Columns (3)-(7) report corresponding calendar-year window, control states and household survey waves used in our analysis. Unshocked states are defined as states whose annual disaster losses are below one bn dollars throughout the [-3, +3] window and they are used as the control group. I remain only the first shock year for each shocked state within the [-3,+3] window (dropped events marked by strikethrough). For example, though Texas (TX) experienced blockbuster disasters in 2016, 2017, and 2019, I only include the 2016 catastrophe in analysis for cleaner inference because the pre-shock period of a subsequent catastrophe that occurred shortly after the previous one can be contaminated by the previous catastrophe.

Cohort year	**Catastrophe shocked states**	**Year window**	**Control states selection criteria**	**List of control states**	**# of control states**	**HH survey waves used**
(1)	(2)	(3)	(4)	(5)	(6)	**(7)**
2012	NJ, NY	[2009, 2015]	Annual disaster loss < 1 bn from 2009 to 2015	AK, DC, DE, FL, HI, ID, ME, MI, MT, ND, NH, NM, NV, OR, RI, SC, SD, UT, WA, WV, WY	21	[-2, 2]: 2009, 2011, 2013, 2015
2016	TX	[2013, 2019]	Annual disaster loss < 1 bn from 2013 to 2019	AK, AR, AZ, CT, DC, DE, HI, ID, IN, KS, KY, LA, MA, ME, MI, ND, NH, NJ, NM, NV, OR, RI, SD, UT, VT, WA, WI, WV, WY	29	[-2, 2]: 2013, 2015, 2017, 2019
2017	~~TX,~~ CA, FL	[2014, 2020]	Annual disaster loss < 1 bn from 2014 to 2020	AK, AZ, CT, DC, DE, HI, ID, IN, KS, KY, MA, ME, MI, ND, NH, NM, NV, RI, SD, UT, VT, WA, WI, WV, WY	25	[-1, 1]: 2015, 2017, 2019
2018	NC,~~ FL, CA~~	[2015, 2021]	Annual disaster loss < 1 bn from 2015 to 2021	AK, AZ, DC, DE, HI, ID, KS, MA, ME, ND, NH, NM, NV, RI, SD, UT, VT, WA, WI, WV, WY	21	[-2, 2]: 2015, 2017, 2019, 2021
~~2019~~	~~TX~~	~~[2016, 2022]~~	~~Annual disaster loss < 1 bn from 2016 to 2021~~	~~AK, AZ, DC, DE, HI, ID, KS, MA, ME, ND, NH, NV, RI, UT, VT, WA, WV, WY~~	~~18~~	~~[1, 1]: 2017, 2019, 2021~~
2020	LA, ~~CA,~~ IA	[2017, 2023]	Annual disaster loss < 1 bn from 2017 to 2023	AK, AZ, DC, DE, ID, KS, MA, ME, ND, NH, NV, RI, UT, VT, WA, WV, WY	17	[-2, 2]: 2017, 2019, 2021, 2023
2021	~~LA, TX,~~ NY, NJ	[2018, 2023]	Annual disaster loss < 1 bn from 2018 to 2023	AK, AZ, DC, DE, ID, KS, MA, ME, MT, ND, NH, NV, RI, UT, VT, WA, WV, WY	18	[-1, 1]: 2019, 2021, 2023
~~2022~~	~~FL~~	~~[2019, 2023]~~	~~Annual disaster loss < 1 bn from 2019 to 2023~~	~~AK, AZ, DC, DE, ID, KS, MA, MD, ME, MT, ND, NH, NV, RI, UT, VA, VT, WA, WV, WY~~	~~20~~	~~[2, 1]: [2019, 2021, 2023]~~

Table 2. Summary statistics for key variables in the shocked and unshocked sample

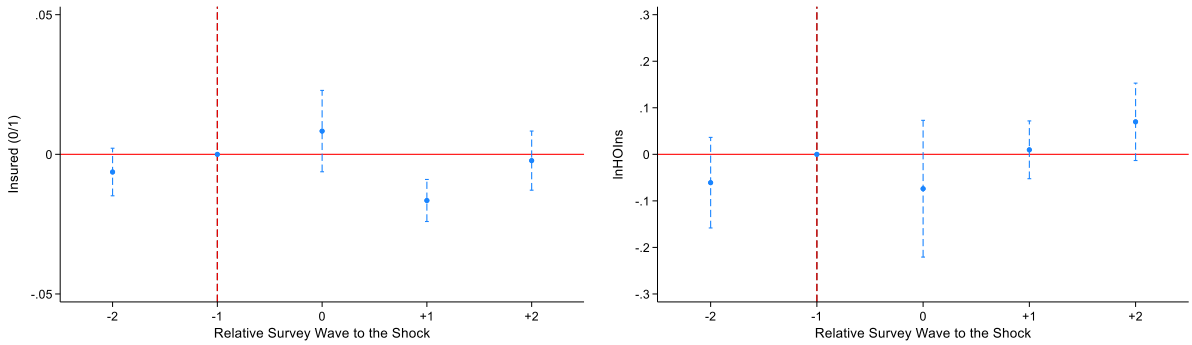
The table provides the summary statistics for the key variables in the cohort-based stacked household sample over the three-year window surrounding each shock. The treatment group consists of households in states directly affected by a catastrophe, defined as a state-year in which annual disaster losses (excluding flooding, droughts, and earthquakes) exceed 10 billion dollars in CPI-adjusted terms. The control group includes households in states whose annual disaster losses remain below one billion dollars throughout the [-3,+3] window. Survey waves falling within the [-3,+3] year window (as listed in Table 1) are included in each cohort. All continuous and non-logged variables are winsorized at the 1st and 99th percentiles in the stacked sample, unless stated otherwise. Detailed variable definitions are provided in Appendix Table A1.

	N	Mean	SD	P10	Median	P90
Household-level variables						
Insured (0/1)	15918	0.967	0.179	1	1	1
HOIns (non-winsorized raw)	15918	1183.948	1016.399	350	995.49	2250
HOIns	15918	1168.822	901.365	350	995.49	2250
*HOIns (*for *Insured* =1)	15393	1208.686	889.935	400	1000	2300
HOI_Burden	15883	1.667	1.963	0.345	1.062	3.535
*HOI_Burden (*for *Insured* =1)	15358	1.724	1.972	0.4	1.101	3.582
HomeRepair	15918	2852.863	5828.275	0	800	8000
CrCard	15918	3228.89	6544.397	0	0	10000
Age	15918	53.664	14.819	34	54	73
Married (0/1)	15918	0.746	0.435	0	1	1
Child (0/1)	15918	0.862	0.345	0	1	1
College (0/1)	15894	0.396	0.489	0	0	1
TotFamInc (in 1,000)	15918	106.854	84.912	28.08	86.1	208.25
HouseValue (in 1,000)	15918	496.993	1393.456	70	230	670
Mortgage (0/1)	15918	0.678	0.467	0	1	1
MortgBalance (in 1,000)	15918	407.75	1692.916	0	80	320
State-level variables, lagged year						
DisasterLoss (in bn)	15918	4.093	19.747	0	0.175	3.5
lnDisaLoss	15918	14.783	8.911	0	18.98	22.025
lnPerGDP	15918	10.924	0.238	10.658	10.913	11.217
lnPopu	15918	0.045	0.048	-0.013	0.049	0.095
HPI_Chg	15918	15.693	0.91	14.566	15.748	16.866
Democracy	15918	0.46	0.163	0.262	0.417	0.665

Table 3. Effect of catastrophe shocks on homeowners insurance take-up and expenditure

The table shows the effects of catastrophe shocks on household homeowners insurance take-up and expenditure, based on the stacked household sample over the [-3,+3] event window. *Shock* is the treatment indicator, equal to one for households located in states directly shocked by a catastrophe and zero for households located in the control states. *Post* is the post-event indicator, set to one for survey years in or after the shock year. In Columns (1)-(3), the outcome variable is a dummy (*Insured*) indicating whether a household holds homeowners insurance in the survey year; the sample is restricted to homeowners who already held homeowners insurance before the shock (*Pre-HOI*). In Columns (4)-(6), the outcome variable is the natural logarithm of annual homeowners insurance expenditure (*lnHOIns*) conditional on having homeowners insurance throughout the cohort window (*Always-HOI*). Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*			*lnHOIns*		
	(1)	(2)	(3)	(4)	(5)	(6)
*Shock*Post*	-0.008***	-0.008**	-0.008**	0.011	0.011	0.026
	(-2.854)	(-2.707)	(-2.319)	(0.310)	(0.297)	(0.685)
lnAge		-0.013	-0.011		0.264	0.316
		(-0.193)	(-0.170)		(0.300)	(0.359)
Married		0.024*	0.025**		0.068	0.073
		(1.992)	(2.082)		(1.494)	(1.627)
Child		0.002	0.002		0.205**	0.211**
		(0.582)	(0.656)		(2.517)	(2.671)
College		0.007***	0.007***		0.070	0.071
		(2.759)	(2.899)		(0.378)	(0.386)
lnFamInc		0.004	0.004		0.024	0.021
		(0.969)	(0.946)		(1.278)	(1.114)
lnHouseValue		-0.004	-0.005		0.061***	0.058***
		(-0.735)	(-0.774)		(3.164)	(3.112)
Mortgage		0.012	0.012		0.006	0.004
		(1.357)	(1.335)		(0.167)	(0.104)
LlnDisaLoss			0.000			0.001
			(0.723)			(0.798)
LlnPerGDP			-0.016			0.384
			(-0.447)			(1.254)
LHPI_Chg			0.137			1.070
			(1.471)			(1.322)
LlnPopu			0.048			0.272
			(0.957)			(0.450)
LDemocracy			-0.023			-0.421
			(-0.693)			(-1.446)
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
Mean of Y (non-logged)	0.99	0.99	0.99	1213.05	1214.16	1214.16
N	14852	14796	14796	14534	14479	14479
Adj. R^2	0.277	0.279	0.279	0.441	0.441	0.442



(a) Dynamic effects of catastrophe shocks on homeowners insurance take-up

(b) Dynamic effects of catastrophe shocks on homeowners insurance expenditure

Figure 2. Dynamic effects of catastrophe shocks on homeowners insurance take-up and expenditure
Figures 2(a) and 2(b) plot the estimated dynamic DiD coefficients over the [-2,+2] survey-wave window around the catastrophe shock, corresponding to Columns (3) and (6) of Table 3, respectively. The dashed lines denote the 90% confidence intervals. Standard errors are clustered at the state level.

Table 4. Effect of catastrophe shocks on homeowners insurance take-up and expenditure, sorted by rate regulation

The table compares the effects of catastrophe shocks on homeowners insurance take-up and expenditure, depending on the shocked states' rate regulation. Panel A reports the pre-to-post changes for households located in shocked states over the [-3,+3] event window. *Post* is the post-event indicator for survey years in or after the shock year. Subsample analyses are conducted based on the pre-shock regulatory stringency of homeowners insurance rates. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Columns (1) and (3) report results for high-regulation states, and Columns (2) and (4) report results for low-regulation states. Following that, the table presents the *p-values* of Chow tests on the difference of the estimates across two samples. Due to the limited number of shocked states, standard errors are clustered at the state-year level. Panel B reports the DiD results based on the full stacked household sample over the [-3,+3] event window. The treatment variable in the baseline Table 3, *Shock*, is decomposed into two indicators for shocked states to indicate different homeowners insurance regulatory stringency. *LowReg*Shock* equals one for shocked states with low regulatory stringency before the shock and *HighReg*Shock* equals one for shocked states with high regulatory stringency before the shock. Households in control states serve as the reference group. In Columns (1)-(2), the sample is restricted to homeowners who already held homeowners insurance before the shock. In Columns (3)-(4), the sample is conditional on homeowners having homeowners insurance throughout the cohort window. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Panel A: Pre-to-post changes in homeowners insurance outcomes for households in shocked states

Y =	*Insured (0/1)*		*lnHOIns*	
	(1)	(2)	(3)	(4)
Post (b_0)	-0.017	-0.042*	-0.056	0.224**
	(-1.376)	(-2.557)	(-1.058)	(3.237)
diff. in b_0 (Col. (1) - Col. (2))	0.025			
p-value of the Chow test	1.273			
diff. in b_0 (Col. (3) - Col. (4))			-0.280***	
p-value of the Chow test			-3.414	
Cohort-by-HH FE	Y	Y	Y	Y
HH control	Y	Y	Y	Y
Lagged state control	N	N	N	N
State sample	High-reg	Low-reg	High-reg	Low-reg
Mean of Y (non-logged)	0.99	0.99	1370.68	1521.72
N	3063	717	2983	696
Adj. R^2	0.250	0.233	0.443	0.489

Panel B: The moderating effects of homeowners insurance rate regulation

Y =	*Insured (0/1)*			*lnHOIns*		
	(1)	(2)	(3)	(4)	(5)	(6)
*LowReg*Shock*Post* (b_1)	-0.018***	-0.019***	-0.019***	0.129***	0.132***	0.139***
	(-6.358)	(-6.815)	(-3.831)	(3.115)	(2.927)	(3.481)
*HighReg*Shock*Post* (b_2)	-0.006*	-0.005	-0.005	-0.020	-0.021	-0.004
	(-1.692)	(-1.535)	(-1.192)	(-0.590)	(-0.621)	(-0.121)
b_1-b_2	-0.012***	-0.014***	-0.014**	0.149***	0.153***	0.143***
p-value for testing b_1-b_2=0	0.003	0.001	0.033	0.003	0.004	0.003
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	N	Y	Y	N	Y	Y
Lagged state control	N	N	Y	N	N	Y
Mean of Y (non-logged)	0.99	0.99	0.99	1213.05	1214.16	1214.16
N	14852	14796	14796	14534	14479	14479
Adj. R^2	0.278	0.280	0.280	0.441	0.442	0.442

Table 5. Effect of catastrophe shocks on homeowners insurance take-up and expenditure, based on the propensity score matched sample

The table shows the effects of catastrophe shocks on homeowners insurance take-up and expenditure, based on the one-to-one propensity score matched household sample over the [-3,+3] event window. In the survey wave before the shock year (e.g., Survey Wave 2011 in cohort 2012), each treated household in a shocked state is matched to one household in a selected unshocked state within the same cohort, using a caliper of 0.05 and allowing for replacement. Covariates used for matching include *lnHOIns,* the ratio of homeowners insurance expenditure to income, *lnAge, Married, College, lnHouseValue, Mortgage* and state-level *GDP per capita*. *Shock* is the treatment indicator, which equals one for households in states directly shocked by a catastrophe and zero for households in the control states. *LowReg*Shock* equals one for shocked states with low regulatory stringency before the shock and *HighReg*Shock* equals one for shocked states with high regulatory stringency before the shock. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Households in control states serve as the reference group. In Columns (1)-(2), the sample is restricted to homeowners who already held homeowners insurance before the shock. In Columns (3)-(4), the sample is conditional on homeowners having homeowners insurance throughout the cohort window. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*		*lnHOIns*	
	(1)	(2)	(3)	(4)
*Shock*Post*	-0.001		0.023	
	(-0.110)		(0.373)	
*LowReg*Shock*Post* (b_1)		-0.011		0.236***
		(-1.263)		(3.732)
*HighReg*Shock*Post* (b_2)		0.002		-0.035
		(0.488)		(-0.648)
b_1-b_2		-0.013*		0.271***
p-value for testing b_1-b_2=0		0.081		0.000
Cohort-by-Year FE	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y
HH control	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y
Mean of Y (non-logged)	0.99	0.99	1307.74	1307.74
N	7292	7292	7095	7095
Adj. R^2	0.305	0.306	0.485	0.487

Table 6. Use homeowners insurance burden as an alternative outcome

The table shows the effects of catastrophe shocks on homeowners insurance burden, based on the stacked household sample over the [-3,+3] event window. Homeowners insurance burden (*HOI_Burden*) is defined as annual homeowners insurance expenditure ÷ annual household income * 100. All columns are based on the sample of homeowners holding homeowners insurance throughout the cohort window. *Post* is the post-event indicator for survey years in or after the shock year. *Shock* is the treatment indicator, which equals one for households in states directly shocked by a catastrophe and zero for households in the control states. From Columns (1) to (3), a pre-to-post test is conducted in low-friction shocked, high-friction shocked and unshocked control states, respectively, controlling for Cohort-by-Household fixed effects. The standard errors are clustered at the state-year level due to the limited number of states. Columns (4) and (5) report the DiD results based on the whole sample from Table 3. *LowReg*Shock* equals one for shocked states with low regulatory stringency before the shock and *HighReg*Shock* equals one for shocked states with high regulatory stringency before the shock. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Households in control states serve as the reference group. Household characteristics in the survey year, lagged state-level covariates, Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are included in Columns (4) and (5). Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y = HOI_Burden	(1)	(2)	(3)	(4)	(5)
Post	0.198**	0.359*	0.230***		
	(2.183)	(2.137)	(6.415)		
*Shock*Post*				-0.009	
				(-0.115)	
*LowReg*Shock*Post* (b_1)					0.203**
					(2.690)
*HighReg*Shock*Post* (b_2)					-0.067
					(-0.914)
b_1-b_2					0.270***
p-value for testing b_1-b_2=0					0.001
Cohort-by-Year FE	N	N	N	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y
HH control	N	N	N	Y	Y
Lagged state control	N	N	N	Y	Y
State sample	High-reg & Shocked	Low-reg & Shocked	Control	Shocked & Control	
Mean of Y	1.85	2.36	1.63	1.70	1.70
N	2986	701	11315	14497	14479
Adj. R^2	0.493	0.582	0.514	0.524	0.685

Table 7. Effect of catastrophe shocks on other household outcomes

The table shows the effects of catastrophe shocks on other household outcomes, based on the stacked household sample over the [-3,+3] event window. *Post* is the post-event indicator for survey years in or after the shock year. *Shock* is the treatment indicator, which equals one for households in states directly shocked by a catastrophe and zero for households in the control states. Then it is decomposed into two indicators for different homeowners insurance regulatory stringency in Columns (2), (4), and (6). *LowReg*Shock* equals one for shocked states with low regulatory stringency before the shock and *HighReg*Shock* equals one for shocked states with high regulatory stringency before the shock. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Households in control states serve as the reference group. The outcome variables are house repair expenditure in the past year (*HomeRepair*), mortgage balance (*MortgBalance*), and credit card balance (*CrCard*) at the time of the survey, respectively. All variables are measured in 1,000 dollars, so Poisson models are used. Regressions are based on the sample of homeowners holding homeowners insurance throughout the cohort window. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*HomeRepair*		*MortgBalance*		*CrCard*	
	(1)	(2)	(3)	(4)	(5)	(6)
*Shock*Post*	0.053		0.101		0.176*	
	(0.505)		(0.594)		(1.828)	
*LowReg*Shock*Post* (b_1)		0.368***		-0.235		0.100
		(2.913)		(-0.840)		(0.783)
*HighReg*Shock*Post* (b_2)		-0.033		0.213		0.203**
		(-0.346)		(1.316)		(1.987)
b_1-b_2		0.400***		-0.448		-0.103
p-value for testing b_1-b_2=0		0.000		0.121		0.398
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
Mean of Y (in 1,000)	3.08	3.08	573.49	573.49	5.84	5.84
N	12420	12420	10026	10026	8184	8184
Pseudo R^2	0.454	0.454	0.786	0.786	0.510	0.510

Table 8. Summary statistics for selected unshocked households

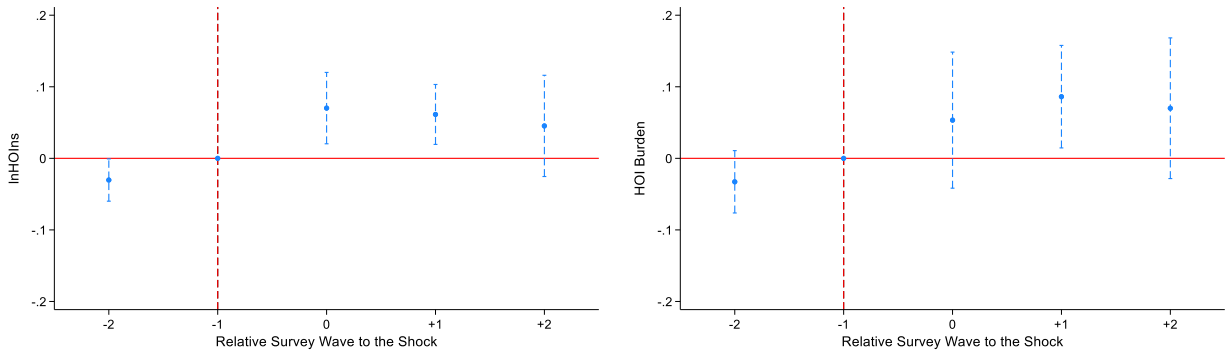
The table provides summary statistics for key variables in the cohort-based stacked sample for selected unshocked (control) households over the three-year window surrounding the shock. The treatment group includes households in states directly affected by a catastrophe, defined as a state-year in which annual disaster losses (excluding flooding, droughts, and earthquakes) exceed 10 bn dollars in CPI-adjusted terms. The control group comprises households in states with annual disaster losses below one bn dollars throughout the [-3,+3] window. Survey waves within the [-3,+3] year window (as listed in Table 1) are included in each cohort. All continuous variables at the household level are winsorized at the 1st and 99th percentiles (unless otherwise noted) in the stacked sample in Table 2. Detailed variable definitions are provided in Appendix Table A1.

	N	**Mean**	**SD**	**P10**	**Median**	**P90**
LossShrExp	11929	1.474	1.495	0.052	1.014	3.868
Insured (0/1)	11929	0.971	0.169	1	1	1
HOIns (non-winsorized raw)	11929	1136.53	917.725	350	926	2100
HOIns	11929	1126.058	858.84	350	926	2100
*HOIns (*for *Insured* =1)	11578	1160.196	848.74	400	980.33	2157
HOI_Burden	11905	1.594	1.878	0.345	1.026	3.38
*HOI_Burden (*for *Insured* =1)	11554	1.643	1.885	0.394	1.059	3.448
HomeRepair	11929	2929.374	5930.281	0	800	8000
CrCard	11929	3126.097	6330.331	0	0	10000
Age	11929	53.525	15.033	33	54	73
Married (0/1)	11929	0.747	0.435	0	1	1
Child (0/1)	11929	0.859	0.348	0	1	1
College (0/1)	11917	0.406	0.491	0	0	1
TotFamInc (in 1,000)	11929	107.347	85.055	28.8	87.109	207
HouseValue (in 1,000)	11929	477.69	1308.975	70	240	675
Mortgage (0/1)	11929	0.678	0.467	0	1	1
MortgBalance (in 1,000)	11929	375.833	1600.645	0	80	315

Table 9. Effect of catastrophe shocks on homeowners insurance take-up and expenditure for unshocked households

The table shows the continuous treatment effects of catastrophe shocks on homeowners insurance take-up and expenditure for households in unshocked states, based on the stacked household sample over the [-3,+3] event window. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. The outcomes variables are a dummy (*Insured*) indicating whether a household holds homeowner insurance in the survey year, the natural logarithm of annual homeowners insurance expenditure (*lnHOIns*), and homeowners insurance expenditure burden (*HOI_Burden*). In Columns (1)-(3), the sample is restricted to homeowners who already held homeowners insurance before the shock. Columns (4)-(9) are based on the sample of homeowners holding homeowners insurance throughout the cohort window. Household characteristics in the survey year and lagged state-level covariates are added stepwise as controls. All regressions include both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*			*lnHOIns*			*HOI_Burden*		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
*LossShrExp*Post*	-0.002	-0.002	-0.004	0.070***	0.064**	0.069**	0.083*	0.088*	0.087**
	(-0.843)	(-0.825)	(-1.104)	(2.821)	(2.596)	(2.568)	(1.790)	(1.851)	(2.055)
lnAge		-0.068	-0.058		0.488	0.505		-0.015	0.006
		(-0.858)	(-0.758)		(0.454)	(0.470)		(-0.011)	(0.004)
Married		0.023	0.024*		0.081	0.089*		0.286*	0.309**
		(1.607)	(1.721)		(1.566)	(1.726)		(2.038)	(2.282)
Child		0.003	0.004		0.206*	0.215**		0.425**	0.443**
		(0.649)	(0.766)		(1.888)	(2.066)		(2.402)	(2.606)
College		0.006*	0.006*		-0.075	-0.074		0.175	0.190
		(1.918)	(1.973)		(-0.467)	(-0.458)		(0.956)	(1.004)
lnFamInc		0.004	0.003		0.025	0.021		-1.792***	-1.799***
		(0.678)	(0.618)		(1.229)	(1.064)		(-8.944)	(-8.906)
lnHouseValue		-0.005	-0.005		0.077***	0.075***		0.110**	0.106**
		(-0.615)	(-0.683)		(3.637)	(3.588)		(2.630)	(2.538)
Mortgage		0.004	0.003		-0.020	-0.020		0.117	0.113
		(0.481)	(0.410)		(-0.475)	(-0.457)		(1.447)	(1.414)
LlnDisaLoss			0.000			0.001			0.002
			(0.750)			(1.386)			(1.006)
LlnPerGDP			-0.016			0.673*			0.534
			(-0.489)			(1.884)			(0.808)
LHPI_Chg			0.072			0.137			-0.249
			(1.697)			(0.170)			(-0.180)
LlnPopu			0.240**			-0.227			1.581
			(2.410)			(-0.211)			(0.537)
LDemocracy			-0.029			-0.422			-1.399**
			(-0.902)			(-1.302)			(-2.414)
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
HH sample		Pre-HOI				Always-HOI			
Mean of Y (non-logged)	0.99	0.99	0.99	1162.06	1163.66	1163.66	1.63	1.63	1.63
Mean of *LossShrExp*	1.39	1.39	1.39	1.40	1.40	1.40	1.40	1.40	1.40
SD of *LossShrExp*	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
N	11193	11156	11156	10969	10933	10933	10943	10933	10933
Adj. R^2	0.308	0.310	0.310	0.433	0.434	0.435	0.519	0.688	0.689



(a) Dynamic effects of catastrophe shocks on HOI costs, for unshocked households

(b) Dynamic effects of catastrophe shocks on HOI burden, for unshocked households

Figure 3. Dynamic effects of catastrophe shocks on homeowners insurance take-up and expenditure for unshocked households

Figures 3(a) and 3(b) plot the estimated dynamic DiD coefficients over the [-2,+2] survey-wave window around the catastrophe shock for households in the control group, corresponding to the dynamics of Columns (6) and (9) of Table 9, respectively. The dashed lines denote the 90% confidence intervals. Standard errors are clustered at the state level.

Table 10. Effect of catastrophe shocks on homeowners insurance take-up and expenditure for unshocked households, moderated by rate regulation

The table compares the continuous treatment effects of catastrophe shocks on homeowners insurance take-up and expenditure for households in unshocked states depending on homeowners insurance rate regulation, based on the stacked household sample over the [-3,+3] event window. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. *LowReg (HighReg)* equals one for states with low (high) regulatory stringency and zero otherwise. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. In addition to household characteristics in the survey year and lagged state-level covariates, *LowReg*Post* are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*	*lnHOIns*	*HOI Burden*
	(1)	(2)	(3)
*LowReg*LossShrExp*Post (b_1)*	-0.001	0.087***	0.133***
	(-0.380)	(4.583)	(3.577)
*HighReg*LossShrExp*Post (b_2)*	-0.006	0.058*	0.057
	(-1.379)	(1.948)	(1.437)
b_1-b_2	0.004**	0.030	0.076**
p-value for testing b_1-b_2=0	0.041	0.159	0.016
Cohort-by-Year FE	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y
HH control	Y	Y	Y
Lagged state control	Y	Y	Y
HH sample	Pre-HOI	Always-HOI	
Mean of Y (non-logged)	0.99	1163.66	1.63
Mean of *LossShrExp*	1.39	1.40	1.40
SD of *LossShrExp*	1.43	1.43	1.43
N	11156	10933	10933
Adj. R^2	0.311	0.435	0.689

Table 11. Heterogeneity sorted by market competition: Effect of catastrophe shocks on homeowners insurance take-up and expenditure for unshocked households

The table compares the continuous treatment effects of catastrophe shocks on homeowners insurance take-up and expenditure of households in unshocked states depending on homeowners insurance market competition, in the low-regulation and high-regulation groups, respectively. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. Market competition in homeowners insurance is measured using the average Herfindahl-Hirschman Index (HHI) over the [-3,-1] year window. An unshocked state is classified as low competition (*LowComp*) if its average HHI is above the median among the 50 states and DC, and as high competition (*HighComp*) otherwise. Columns (1)-(3) report the results for low-regulation states and Columns (4)-(6) report the results for high-regulation states. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	Low-regulation states			High-regulation states		
	Insured (0/1)	*lnHOIns*	*HOI_Burden*	*Insured (0/1)*	*lnHOIns*	*HOI_Burden*
	(1)	(2)	(3)	(4)	(5)	(6)
*LossShrExp*Post*LowComp* (b_1)	-0.017	0.175***	0.217***	-0.005	0.051*	0.067
	(-1.242)	(4.106)	(3.863)	(-1.180)	(1.889)	(1.712)
*LossShrExp*Post*HighComp* (b_2)	-0.009	0.118***	0.102**	-0.001	0.076	0.047
	(-0.820)	(3.706)	(2.129)	(-0.228)	(1.267)	(0.728)
b_1-b_2	-0.008	0.057**	0.115***	-0.005	-0.025	0.020
p-value for testing b_1-b_2=0	0.104	0.030	0.001	0.287	0.524	0.695
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
HH sample	Pre-HOI	Always-HOI		Pre-HOI	Always-HOI	
Mean of Y (non-logged)	0.99	1159.71	1.60	0.99	1166.28	1.65
Mean of *LossShrExp*	1.50	1.51	1.51	1.32	1.32	1.32
SD of *LossShrExp*	1.40	1.40	1.40	1.45	1.45	1.45
N	4460	4361	4361	6696	6572	6572
Adj. R^2	0.304	0.432	0.680	0.320	0.438	0.702

Table 12. Effect of catastrophe shocks on other household outcomes for unshocked households

The table shows the continuous treatment effects of catastrophe shocks on other household outcomes in unshocked states based on the stacked household sample over the [-3,+3] event window. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. *HighReg (LowReg)* equals one for states with high (low) regulatory stringency and zero otherwise. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. The outcome variables are house repair expenditure in the past year (*HomeRepair*), mortgage balance (*MortgBalance*), and credit card balance (*CrCard*) at the time of the survey, respectively. All variables are measured in 1,000 dollars, so Poisson models are used. Regressions are based on the sample of homeowners who consistently hold homeowners insurance throughout the cohort window. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*HomeRepair*		*MortgBalance*		*CrCard*	
	(1)	(2)	(3)	(4)	(5)	(6)
*LossShrExp*Post*	-0.064		-0.173**		0.074	
	(-1.228)		(-2.017)		(1.360)	
*LowReg*LossShrExp*Post*		-0.068		-0.205*		0.012
		(-0.909)		(-1.886)		(0.205)
*HighReg*LossShrExp*Post*		-0.064		-0.146*		0.079
		(-1.255)		(-1.766)		(1.489)
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
Mean of Y (non-logged)	3.09	3.09	521.40	521.40	5.72	5.72
Mean of *LossShrExp*	1.40	1.40	1.40	1.40	1.36	1.36
SD of *LossShrExp*	1.41	1.41	1.42	1.42	1.49	1.49
N	10358	10358	7521	7521	6078	6078
Pseudo R^2	0.453	0.453	0.814	0.814	0.500	0.501

Table 13. Heterogeneity sorted by household income: Effect of catastrophe shocks on homeowners insurance take-up and expenditure

The table compares the effects of catastrophe shocks on homeowners insurance take-up and expenditure, depending on household income. *Post* is the post-event indicator for survey years in or after the shock year. *LowReg*Shock* equals one for shocked states with low regulatory stringency before the shock and *HighReg*Shock* equals one for shocked states with high regulatory stringency before the shock. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Households in control states serve as the reference group. Columns (1)-(3) report results for low-income households, and Columns (4)-(6) report results for high-income households. Households with annual family income below (above) the state median in the survey wave that was immediately before the shock are classified as low-income (high-income). Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

	Low-income group			High-income group		
Y =	*Insured (0/1)*	*lnHOIns*	*HOI Burden*	*Insured (0/1)*	*lnHOIns*	*HOI Burden*
	(1)	(2)	(3)	(4)	(5)	(6)
*LowReg*Shock*Post* (b_1)	-0.035***	0.200**	0.332**	-0.003	0.081*	0.062
	(-5.263)	(2.612)	(2.230)	(-0.289)	(1.737)	(1.200)
*HighReg*Shock*Post* (b_2)	-0.016**	-0.002	-0.149	0.008**	-0.004	0.004
	(-2.038)	(-0.034)	(-1.335)	(2.668)	(-0.082)	(0.085)
b_1-b_2	-0.019*	0.201***	0.482***	-0.011	0.085	0.057
p-value for testing b_1-b_2=0	0.053	0.003	0.003	0.285	0.134	0.367
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
HH sample	Pre-HOI	Always-HOI		Pre-HOI	Always-HOI	
Mean of Y (non-logged)	0.99	1038.94	2.37	1.00	1364.90	1.12
N	6934	6696	6696	7862	7783	7783
Adj. R^2	0.278	0.412	0.663	0.282	0.430	0.644

Table 14. Heterogeneity sorted by household income: Effect of catastrophe shocks on homeowners insurance take-up and expenditure for unshocked households

The table compares the continuous treatment effects of catastrophe shocks on homeowners insurance take-up and expenditure for households in unshocked states depending on household income, in the low-regulation and high-regulation groups, respectively. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. *LowInc* (*HighInc*) is an indicator for low-income (high-income) households. Households with annual family income below (above) the state median in the survey wave that was immediately before the shock are classified as low-income (high-income). Columns (1) to (3) report the results for low-regulation states and Columns (4) to (6) report the results for high-regulation states. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	Low-regulation states			High-regulation states		
	Insured (0/1)	*lnHOIns*	*HOI_Burden*	*Insured (0/1)*	*lnHOIns*	*HOI_Burden*
	(1)	(2)	(3)	(4)	(5)	(6)
*LossShrExp*Post*LowInc* (b_1)	-0.009	0.123***	0.144**	-0.008*	0.069	0.155***
	(-0.847)	(3.046)	(2.505)	(-1.929)	(1.326)	(3.011)
*LossShrExp*Post*HighInc* (b_2)	-0.012	0.126***	0.086	-0.003	0.055	0.034
	(-0.962)	(4.296)	(1.617)	(-1.075)	(1.706)	(1.225)
b_1-b_2	0.003	-0.004	0.058	-0.005**	0.013	0.121***
p-value for testing b_1-b_2=0	0.354	0.900	0.137	0.032	0.557	0.005
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
HH sample	Pre-HOI	Always-HOI		Pre-HOI	Always-HOI	
Mean of Y (non-logged)	0.99	1159.71	1.60	0.99	1166.28	1.65
Mean of *LossShrExp*	1.50	1.51	1.51	1.32	1.32	1.32
SD of *LossShrExp*	1.40	1.40	1.40	1.45	1.45	1.45
N	4460	4361	4361	6696	6572	6572
Adj. R^2	0.303	0.431	0.680	0.320	0.438	0.703

Table 15. Mechanism: The change of homeowners insurance premium growth at the state level

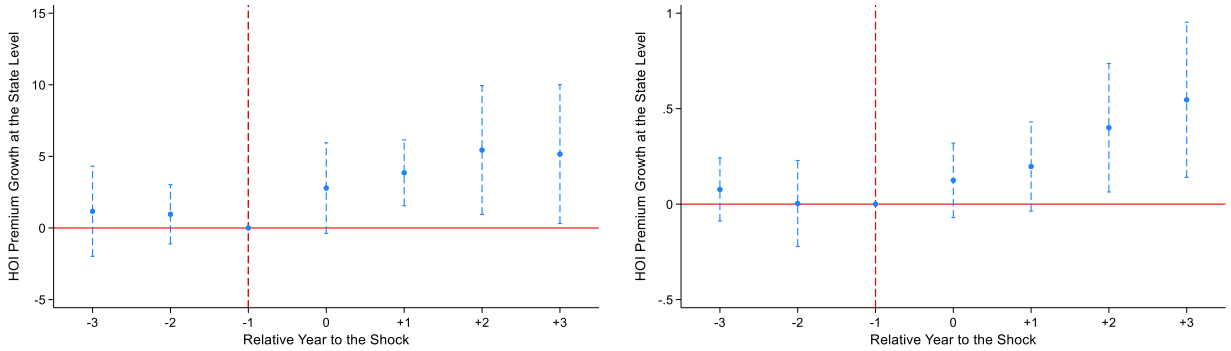
The table shows the effects of catastrophe shocks on state-level homeowners insurance premium growth using the cohort-based stacked sample over the [-3,+3] event window. The outcome variable is the growth of average homeowners insurance premium at the state level (*HOIPrem_Growth*), calculated as (average homeowners insurance premium - lagged average homeowners insurance premium) / lagged average homeowners insurance premium *100. Panel A is based on the full sample of both shocked and unshocked states. *Shock* is the treatment indicator, which equals one for states directly shocked by a catastrophe and zero for the control states. *HighReg (LowReg)* equals one for unshocked states with high (low) regulatory stringency and zero otherwise. *Post* is the post-event indicator for survey years in or after the shock year. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Panel B is based on the sample of unshocked states. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Panel A. DiD tests on homeowners insurance premium growth for shocked and unshocked states

Y = *HOIPrem_Growth*	(1)	(2)	(3)	(4)
*Shock*Post*	2.745*		3.381*	
	(1.764)		(1.990)	
*LowReg*Shock*Post* (b_1)		5.166**		6.436**
		(2.301)		(2.094)
*HighReg*Shock*Post* (b_2)		2.087		2.647
		(1.230)		(1.638)
b_1-b_2		3.079		3.789
p-value for b_1-b_2=0		0.283		0.256
Cohort-by-Year FE	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y
Pre_HOIPrem_Post	N	N	Y	Y
State controls in Table 3 Col. (3)	N	N	Y	Y
Mean of Y	3.892	3.874	3.892	3.874
N	928	918	928	918
Adj. R^2	0.423	0.423	0.435	0.435

Panel B. Continuous DiD tests on homeowners insurance premium growth for unshocked states

Y = *HOIPrem_Growth*	(1)	(2)	(3)	(4)
*LossShrExp*Post*	0.258**		0.237**	
	(2.484)		(2.450)	
*LowReg*LossShrExp*Post* (b_1)		0.804**		0.623**
		(2.610)		(2.299)
*HighReg*LossShrExp*Post* (b_2)		0.202**		0.196**
		(2.318)		(2.199)
b_1-b_2		0.602**		0.427
p-value for b_1-b_2=0		0.049		0.117
Cohort-by-Year FE	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y
Pre_HOIPrem_Post	N	N	Y	Y
Lagged state control	N	N	Y	Y
Mean of Y	3.892	3.878	3.892	3.878
Mean of *LossShrExp*	2.296	2.236	2.296	2.236
SD of *LossShrExp*	2.309	2.202	2.309	2.202
N	864	854	864	854
Adj. R^2	0.430	0.435	0.443	0.445



(a) Dynamic effects of catastrophe shocks on state-level premium growth

(b) Dynamic effects of catastrophe shocks on state-level premium growth, for unshocked states

Figure 4. Dynamic effects of catastrophe shocks on homeowners insurance premium growth at the state level

Figures 4 plots the estimated dynamic DiD coefficients over the [-3,+3] year window around the catastrophe shock. Figures 4(a) and 4(b) correspond to the dynamics of Column (3) of Table 15 Panel A and B, respectively. The dashed lines denote the 90% confidence intervals. Standard errors are clustered at the state level.

Appendix

Appendix A1. The screening procedure for homeowners insurance rate filings

Starting from 89,595 downloaded homeowners insurance rate-related filings, I apply the following screening procedures to construct a clean and reliable regulation index.

First, I focus exclusively on HO-3 type insurance contracts, the most widely held form of homeowners insurance, which accounts for over 85% of all contracts sold in the private market. Accordingly, within the Line of Business labeled "Homeowners," I retain only the Sub Types "*04.0000 Homeowners Sub-TOI Combinations*" and "*04.0003 Owner Occupied Homeowners*," while dropping all other minor types, like "*04.0001 Condominium Homeowners*", "*04.0002 Mobile Homeowners*", "*04.0004 Tenant Homeowners*", and "*04.0005 Other Homeowners*". As these do not correspond to HO-3 type contracts. This step removes approximately 16% of the observations from the raw sample.

Second, I drop filings if Filing Status is "*Pending*", indicating a regulatory decision has not yet been made. These account for less than 1% of the sample.

Third, I retain only rate filings from large insurers, defined as the top 50 insurers in each state and year based on homeowners insurance market share. This is because smaller insurers file less frequently, and their filing behavior is more likely to be endogenous (Oh et al., 2025). Among the top 50 insurers in each state-year, market shares range from 0.2% to 34%, with a median of 1.1%.[28] This step removes around 49% of the remaining sample.

Fourth, I focus on rate increase requests and exclude filings with missing, negative, or zero indicated rate changes, as these may not represent genuine rate increase requests or could reflect data errors. Filings with an "*Approved*" status but missing or negative received rates are also treated as data errors and are therefore excluded. Together, these two filters remove 56% of the remaining sample.

[28] Oh et al. (2025) restrict their sample to large insurers with a market share of at least 1%, which results in an average of 20 insurers per state and leaves some state-years without any rate filing data. To maintain sufficient coverage, we retain a moderately larger number of insurers in each state.

Lastly, for filings with a "*Disapproved*" status, indicating that the regulator rejected the rate change request, I consider the *Rate*Δ*Received* as zero and set *RateGap* to one. These filings account for 2.6% of the remaining sample.

After applying all screening procedures, I obtain 16,830 rate filings from 421 unique insurance companies between 2009 and 2023 across all 50 states and DC.

Table A1. Definition of key variables

Variables	Definition	Data sources
Household-level variable		The Panel Study of Income Dynamics (PSID)
Insured	A dummy indicator that equals one if the household take up HO insurance in the year, and zero otherwise	
lnHOIns	Logged (annual HO insurance expenditure in survey year), in dollars	
HOI_Burden	HO insurance cost burden, which is calculated as annual HO insurance expenditure / annual total family income *100	
HomeRepair	Annual expenditure on home repairs and maintenance for last year, including materials plus any costs for hiring a professional, in dollars	
CrCard	Outstanding balance of credit card at the time of survey, in dollars	
lnAge	Logged (the age of household head)	
Married	A dummy indicator for the marriage status of household heads, which equals one for the married, and zero otherwise	
Child	A dummy indicator for the children status in the household, which equals one if the household has children, and zero otherwise	
College	A dummy indicator for the education level of household heads, which equals one if the household head holds a college degree, and zero otherwise.	
lnFamInc	Logged (total family income), in dollars	
lnHouseValue	Logged (market value of all houses), in dollars	
Mortgage	A dummy indicator for the mortgage status of households, which equals one if the household has outstanding mortgages, and zero otherwise	
MortgBalance	Mortgage balance at the time of survey, in dollars	

(Continued)

Table A1. Continued

State-level variable		
LowReg/HighReg	A dummy indicator for the average HO insurance regulatory regulation index in the three-year window before the shock year. States with an average regulation index ranking in the bottom tercile among 50 states and DC are defined as low regulation (*LowReg*), and otherwise as high regulation (*HighReg*). The regulatory regulation index is constructed from aggregating the rate gap between the received rate increase by regulators and the indicated rate increase by filing insurers across all HO insurance rate related rate filings in a state-year. See details of its construction in Section 3.2.	S&P Capital IQ Pro - U.S. Insurance Product Filing Search, 2009-2023
LossShrExp	The loss sharing exposure index for an unshocked state, which is the sum of all insurers' loss sharing ratio from high-regulation shocked states weighted by each insurer's market share in this unshocked state. An insurer's loss sharing ratio is calculated by *Total direct loss paid* in high-regulation shocked states / *Total direct premium written* in the control states in the shock year. See details of its construction in Section 4.1.	The SNL Insurance Regulatory Data dataset
lnHOIPrem	The natural logarithm of average annual HO insurance premium (*HOIPrem*), where *HOIPrem* = Annual HO insurance premiums / exposure per house years, in dollars	Insurance Information Institute, with data sourced from The National Association of Insurance Commissioners (NAIC)
HOIPrem_Growth	The growth rate of average HO insurance premium, calculated as (*HOI_Prem* -lagged *HOIPrem)* / lagged *HOIPrem**100	
lnDisaLoss	Logged (total annual natural disaster loss), in dollars. It includes the five types of disaster losses covered by HO-3 home insurance policies: tropical cyclone, severe storm, wildfire, freeze, and winter storm (excluding flooding, drought and earthquake).	NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters
lnPerGDP	Logged (local GDP per capita), where GDP per capita = GDP / Population, in dollars	U.S. Bureau of Economic Analysis(BEA): Regional Economic Accounts
lnPopu	Logged (number of local population), in person	Federal Reserve Economic Data (FRED) in St. Luis
HPI_Chg	Housing price index (HPI) change: (HPI-Lagged HPI) / Lagged HPI	Federal Housing Finance Agency (FHFA)
Democracy	The fraction of Democrats in a state's legislature, both in Senate and House. It is calculated as (The number of democratic seats in Senate + The number of democratic seats in House) / The total number of seats in Senate and House.	National Conference of State Legislatures (NCSL)

Table A2. Pre-to-post tests in shocked and control household sample, respectively

The table shows the pre-to-post changes in homeowners insurance take-up and expenditure for households in shocked and control states over the [-3,+3] event window, respectively. *Post* is the post-event indicator for survey years in or after the shock year. Columns (1) and (2) report results for shocked states, and Columns (3) and (4) report results for unshocked control states. In Columns (1) and (3), the outcome variable is a dummy (*Insured*) indicating whether a household holds homeowners insurance in the survey year and the sample is restricted to homeowners who already held homeowners insurance before the shock. In Columns (2) and (4), the outcome variable is the natural logarithm of annual homeowners insurance expenditure (*lnHOIns*) conditional on homeowners' taking homeowners insurance throughout the cohort window. All regressions include Cohort-by-Household fixed effects. Due to the limited number of shocked states, standard errors are clustered at the state-year level in this table. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*	*lnHOIns*	*Insured (0/1)*	*lnHOIns*
	(1)	(2)	(3)	(4)
Post	-0.017***	0.139***	-0.008***	0.131***
	(-3.599)	(3.375)	(-4.611)	(7.794)
Cohort-by-HH FE	Y	Y	Y	Y
State sample	Shocked	Shocked	Control	Control
Mean of Y	0.99	1399.21	0.99	1177.22
N	3799	3698	11570	11341
Adj. R^2	0.247	0.455	0.325	0.437

Table A3. Comparing household characteristics between the treatment and control group in the pre-shock survey year

The table shows the mean-differences of key variables for shocked and control households in the pre-shock survey year. Panel A presents results based on the non-matched sample, and Panel B presents results based on the one-to-one propensity score matched (PSM) sample. In the survey wave before the shock year (e.g., Survey Wave 2011 in cohort 2012), each treated household in a shocked state is matched to one household in a selected unshocked state within the same cohort, using a caliper of 0.05 and allowing for replacement. Covariates used for matching include *lnHOIns,* the ratio of homeowners insurance expenditure to income, *lnAge, Married, College, lnHouseValue, Mortgage* and state-level *GDP per capita*.

Panel A: Before matching

Variable	Num. of control	Mean of control	Num. of treated	Mean of treated	Mean (Control - Treated)
Insured (0/1)	3606	0.971	1219	0.955	0.016***
lnHOIns	3502	6.739	1164	6.888	-0.149***
lnAge	3606	3.901	1219	3.921	-0.020**
Married (0/1)	3606	0.739	1219	0.737	0.002
Child (0/1)	3606	0.846	1219	0.858	-0.012
College (0/1)	3601	0.395	1215	0.365	0.030*
lnFamInc	3599	11.258	1217	11.251	0.006
lnHouseValue	3606	12.212	1219	12.259	-0.047
Mortgage (0/1)	3606	0.705	1219	0.714	-0.008

Panel B: After one-to-one PSM

Variable	Num. of control	Mean of control	Num. of treated	Mean of treated	Mean (Control - Treated)
Insured (0/1)	1159	1	1159	1	0
lnHOIns	1159	6.927	1159	6.887	0.039
lnAge	1159	3.931	1159	3.921	0.010
Married (0/1)	1159	0.736	1159	0.750	-0.014
Child (0/1)	1159	0.844	1159	0.862	-0.018
College (0/1)	1159	0.368	1159	0.375	-0.008
lnFamInc	1159	11.275	1159	11.292	-0.017
lnHouseValue	1159	12.337	1159	12.306	0.032
Mortgage (0/1)	1159	0.758	1159	0.745	0.013

Table A4. Effect of catastrophe shocks on homeowners insurance take-up and expenditure, moderated by shocked states' rate regulation change

Panel A shows the effects of catastrophe shocks on state-level *Regulation index*, based on the stacked sample at the state level. *Shock* equals one for shocked states, and zero for the control states. *Post* is the post-event indicator for years in or after the shock year. Columns (1)-(2) show the pre-to-post changes in the regulation index (controlling for Cohort-by-State fixed effects) for shocked and control states, respectively. Column (3) reports the DiD results in a full stacked sample. Panel B compares the effects of catastrophes on homeowners insurance take-up and expenditure, depending on states' pre-shock regulation and regulation changes following the shock. *LowReg*Shock* equals one for ex-ante low-regulation shocked states, which remain low regulation in the shock year. *HighReg*Shock* in Table 4 is further decomposed into two indicators to indicate the change of homeowners insurance rate regulatory stringency in the shock year. *HighToLowReg*Shock* equals one for shocked states with high regulatory stringency before the shock but transfer into the low-regulation group in the shock year. *AlwaysHighReg*Shock* equals one for shocked states with ex-ante high regulatory stringency and remain high regulation in the shock year. States with the regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Households in control states serve as the reference group. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Panel A: DiD tests in the change in *Friction* index for the shocked and unshocked states

Y= *Regulation index*	(1)	(2)	(3)
Post	-0.053*	-0.006	
	(-2.005)	(-0.699)	
*Shock*Post*			-0.048*
			(-1.806)
Cohort-by-Year FE	N	N	Y
Cohort-by-State FE	Y	Y	Y
Lagged state control	N	N	Y
State sample	Shocked	Control	All
N	64	847	911
Adj. R^2	0.396	0.201	0.292

Panel B: Effects moderated by shocked states' rate regulation change

Y =	*Insured (0/1)*	*lnHOIns*
	(1)	(2)
*LowReg*Shock*Post* (b_1)	-0.018***	0.123***
	(-3.481)	(2.740)
*HighToLowReg*Shock*Post* (b_2)	-0.009	0.064*
	(-1.472)	(1.870)
*AlwaysHighReg*Shock*Post* (b_3)	-0.000	-0.069
	(-0.070)	(-1.201)
p-value for testing b_1-b_2=0	0.298	0.231
p-value for testing b_1-b_3=0	0.020*	0.002**
p-value for testing b_2-b_3=0	0.312	0.064*
Cohort-by-Year FE	Y	Y
Cohort-by-HH FE	Y	Y
HH control	Y	Y
Lagged state control	Y	Y
HH sample	Pre-HOI	Always-HOI
Mean of Y (non-logged)	0.99	1214.16
N	14796	14479
Adj. R^2	0.280	0.442

Table A5. Changes in the number of homeowners insurance suppliers in a state after the shock

The table shows the effects of catastrophe shocks on the number of insurers that supply homeowners insurance in a state based on the cohort-based stacked sample over the [-3,+3] event window. The outcome variable is the natural logarithm of the number of private homeowners insurance providers in a state-year, identified as those with positive premium written in homeowners insurance (*lnNumInsurer*). Columns (1)-(2) are based on the full sample of both shocked and unshocked states. *Shock* is the treatment indicator, which equals one for states directly shocked by a catastrophe and zero for the control states. *Post* is the post-event indicator for survey years in or after the shock year. *HighReg (LowReg)* equals one for unshocked states with high (low) regulatory stringency and zero otherwise. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Columns (3)-(4) are based on the sample of unshocked states. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y = *lnNumInsurer*	(1)	(2)	(3)	(4)
*Shock*Post*	0.022			
	(0.947)			
*LowReg*Shock*Post*		0.019**		
		(2.278)		
*HighReg*Shock*Post*		0.022		
		(0.772)		
*LossShrExp*Post*			0.001	
			(0.612)	
*LowReg*LossShrExp*Post*				0.001
				(0.253)
*HighReg*LossShrExp*Post*				0.000
				(0.123)
Cohort-by-Year FE	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y
State sample	All	All	Control	Control
Mean of Y (non-logged)	111	111	108	109
N	928	918	864	854
Adj. R^2	0.991	0.991	0.992	0.992

Table A6. Robustness checks using alternative loss-sharing exposure index

The table reports the continuous treatment effects of catastrophe shocks on homeowners insurance take-up and expenditure for households in unshocked states depending on homeowners insurance rate regulation, using alternative loss-sharing exposure indices. In Panel A, the construction of the loss-sharing exposure index is restricted to large insurers in the focal state, defined as those with a market share above 1% (*LossShrExp1*). In Panel B, based on the index construction process in Equation (6), I additionally interact a factor that measures each insurer's reliance on the focal state when aggregating the insurer-level index (*LossShrExp2*). *Post* is the post-event indicator for survey years in or after the shock year. *LowReg (HighReg)* equals one for states with low (high) regulatory stringency and zero otherwise. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. In addition to household characteristics in the survey year and lagged state-level covariates, *LowReg*Post* are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Panel A: Use large insurers with a market share over 1% to construct the state-level exposure index

Y =	*Insured (0/1)*		*lnHOIns*		*HOI_Burden*	
	(1)	(2)	(3)	(4)	(5)	(6)
*LossShrExp1*Post*	-0.003		0.094***		0.112**	
	(-0.896)		(3.125)		(2.673)	
*LowReg*LossShrExp1*Post (b_1)*		0.001		0.097***		0.146***
		(0.292)		(4.219)		(3.656)
*HighReg*LossShrExp1*Post (b_2)*		-0.009**		0.094		0.067
		(-2.295)		(1.653)		(1.023)
b_1-b_2		0.010**		0.003		0.079
p-value for testing b_1-b_2=0		0.010		0.952		0.169
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
HH sample	Pre-HOI			Always-HOI		
N	11156	11156	10933	10933	10933	10933
Adj. R^2	0.310	0.311	0.435	0.435	0.689	0.689

Panel B: Consider each insurer's reliance on the focal state in homeowners insurance

Y =	*Insured (0/1)*		*lnHOIns*		*HOI_Burden*	
	(1)	(2)	(3)	(4)	(5)	(6)
*LossShrExp2*Post*	-0.056		0.099		0.292	
	(-1.097)		(0.555)		(1.032)	
*LowReg*LossShrExp2*Post (b_1)*		-0.190		1.026***		1.468***
		(-1.547)		(3.441)		(4.004)
*HighReg*LossShrExp2*Post (b_2)*		-0.038		-0.023		0.105
		(-1.505)		(-0.157)		(0.483)
b_1-b_2		-0.343		2.075***		2.831***
p-value for testing b_1-b_2=0		0.149		0.001		0.000
Cohort-by-Year FE	Y	Y	Y	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y	Y	Y	Y
HH control	Y	Y	Y	Y	Y	Y
Lagged state control	Y	Y	Y	Y	Y	Y
HH sample	Pre-HOI			Always-HOI		
N	11156	11156	10933	10933	10933	10933
Adj. R^2	0.312	0.314	0.434	0.435	0.689	0.689

Table A7. Heterogeneity by homeowners insurance regulation and market competition

The table compares the effects of catastrophe shocks on homeowners insurance take-up and expenditure for households in unshocked states, depending on different homeowners insurance regulation and market competition. *LossShrExp* is the continuous treatment indicator, calculated as the average potential for sharing homeowners insurance losses from high-regulation shocked states to control states across all insurers in the focal state, weighted by each insurer's homeowners insurance market share in the shock year. *Post* is the post-event indicator for survey years in or after the shock year. The regulation groups are defined using each state's average homeowners insurance rate regulation index over the [-3,-1] year window. States with an average regulation index that falls in the bottom tercile among the 50 states and DC are classified as the low-regulation group, and all others are classified as the high-regulation group. Market competition in homeowners insurance is measured using the average Herfindahl-Hirschman Index (HHI) over the [-3,-1] year window. An unshocked state is classified as low competition if its average HHI is above the median among the 50 states and DC, and as high competition otherwise. *LowReg_LowComp* denotes unshocked states with low regulation and low competition. *LowReg_HighComp* denotes unshocked states with low regulation and high competition. *HighReg_LowComp* denotes unshocked states with high regulation and low competition. *HighReg_HighComp* denotes unshocked states with high regulation and high competition. Household characteristics in the survey year and lagged state-level covariates are controlled for in all regressions. Both Cohort-by-Household fixed effects and Cohort-by-Year fixed effects are also included. Standard errors are clustered at the state level. *, **, and *** indicate significance at the 0.10, 0.05, and 0.01 level (two-tailed), respectively.

Y =	*Insured (0/1)*	*lnHOIns*	*HOI_Burden*
	(1)	(2)	(3)
*LossShrExp*Post*LowReg_LowComp* (b_1)	-0.012	0.131***	0.197***
	(-1.420)	(3.550)	(3.405)
*LossShrExp*Post*LowReg_HighComp* (b_2)	-0.001	0.080**	0.084*
	(-0.265)	(2.575)	(1.893)
*LossShrExp*Post*HighReg_LowComp* (b_3)	-0.005	0.061***	0.092*
	(-1.203)	(3.123)	(2.034)
*LossShrExp*Post*HighReg_HighComp* (b_4)	-0.004	0.075	0.071
	(-0.883)	(1.688)	(1.150)
p-value for testing b_1-b_2=0	0.032*	0.056*	0.014**
p-value for testing b_1-b_3=0	0.421	0.013**	0.063*
p-value for testing b_1-b_4=0	0.106	0.075*	0.017**
p-value for testing b_2-b_3=0	0.356	0.387	0.849
p-value for testing b_2-b_4=0	0.034*	0.806	0.631
p-value for testing b_3-b_4=0	0.759	0.660	0.689
Cohort-by-Year FE	Y	Y	Y
Cohort-by-HH FE	Y	Y	Y
HH control	Y	Y	Y
Lagged state control	Y	Y	Y
Mean of Y (non-logged)	0.99	1163.66	1.63
Mean of *LossShrExp*	1.39	1.40	1.40
SD of *LossShrExp*	1.43	1.43	1.43
N	11156	10933	10933
Adj. R^2	0.311	0.435	0.689