Engaging Local Climate Risk:
Property-Casualty Insurers as Protection and Capital Providers

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Abstract

This study examines how property and casualty (P&C) insurers' assets and liability exposures to climate risk affect firm performance and transmit risk to the municipal bond market. Using sea-level and catastrophe data from NOAA, combined with the NAIC quarterly financial statement data from 2010 to 2020, we find that liability exposure to sea-level rise reduces profitability and increases volatility by increasing insurers' loss ratios. While asset exposure follows an inverted U-shaped pattern: moderate exposure enhances investment returns, but excessive exposure erodes profitability. When both exposures are high, their adverse effects jointly amplify balance-sheet stress. Event-study evidence further reveals a capacity-reducing feedback effect: climate shocks that strike both sides of the balance sheet constrain insurers' ability to supply coverage in subsequent periods. Insurers also respond to climate shocks by selling municipal bonds, leading to wider spreads. Overall, the results reveal interconnected underwriting and investing channels through which climate risk aggregates within insurers and spills over to municipal bond markets, highlighting a new mechanism of climate risk transmission in the financial system.

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1 Introduction

Insurance companies are uniquely positioned in local economies, both as risk absorbers on the liability side and as capital providers on the asset side. By offering coverage against property damages from natural disasters, insurers provide crucial financial protection to households and firms; by purchasing municipal bonds, they finance local infrastructure and public services. This dual commitment ties insurers' balance sheets directly to the resilience of climate-vulnerable regions.

Climate risk, however, is fundamentally non-diversifiable. It cannot be spread away through conventional pooling, as systemic physical hazards such as sea-level rise or intensifying hurricanes simultaneously affect wide swathes of the economy. As climate shocks accumulate, insurers' costs of underwriting and investing rise in tandem, ultimately exerting upward pressure on insurance premiums and straining municipal financing capacity. A more comprehensive understanding of how climate risk aggregates across both liabilities and assets is crucial for evaluating insurers' performance, regulatory solvency, and the stability of the broader financial system.

Prior studies have tended to examine these exposures in isolation. On the liability side, the United States is confronting a mounting insurance crisis, with premiums rising and coverage shrinking as climate-related catastrophes intensify. Wildfires, hurricanes, and flooding, amplified by warming temperatures, heavier precipitation, and sea-level rise, are driving higher average annual losses and fatter tails in insurers' catastrophe loss distributions. At the same time, rate-regulation constraints limit the ability to reprice risk (Boomhower et al., 2024). The result is a squeeze on underwriting margins and capital: loss ratios climb, reinsurance costs surge, and some carriers retrench or exit high-risk markets, raising costs for households and businesses. Figure 1 shows that U.S. states with higher sea levels experience both more billion-dollar disaster events and higher average losses per event (IPCC, 2021), evidence of a direct channel through which climate risk translates into larger insured losses and mounting pressure on insurance availability and affordability.

[insert Figure 1]

On the asset side, climate risk threatens the value of municipal bonds that constitute a major component of insurers' investment portfolios. Rising seas and recurrent flooding weaken property tax bases and local fiscal capacity, increasing both default and liquidity risks (Painter, 2020; Goldsmith-Pinkham et al., 2023). Auh et al. (2022) show that institutional investors,

including insurers, may be forced into "fire sales" when climate uncertainty spikes. Relatedly, recent evidence suggests that insurers' post-disaster asset liquidations can themselves amplify price dislocations through crowded selling, highlighting a channel through which balance-sheet stress spills over into bond markets (Chaderina et al., 2026). While these studies yield important insights, they largely treat asset- and liability-side exposures in isolation. Only a few, such as Manconi, Massa, and Zhang (2016), consider cross-balance-sheet interactions following major disasters.

This paper aims to bridge the gap by examining how sea-level rise affects U.S. property-casualty (P&C) insurers through both sides of their balance sheets. Compared to the existing studies that examine climate risk on either the liability side or the asset side in isolation, we jointly measure insurers' local climate exposure on both sides of the balance sheet and show how these exposures interact. By linking insurers' exposure to climate shocks with their holdings and trading of municipal bonds, we provide new evidence on how climate risk is transmitted through insurers to municipal bond markets. Moreover, we document that when climate shocks simultaneously strain insurers' assets and liabilities, the resulting balance-sheet pressure reduces insurers' subsequent underwriting capacity, revealing a feedback mechanism that has not been documented in the prior literature.

To operationalize this framework, we construct insurer-level measures of local climate exposure on both sides of the balance sheet. On the liability side, we measure exposure using insurers' direct premiums written in coastal regions that face elevated risks of floods and storms, which increase claims, reserves, and solvency pressures. On the asset side, we assess insurers' holdings of municipal bonds issued by coastal counties, where sea-level rise heightens default and liquidity risk as local economies and tax bases erode. We develop an empirical framework that links these exposures to firm-level outcomes to evaluate how climate risk, on its own and in combination, affects profitability, investment behavior, and balance-sheet resilience.

Our analysis proceeds in three steps. First, we test whether greater exposure to climate-vulnerable assets or liabilities is associated with weaker financial performance and higher risk. Second, we examine the interaction effects of dual exposures, asking whether high climate risk on both sides amplifies balance-sheet stress beyond their individual effects. Third, we explore the transmission mechanisms, such as post-disaster fire sales in municipal bond markets and rising loss ratios after catastrophic events, to identify how climate shocks propagate across insurers' financial activities.

The findings reveal that climate risk operates through two interconnected channels. On the liability side, escalating disaster losses compress underwriting margins and tighten capital capacity, particularly in coastal and catastrophe-prone lines. On the asset side, insurers initially act as liquidity providers by purchasing discounted municipal bonds after moderate shocks, harvesting temporarily elevated spreads. But when sea-level or catastrophe risk crosses a critical threshold, these holdings suffer mark-to-market losses as broader investors sell, leading insurers to curtail purchases or become net sellers. This dynamic could raise borrowing costs and weaken market access for affected municipalities precisely when funding for adaptation and recovery is most needed.

When both sides of the balance sheet are simultaneously exposed, the adverse effects are additive and mutually reinforcing. The gains from investing in discounted municipal bonds disappear as claims surge and liquidity needs rise, amplifying stress across insurers' financial positions and the local bond market. The result is a feedback loop in which climate shocks simultaneously erode insurance capacity and increase municipal financing costs—threatening the affordability of insurance for households and the fiscal resilience of climate-vulnerable communities. This capacity contraction is economically meaningful, aligning with the real-world withdrawal of insurers from high-risk U.S. states and highlighting a critical mechanism linking climate exposure to the worsening availability and affordability crisis in insurance markets.

The remainder of the paper is organized as follows. The next section reviews the literature and develops the hypotheses. Section 3 describes the data and sample. Section 4 outlines the empirical strategy. Section 5 presents the baseline results, followed by additional analyses on mechanisms, additive effects, and mitigation strategies. The final section concludes.

2 Literature and Hypotheses

Climate risk on the liability side

The liability channel is the most direct pathway through which climate risk impairs insurers' performance. Natural disasters raise the frequency and severity of insured losses, worsening underwriting outcomes and compressing margins (Boomhower et al., 2024; Ding & Li, 2025). These shocks are not confined to property lines: when climate events disrupt productive capacity and revenues—for example, through damage to manufacturing supply chains and local business interruptions—loss experience deteriorates across commercial

property and specialty lines as well (Pankratz et al., 2023; Pankratz et al., 2024). In our setting, local liability exposure—the extent to which an insurer writes business in sea-level- or flood-exposed counties—captures the intensity of this risk on the claims side of the balance sheet.

The magnitude of liability-side climate risk is institution-specific. Both physical and transition risks reduce profitability, but small P&C insurers tend to be more exposed to acute (physical) shocks and have less diversification and risk-transfer capacity (Chen & Lin, 2024). A complementary banking literature suggests that larger institutions can better absorb transition shocks, thereby attenuating the impact on performance (Li & Pan, 2022). These differences imply heterogeneous underwriting responses, even when local hazards intensify.

Institutional and market frictions amplify liability stress. Rate regulation can delay or constrain repricing, leading to systematic underpricing and higher loss ratios when hazards rise (Jung et al., 2023). Simultaneously, reinsurance markets transmit climate shocks back to primary insurers through hardening prices, higher retentions, and tighter terms, further squeezing their margins (Chen & Lin, 2024). Post-event loss creep, litigation waves, and claims-handling cost inflation exacerbate these pressures, particularly in coastal jurisdictions vulnerable to sea-level rise and recurrent flooding.

Insurers and investors are adapting—tightening risk management, refining CAT models, and expanding disclosure—but adjustments remain partial. Disasters catalyze better internal risk controls (Berry-Stölzle et al., 2024), and institutional investors press for higher-quality climate disclosure (Ilhan et al., 2023). Yet in markets where premiums cannot fully reflect risk—notably coastal areas—underpricing persists and elevated loss ratios endure. Therefore, we propose the following hypothesis:

Hypothesis 1 (Liability channel). Higher local liability exposure to climate risk is associated with less firm profitability and higher firm risk.

Climate risk on the asset side

Climate risk also operates through the asset side of insurers' balance sheets. A key channel is municipal bonds, which constituted 15.8% of P&C insurers' bond holdings in 2024 (NAIC, 2025). For coastal counties exposed to sea-level rise, municipal credit risk increases as tax bases erode, business revenues falter, and adaptation/repair costs rise—pressuring debt-service capacity and elevating both default and liquidity risk (Painter, 2020; Goldsmith-Pinkham et al., 2023). Because many coastal municipalities rely heavily on property taxes and local

sales/activity-based revenues, climate shocks can simultaneously weaken repayment fundamentals and trigger market-wide repricing, transmitting losses to insurers' municipal portfolios. Liquidity frictions magnify these effects: during stress, institutional investors—including insurers—can face funding, risk-limit, or RBC constraints that prompt fire-sales, further widening spreads (Auh et al., 2022).

The performance impact is nonlinear. After moderate climate events, informed insurers often act as liquidity providers by purchasing discounted municipal bonds and harvesting temporarily elevated spreads as markets overreact and then revert to the mean, which can improve investment returns (Abbassi et al., 2016; Becker & Ivashina, 2015). However, when exposure becomes high—because hazards intensify, downgrades threaten, or correlated outflows hit intermediaries—coordination failures in thin secondary markets, behavioral amplification of bad news, and balance-sheet constraints interact to produce persistent spread widening and mark-to-market losses (Morris & Shin, 2004; Fortin & Hlouskova, 2024). Broader evidence that climate shocks raise crash risk, increase the cost of capital, and push up borrowing spreads reinforces this deterioration in municipal bond valuations and insurer portfolio performance (Dong & Liu, 2023; Balvers et al., 2017; Ginglinger & Moreau, 2023). In this high-exposure regime, insurers' net purchases tend to decline or turn negative, weakening primary-market demand and raising issuance costs precisely when municipalities need financing for adaptation and recovery.

These mechanisms imply that small-to-moderate local climate risk can be return-positive for insurers who supply liquidity, but high local exposure becomes return-negative as credit deterioration, downgrade risk, and liquidity spirals dominate. Therefore, we propose the following hypothesis:

Hypothesis 2 (Asset channel—nonlinearity). The relationship between asset-side exposure to local climate risk (e.g., holdings of sea-level-exposed municipal bonds) and insurer performance is inverse-U-shaped: at moderate exposure, performance improves (liquidity provision/yield pickup), but at high exposure, performance deteriorates due to wider spreads, illiquidity, and fire-sale dynamics.

Dual exposure: additive balance-sheet pressure

Climate shocks rarely hit only one side of the balance sheet. When disasters simultaneously raise claims (liabilities) and depress local municipal bond valuations (assets), correlated stress can amplify fragility. Related financial-stability studies show that correlated

shocks across funding and asset risks magnify downturns through coordination failures and liquidity spirals, a mechanism consistent with additive effects of dual exposures in insurance. We extend this logic to insurers' local climate exposure and test whether high liability and high asset exposure together have a more negative impact on performance than the sum of each in isolation.

Hypothesis 3 (Climate risk aggregation). Liability-side and asset-side climate exposures have additive, mutually reinforcing adverse effects on insurer performance; joint exposure worsens margins beyond the sum of individual channels.

Moderators and heterogeneity

The literature also points to institutional and structural moderators. Rate regulation can exacerbate liability-side strain by constraining repricing, while firm size, diversification, reinsurance, and capital buffers may mitigate exposure to climate shocks. We therefore test the following hypothesis.

Hypothesis 4 (Moderation). The adverse effects of climate exposure on performance are stronger under stringent rate regulation and less use of reinsurance, and weaker for insurers with greater capitalization and diversification.

Transmission: from insurers' balance-sheet pressure to municipal finance

Insurers are also major municipal bond investors, so their balance sheet adjustments can propagate to local government financing. When risk crosses a threshold, insurers may curtail purchases or turn net sellers of coastal municipal bonds, widening spreads and raising borrowing costs precisely when municipalities need capital for adaptation and recovery—thus creating a feedback loop between insurance liability and public finance. We therefore test whether insurer-level asset responses (net purchases) and market-level outcomes (spreads) are more adverse in high-sea-level locales and when insurers are also experiencing liability shocks.

Hypothesis 5 (Transmission to municipal finance). In high sea-level-risk counties—especially when insurers simultaneously face elevated local claims—insurers reduce net purchases of local municipal (or sell), and municipal spreads widen more than in comparable low-risk areas, indicating transmission from insurer balance-sheet stress to municipal borrowing costs.

A growing macro-finance literature emphasizes that contractions in insurance capacity following climate-related catastrophes have economically meaningful consequences beyond the insurance sector. Giuzio et al. (2026) show that lower insurance coverage is associated with more severe post-disaster economic losses, highlighting the real effects of insurance capacity shortfalls. This evidence suggests that balance-sheet shocks that impair insurers' ability to supply coverage can propagate beyond financial markets, motivating our focus on the feedback effects of climate shocks on insurers' underwriting capacity.

Hypothesis 6 (Feedback mechanism — underwriting capacity loss). Climate shocks that jointly affect the asset and liability sides reduce insurers' balance-sheet capacity, lowering asset growth, premium growth, capital, and surplus, thereby constraining their ability to supply insurance in subsequent periods.

3 Data and Sample

We study P&C insurance companies based on the National Association of Insurance Commissioners (NAIC) quarterly statements and restrict our sample to those who are actively underwriting business. Specifically, we focus on firm-quarter observations with positive municipal bond holdings, assets of at least 10 million dollars, and positive total direct premiums written in each quarter.

3.1 Sample Construction

Our analysis is based on quarterly data for U.S. P&C insurers between 2010 and 2020. We begin with insurer-level statutory financial information from the Standard & Poor's (S&P) Global Market Intelligence platform, which collects this statutory data from the NAIC. This dataset is widely used by financial literature (Fan et al., 2024; Narayanamoorthy et al., 2023).

We extract three main components from the S&P Global Market Intelligence platform. The first is the insurers' direct premiums written (DPW), including state-level DPW from Schedule T and line-of-business-level DPW. The second is the insurers' holdings of municipal bonds from Schedule D. We also link insurers' bond holdings to the issuing counties of these municipal bonds using Refinitiv SDC Municipals, which provides the county and state of each bond issuer's origin. This bond-county mapping allows us to measure each insurer's asset-side exposure to local climate risks. The third is the financial statements, including assets, liabilities, ROA, ROE, ROI, RBC ratio, and loss ratio.

Then, we merge the data with climate risk. Our climate-related information comes from the National Oceanic and Atmospheric Administration (NOAA), from which we obtain sea-level data and records of catastrophic events between 2010 and 2020. NOAA provides monthly relative sea-level observations for U.S. stations, adjusted to remove regular seasonal fluctuations caused by coastal ocean temperatures, salinity, wind, atmospheric pressure, and currents. All values are referenced to the most recent Mean Sea Level datum established by CO-OPS.[2] For coastal counties[3] with monitoring stations, we calculate county-level relative sea level as the average across all stations within the county. For coastal counties without stations, we interpolate values using data from nearby counties. Specifically, we identify the ten geographically closest counties with available data and assign weights equal to the inverse of their distances. Using these weights, we compute a weighted average of sea-level observations for the corresponding years and months. Finally, we aggregate monthly data to the quarterly level by averaging the three months within each quarter for every county. We also compile data on weather and climate disaster events with CPI-adjusted losses exceeding $1 billion each to affect each state in the U.S.[4]

The merged data contains 3,610,374 insurer-county-quarter observations. We focus on P&C insurance companies with positive ownership of municipal bonds and aggregate our data to a firm-quarter level. We further restrict our sample to firms with positive quarterly direct premiums written and total assets exceeding 10 million dollars to focus on active insurers. Our final matched sample spans from 2010 to 2020, from 1,869 firms across 50 states[5], resulting in 58,122 firm-quarter observations.

3.2 Measures

County-level Relative Sea Level Measures

We construct a county-year level relative sea level (*RSL*) measure to be used for both assets and liabilities.

$$RSL_{j,t} = \text{ the past 5-year (up to } t\text{) average of relative sea level of county } j$$

[2] Please see https://tidesandcurrents.noaa.gov/datum_options.html for more information about the mean sea level datum.

[3] The coastal counties refer to counties that are directly adjacent to the open ocean, major estuaries, and the Great Lakes, which are defined by NOAA.
Please see https://coast.noaa.gov/data/digitalcoast/pdf/defining-coastal-counties.pdf for more details.

[4] Please see https://www.ncei.noaa.gov/access/billions/events for further details.

[5] We don't have bond issuers' information in Washington, D.C., so our sample only contains 50 states.

Similarly, using the past 3-year average of relative sea level of a county, we construct the past 3-year average of relative sea-level measure to confirm the robustness of our results.

State-level Relative Sea Level Measures

The within-state average of county-level sea level measures defined above. Subscript *j* is replaced with state *s*. County-level relative sea levels are broadly similar within each state (see Appendix Figure A1), suggesting that the within-state average provides a reasonable representation of state-level conditions.

Firm-level Asset Climate Exposure Variables

We construct the firm-level measures of the susceptibility of sea-level rise for municipal bond holdings.[6]

$$AssetCLR_{i,t} = \sum_{j} RSL_{j,t} \times \left(\frac{holding_{i,j,t}}{\sum_{j} holding_{i,j,t}}\right)$$

Firm-level Liability Climate Exposure Variables

We construct firm-level variables that measure the susceptibility of P&C insurers' liability to sea-level rise.[7]

$$LiabCLR_{i,t} = \sum_{s} RSL_{s,t} \times \left(\frac{DPW_{i,s,t}}{\sum_{s} DPW_{i,s,t}}\right)$$

Firm-level Aggregate Climate Exposure Variables

To capture insurers' overall exposure, we construct a measure of total climate risk that aggregates risks from both the asset and liability sides. Specifically, we define:

$$TotalCLR_{i,t} = LiabCLR_{i,t} \times \frac{Reserve_{i,t}}{Reserve_{i,t} + holding_{i,t}} + AssetCLR_{i,t} \times \frac{holding_{i,t}}{Reserve_{i,t} + holding_{i,t}}$$

where $Reserve_{i,t}$ represents insurer i's loss and loss adjusted reserve in quarter t and $holding_{i,t}$ denotes insurer i's total holdings of municipal bonds in quarter t. This formulation weights liability and asset climate exposures by the size of insurers' underwriting and investment activities, thereby reflecting the balance-sheet-wide exposure to sea-level risks. This weighting approach is conceptually similar to the allocation of risk volumes under

[6] In the following variable constructions, we also use the sea level measures in quarter *t*-1 in the numerator. And the results using $sea_level_{j,t}$ and $sea_level_{j,t-1}$ are similar, where $sea_level_{j,t}$.are sea level measures.

[7] In Jung et al. (2023), they use homeowners' multiple peril line and commercial multiple peril line.

frameworks such as Solvency II and RBC (Cofield et al., 2012; Liu et al., 2019).

A full definition of variables is shown in Table 1.

[Insert Table 1]

3.3 Descriptive Statistics

Table 2 reports the descriptive statistics of our sample.

[insert Table 2]

Figure 2 illustrates the increasing trend of relative sea level over the years. Panel (a) is produced in the firm-county-quarter sample, while panel (b) is produced in the county-quarter sample. The increasing trend of the sea level suggests that climate risk does exist.

[insert Figure 2]

Relative sea levels vary substantially across regions. Figure 3(a) illustrates the spatial pattern in 2020 Q4, showing that the highest relative sea levels are concentrated along the Atlantic Coast and the Gulf of Mexico. Panels (b) and (c) then present the county-level distribution of municipal bonds held by insurers and the state-level distribution of underwritten premiums in 2020 Q4, respectively. Both figures indicate that insurers' exposures are predominantly concentrated in coastal areas.

[insert Figure 3]

Figure 4 illustrates the time trend of climate risk exposure from both the asset and liability sides. It shows that firms' exposure to sea-level rise has been generally increasing over the years, aligning with the trend observed in Figure 2. Notably, liability exposure is higher than asset exposure on average, suggesting that liability exposure may have a more significant impact on firms.

[insert Figure 4]

Figure 5 illustrates the concentration of climate risk. It reveals a positive correlation between exposures on the asset and liability sides. Additionally, climate risk appears to be more pronounced in later years compared to earlier ones, as evidenced by the blue plots (2018-2020), which cover the largest area, followed by the green plots (2014-2017), and then the orange plots. This trend aligns with the pattern observed in Figure 4.

[insert Figure 5]

Figure 6 presents heatmaps showing the relationship between asset-side and liability-side climate risk exposures and firms' performance (ROA, ROE, SDROA, and SDROE). The x-axis measures asset exposure to climate risk, while the y-axis measures liability exposure. The colors represent the binned mean of each performance measure, with darker shades indicating higher values and lighter shades indicating lower values.

For ROA and ROE, the heatmaps show that firms facing high climate risk on both the asset and liability sides tend to exhibit poorer profitability, as indicated by the concentration of lighter (yellow) areas in the upper-right region (Figure 6(a) and 6(b)). In contrast, moderate exposure levels are associated with relatively better performance, reflected in darker regions. This pattern highlights a non-linear relationship in which joint climate-risk exposure on both sides coincides with deteriorating profitability.

For SDROA and SDROE, the pattern is reversed in interpretation: darker shades indicate higher volatility (Figure 6(c) and 6(d)). Consistent with the profitability results, the upper-right region where both asset and liability climate risks are elevated shows darker colors, implying that firms with simultaneously high exposures experience greater earnings volatility. Regions with lower or moderate exposures display relatively lighter colors, corresponding to more stable performance.

Overall, the heatmaps reveal that jointly high climate-risk exposures are associated not only with lower profitability but also with increased volatility, reinforcing the non-linear and compounding nature of climate-risk impacts on insurers' performance.

[insert Figure 6]

4 Empirical strategies

4.1 Climate Risk Exposure and Firm Performance

The empirical analysis employs a panel model to examine the relationship between climate risk and insurers' performance. The baseline specification is:

$$Performance_{it} = \beta_0 + \beta_1 AssetCLR_{it} + \beta_2 AssetCLR_{it}^2 + \beta_3 LiabCLR_{it} + \beta_4 LiabCLR_{it}^2 + \gamma \boldsymbol{X}_{it} + \alpha_i + \alpha_t + \varepsilon_{it} \quad (1)$$

In this equation, $Performance_{it}$ represents the financial outcomes of firm i at time t, including return on assets (ROA), return on equity (ROE), standard deviation of ROA (SDROA), and standard deviation of ROE (SDROE). $AssetCLR_{it}$ and $LiabCLR_{it}$ represent the climate risk exposure of assets and liabilities defined in Section 3.4, respectively. α_i and α_t represent firm i fixed effect and quarter t fixed effect, respectively. $\boldsymbol{X}_{it}$ includes firm-specific control variables.

The control variables are categorized into three groups. The first group relates to firm size and financial structure, including firm size and the leverage ratio. Firm size is measured by the natural logarithm of total admitted assets (*lnasset*) and is included as a proxy for the scale of the insurer. Larger firms often benefit from greater risk diversification and economies of scale, which can significantly affect their performance, risk-taking behavior, and financial decisions. The leverage variable (*leverage*) measures the proportion of debt in the firm's capital structure, capturing the extent of reliance on external financing. While higher leverage may enhance returns, it also exposes the firm to greater financial risk, with potential implications for stability and performance.

The second group of variables captures business risk and diversification, including the proportion of business written in long-tail lines (*longtail*), the geographic Herfindahl Index (*geoh)*, the lines-of-business Herfindahl Index (*lobh*), and the reinsurance ratio (*reins*). The geographic Herfindahl Index measures the degree of geographic diversification, reflecting how widely the firm's operations are distributed across regions. Greater geographic diversification can reduce concentration risk and mitigate exposure to region-specific economic shocks or natural catastrophes. The long-tail variable represents the proportion of long-tail lines in the firm's underwriting portfolio. Long-tail insurance lines, such as liability and workers' compensation, are characterized by longer claim settlement periods, which increase uncertainty in reserve requirements while also providing greater opportunities for investment income over time. The lines-of-business Herfindahl Index measures the concentration of the firm's business across insurance lines. Higher values indicate lower diversification and greater concentration in specific types of insurance, which can influence both risk exposure and profitability. The reinsurance ratio is defined as the ratio of reinsurance ceded to total written premiums and reflects the extent to which the firm relies on reinsurance as a risk management tool. A higher reinsurance ratio indicates greater risk transfer, which may affect both financial stability and profitability.

The third group of variables reflects growth dynamics and includes asset growth (growth). This variable captures the quarterly change in the insurer's total assets and reflects the expansion of the firm's asset base. Rapid asset growth can alter the firm's risk profile and financial performance, as expansions are often accompanied by changes in liquidity management, risk-taking behavior, and exposure to market fluctuations.

To investigate the impact of insurers' overall exposure on their profitability, we also use both the linear and quadratic terms of this total climate risk measure as explanatory variables, allowing us to capture not only its direct effect but also potential nonlinearities.

4.2 Exogenous Shock

We follow Beck et al. (2010) and use climate and weather-related events from NOAA to validate the findings in equation (1). These events provide a more comprehensive measure of climate risk than focusing solely on sea-level rise. Furthermore, the shocks are exogenous, making them an ideal instrument for robustness testing. Specifically, our estimating equation is an event study specification of the following form:

$$Performance_{it} = \beta + \sum_{\tau=-3,\tau\neq-1}^{5} \beta_\tau^a \boldsymbol{I}(t - t_{AssetCLShock} = \tau) + \sum_{\tau=-3,\tau\neq-1}^{5} \beta_\tau^l \boldsymbol{I}(t - t_{LiabCLShock} = \tau) + \gamma \boldsymbol{X}_{it} + \alpha_i + \alpha_t + \varepsilon_{it} \quad (2)$$

In this equation, $t_{AssetCLShock}$ and $t_{LiabCLShock}$ denotes the calendar quarter that the insurer experienced a climate shock on the asset and/or liability side. $\tau = 0$ denotes the current quarter of the climate shock event, $\tau = 1, \ldots 5$ refers to the relative time period (each denotes a one-quarter-period) that denotes post-shock periods and $\tau = -3, -2$ is the relative time period (each denotes a one-quarter-period) that denotes pre-shock periods. We omit indicators of the period prior to treatment $\tau = -1$, which refer to the first quarter before the shock. We exclude observations that are 4 or more quarters before the climate shock, and observations that are 6 or more quarters after the climate shock.

The climate shock can arise from the asset side, the liability side, or both. An insurer faces an asset-side shock in quarter *t* if it holds, at the end of quarter *t*-1, municipal bonds issued by a state hit by a disaster in quarter *t*. An insurer faces a liability-side shock in quarter *t* if it has written premiums in that affected state at the end of quarter *t*-1.

We focus on events that took place between 2010 and 2020, with CPI-adjusted costs exceeding the 75th percentile (i.e., greater than 4,901.4 billion dollars) (Auh et al., 2022). Specifically, we select disasters related to sea-level rise risk, including floods, tropical cyclones, severe storms, and winter storms. Floods are the most direct manifestation of rising sea levels, while tropical cyclones and severe storms can amplify storm surges and coastal inundation. Winter storms, though seasonal, can also drive strong winds and abnormal tides that push seawater onto coastlines. Together, these events capture the primary pathways through which sea-level rise intensifies the impact of weather- and climate-related disasters. An insurer is considered recovered from the shock once two years have passed since the event.

5 Results

5.1 Impact of Climate Exposures on Firm Profitability

Table 3 presents the regression results of equation (1) for two profitability measures: Return on Assets (ROA) and Return on Equity (ROE). Panel A explores how a firm's exposure to climate-related liabilities and assets influences these performance metrics. Specifically, liability and asset exposures to sea-level rise are hypothesized to impact all profitability measures. To capture the temporal dynamics of sea-level rise, the study utilizes two measures of relative sea-level rise: the past five-year and three-year average relative sea-level rise (RSL). All results using the three-year average relative sea-level rise (RSL_3Y) are reported in the Appendix for robustness check.

[insert Table 3]

Focusing on the five-year average relative sea-level rise (RSL), the regression results (1)-(4) in Table 3 consistently posit that increased liability exposure due to sea-level rise detrimentally affects firm performance, supporting Hypothesis 1. Specifically, liability exposure has a statistically significant negative relationship with both ROA and ROE. This suggests that firms with higher liability exposures to climate risk may experience substantial reductions in assets and equity efficiency, highlighting the economic vulnerability posed by climate-related liabilities. The magnitude of the liability exposure coefficient suggests that a one-standard-deviation increase in liability exposure is associated with a 0.29-percentage-point decline in ROA and a 0.75-percentage-point decline in ROE (see Figure 7).

The coefficients of the quadratic term for asset exposure to climate risk reported in Table

3 columns (2) and (4) are negative and statistically significant, implying that asset exposure exhibits an inverted U-shape relationship with insurer profitability, confirming Hypothesis 2. The turning point is at about 80th percentile, which means that the asset exposure to climate risk increases insurer profitability up to about the 80th percentile, beyond which its effect turns negative (see Figure 8).

[insert Figure 7]

[insert Figure 8]

The robustness of the findings is further validated using the three-year average relative sea-level rise (RSL_3Y). The regression results reported in Appendix Table A1 show negative and statistically significant coefficients for liability exposure, as well as negative and statistically significant coefficients for the quadratic term of asset exposure, to ROA and ROE. This reinforces the conclusion that liability exposures to climate risk adversely affect firm performance, and asset exposures to climate risk affect firm performance in a quadratic form. We also use decile dummies of 5-year asset and liability exposures as explanatory variables (see Appendix Table A2), and z-scores of 5-year asset and liability exposures as explanatory variables (see Appendix Table A3), and repeat our regressions. The main conclusion remains robust.

Extending the analysis to firm risk, we find that earnings volatility rises with liability exposure to sea-level rise. In specifications (5)-(8) that replace earnings with risk outcomes, the standard deviations of ROA and ROE (computed over rolling five-year windows) are positively and significantly associated with the RSL-based liability exposure measure, indicating that firms facing greater climate-liability pressure experience more unstable profitability. The magnitude of the liability exposure coefficient suggests that a one-standard-deviation increase in liability exposure is associated with a 0.36-percentage-point increase in the standard deviation of ROA and a 0.86-percentage-point increase in the standard deviation of ROE. Column (6) also indicates that the insurer's asset exposure is associated with earnings volatility.

Next, we investigate the impact of aggregated climate exposures on firm profitability. In columns (1)-(4), Panel B, specifications with both the linear term and the quadratic term reveal a nonlinear, concave relationship over the five-year window: the marginal impact of exposure becomes increasingly adverse at higher total risk levels. The estimates imply a concave (inverted-U) nonlinear relationship between total climate risk and firm profitability, where the

adverse impact becomes stronger as risk increases.[8] To illustrate how the marginal effect becomes more adverse at higher exposure levels, we take column (2) as an example. At the median exposure level ($TotalCLR = 0.0474$), a one-standard-deviation increase in total climate risk is associated with a 0.52-percentage-point decline in ROA. At the 75th percentile ($TotalCLR = 0.0720$), a one-standard-deviation increase in total climate risk is associated with a 0.73-percentage-point decline in ROA. These calculations show that the marginal impact of total climate risk becomes substantially more negative as exposure increases, confirming that higher levels of total climate risk disproportionately deteriorate insurer performance.[9]

Taken together, these results indicate that treating the exposure–performance link as purely linear likely understates downside risk for highly exposed firms—particularly when both asset- and liability-side exposures are simultaneously elevated—consistent with the possibility of compounding effects, which we will further discuss in Section 5.2.

To mitigate the concern of endogeneity, Figure 9 (a)-(d) presents the effect of asset and liability shocks of weather and climate-related events on firm performance using equation (2). The result in the figure confirms the findings in Table 3 on the liability side, which show the negative impact of liability exposure on firm profitability and the increasing effect on firm volatility. This figure also indicates that the asset climate shocks caused by the selected events have a positive impact on firm profitability. This result is not surprising because the turning point of the U-shape curve is around 80th, which means that apart from extreme large values, normal asset exposures can raise insurer profitability.

[insert Figure 9]

5.2 Additive Effects of Asset and Liability Exposures

We next examine the additive effects of climate risks on both sides of insurers' balance sheets, focusing on whether asset-side and liability-side exposures reinforce each other in deteriorating firm performance. Beyond the linear effect of liability exposure and the linear and quadratic terms of asset exposure, we additionally include two interaction terms. The first

[8] We also test the robustness of using premium as the weight for liability exposures and generate the total climate risk measures, the results are robust (see Appendix Table A4).

[9] Using the estimated nonlinear specification, the marginal effect of total climate risk on firm performance is given by $ME = \beta_1 + 2\beta_2 \times TotalCLR$. Take column (2) as an example, at the median exposure level ($TotalCLR = 0.0474$), the marginal effect is ME_{median}=-15.77, which means a one-standard-deviation increase in total climate risk is associated with a 0.52-percentage-point decline in ROA.

interaction, $AssetCLR_{it} \times LiabCLR_{it}$, captures whether the marginal effect of asset-side climate risk varies with the insurer's liability-side exposure. The second interaction, $AssetCLR_{it}^2 \times LiabCLR_{it}$, allows the nonlinear component of asset-side risk to change depending on the level of liability-side exposure.

We estimate the model across four subsamples defined by median splits of both asset and liability exposures. This design allows us to assess whether simultaneously high exposures on both sides of the balance sheet exacerbate the adverse impact on firm performance beyond the effect of each exposure considered in isolation. Table 4 presents the regression results for the subsample of insurers whose asset and liability exposures are both above their respective median levels.

[insert Table 4]

In Table 4, the linear interaction between asset-side and liability-side exposures is negative and statistically significant for profitability measures (columns (1)–(2)), and is positive and significant when examining volatility outcomes (columns (3)–(4)). This finding suggests that the effects of asset-side and liability-side climate risks on firm profitability and volatility are not independent but additive and mutually reinforcing, supporting Hypothesis 3. In particular, the coefficient of *LiabCLR*×*AssetCLR* shows that greater asset-side exposure exacerbates the negative impact of liability-side exposure on performance. This implies that, when insurers face high liability risk due to climate exposure, taking on additional climate-related asset risk further amplifies the decline in profitability.

Moreover, liability exposure compresses the range over which asset-side exposure enhances firm performance. Take profitability as an example, while moderate asset exposure may still improve returns under low liability exposure, its benefit is increasingly constrained and eventually reversed when liability exposure is high (see Figure 10). This reflects a compounding effect, whereby the downside risks associated with climate exposure on both the asset and liability sides interact to produce nonlinear and adverse consequences for financial outcomes. In our specification, the interaction terms imply that liability exposure acts as a parameter that shifts the slope and shape of the asset-side effect. As liability exposure increases, it alters the marginal impact of asset exposure and reshapes the relationship between asset exposure and performance, giving rise to the inverse-U patterns illustrated in Figure 10.

[insert Figure 10]

These results underscore the importance of jointly considering both sides of the balance sheet when assessing climate risk. Insurers cannot rely solely on asset-side strategies to mitigate climate-related vulnerabilities, particularly when liability exposures are heightened. The interaction effects highlight the potential for climate risk to propagate across financial channels, ultimately weakening firm resilience.

It is worth noting that this additive effect only appears in the sample where both exposures are above their median levels. In the other three subsamples, in which either asset exposure or liability exposure is below the median, we observe little additive effect (see Appendix Table A5). This suggests that the compounding impact of asset and liability climate risk exposures on firm performance is conditional on the simultaneous presence of elevated risks on both sides of the balance sheet. When only one dimension of exposure is high, insurers may still have sufficient risk-bearing capacity or management flexibility to absorb the shock. However, when both exposures are elevated, the firm's vulnerability increases substantially, likely due to correlated adverse effects that overwhelm internal mitigation mechanisms. These findings highlight the importance of monitoring joint exposure dynamics rather than evaluating asset-side and liability-side climate risks in isolation.

To test the robustness of this result, we also use the exogenous shocks described in Section 4.3 to examine the additive effects of asset and liability exposure to climate risk. Figure 11 illustrates that firms exposed to both types of shocks—those affecting assets and liabilities—exhibit significantly lower profitability and higher volatility compared to firms exposed to only one type of shock. To ensure a clean comparison, the figure excludes firms that experienced neither asset- nor liability-side shocks over the past two years. In other words, the sample includes only firms that encountered at least one climate-related shock during that period. These results support our finding that joint exposure to asset and liability climate shocks compounds the negative impact on firm performance.

[insert Figure 11]

5.3 Channels of Asset and Liability Exposures

In this subsection, we explore why asset and liability exposures affect firm performance in the patterns observed in the previous subsection. We analyze this from two perspectives: investment performance and underwriting performance.

[insert Table 5]

Investment performance

For investment performance, we re-estimate equation (1), with the dependent variable being return on investment (ROI). The regression results in Table 5, column (1) reveal distinct effects of asset climate exposure on insurers' investment performance, as measured through ROI—one of the key channels influencing ROA and ROE.

The impact of asset climate exposures on ROI follows an inverted U-shaped pattern, as indicated by a significant positive coefficient on the linear term and a significant negative coefficient on the squared term. This suggests that moderate levels of asset exposures, such as municipal bonds with embedded climate risks, can enhance investment returns. In addition, the significant and positive coefficient on liability-side climate risk indicates that climate exposures on the liability side meaningfully interact with asset-side exposures, jointly shaping the overall return profile. This finding is consistent with the idea that, when climate risk is relatively low, municipal bond prices appropriately incorporate this risk, allowing investors to earn higher average returns on bonds with greater climate exposure. In this regime, climate risk serves as a priced factor, improving portfolio performance (Painter et al., 2020).

Beyond a critical level of asset exposure, the marginal effect becomes negative. A likely explanation is that the returns generated by extremely high-risk bonds are insufficient to compensate for the rising cost of holding them. Prior studies show that high-yield and high-risk bonds tend to experience larger losses during downturns, driven by sharply increasing liquidity and credit risks (Choi and Kronlund, 2018; Chen and Choi, 2024). In addition, insurers face higher regulatory capital charges when holding low-rated or high-risk securities (Becker and Ivashina, 2015; MetLife, 2020; NAIC, 2023). Taken together, these findings suggest that while high-risk bonds offer higher yields, the associated expected losses and capital costs eventually outweigh the risk premium, leading to lower overall profitability.

We next conduct an event-study estimation to examine how insurers' share of municipal bonds issued by disaster-affected areas changes before and after the asset climate shocks (Figure 12), and how the spread of municipal bonds changes before and after the shocks (Figure 13). The results show that insurers respond strategically to climate shocks by increasing their share of high-spread municipal bonds in affected areas, thereby enhancing investment returns. This result is consistent with Abbassi et al. (2016), which finds the evidence that banks with higher trading expertise increase their investments in securities with a large price drop during

the crisis, and the "reaching for yield behavior" of insurers in the U.S. bond market (Becker and Ivashina, 2015).

[insert Figure 12]

[insert Figure 13]

Underwriting performance

For underwriting performance, the result in Table 5 column (2) reveals that liability climate exposure exerts a positive effect on loss ratio. A one-standard-deviation increase in liability exposure raises the loss ratio by 1.46 percentage points. This indicates that higher exposure to climate-related liabilities—such as underwriting coverage in high-risk areas—consistently undermines financial performance. Unlike asset-side risks, liability-side climate risks are typically pure risks that are not adequately priced into insurance premiums. As a result, increases in liability exposure lead to higher claims without corresponding revenue compensation, thereby directly and proportionally reducing profitability.

To understand why liability exposures to climate risk worsen insurers' underwriting performance, we examine the role of rate regulation in shaping insurers' responses to shocks. In the United States, insurance pricing is regulated at the state level, with states adopting their own rating statutes and procedures and often tailoring them by line of business (e.g., personal auto, homeowners, workers' compensation, title). NAIC and related literature classify these rate regulatory systems into two categories: Under the first, rates are primarily determined jointly by a rate making bureau and state regulators, with insurers having limited flexibility to adjust these rates, including "prior approval" and "state-made rates"; Under the second, regulators grant insurers more flexibility to adjust rates, encouraging competition, including "file and use", "use and file", "flex", and "no file" (Grace & Leverty, 2010; Narayanamoorthy et al., 2023).

Column (1) in Table 6 shows that insurers subject to stringent rate regulation experience significantly lower quarterly premium growth, consistent with more cautious underwriting. Columns (2) and (3) study underwriting performance (loss ratio) in subsamples split by insurers' average liability exposure—$HighLiabRisk$ equals one if an insurer's mean liability exposure over the sample exceeds the 75th percentile and zero otherwise. In both subsamples, higher liability exposure is associated with a higher loss ratio. However, the interaction between stringent rate regulation and liability risk is negative and statistically significant only for the

sample of $HighLiabRisk$= 0 (i.e., for insurers with relatively low mean liability exposure) in Column (2), indicating that regulation mitigates the adverse effect of liability risk on underwriting outcomes in this range. For the sample of $HighLiabRisk$ = 1 in Column (3), the interaction is small and insignificant, suggesting that once liability exposure is already elevated, regulatory constraints do not meaningfully offset loss pressures.

Column (4) confirms this pattern in the full sample by interacting the mitigating term with $HighLiabRisk$: the triple interaction is positive and significant, implying that the protective effect of stringent rate regulation weakens at high levels of liability exposure. Intuitively, while regulation restrains aggressive risk-taking and cushions losses when climate risk is moderate, as risk intensifies, the same stringency slows or caps premium re-rating (e.g., filing/approval frictions, as well as limits on rate increases). As a result, underpricing and adverse selection pressures offset the initial protective channel, and loss ratios continue to rise with exposure despite tighter regulation.

In summary, these results suggest that rate regulation serves as the mediating channel linking liability climate risk to underwriting outcomes. By constraining the pass-through of risk into premiums, regulation determines whether exposure shocks are absorbed in prices or manifest in loss ratios. Where the constraint binds, liability risk transmits to underwriting performance. Thus, regulation is a mechanism through which liability risk degrades insurers' performance.

Together, these results highlight the asymmetric and nonlinear financial implications of climate exposure for insurers. While certain climate-related investment risks may offer return opportunities when managed at moderate levels, liability-side exposures impose unavoidable costs that steadily erode performance.

[insert Table 6]

5.4 Mitigation Strategies

The Mitigating Role of Insurance Lines of Business Diversification

Table 7 further investigates whether insurers' line-of-business diversification can buffer the adverse effects of liability-side climate risk. We measure diversification as one minus the line-of-business Herfindahl index $(1 - lobh)$, where a higher value of $(1 - lobh)$ indicates greater diversification across business lines. The regression results show that the coefficient of the interaction term is positive and statistically significant in the profitability regressions

(columns (1) and (2)), suggesting a moderating effect. Moreover, the negative and statistically significant coefficient in column (3) shows that a similar mitigating role also emerges in the volatility specification. Specifically, insurers that diversify their underwriting across a broader range of business lines are better able to withstand the negative financial consequences of high climate-related liability exposure.

This finding suggests that diversification serves as a risk-sharing mechanism, enabling insurers to spread climate-related underwriting losses across multiple product lines, thereby stabilizing their overall profitability. By not concentrating climate risk exposure in a single line of business—such as property or catastrophe insurance—highly diversified insurers may avoid large simultaneous losses and benefit from the offsetting performance of less climate-sensitive lines. Consequently, underwriting diversification enhances organizational resilience and may be a key strategic tool for managing the growing uncertainties associated with climate risk.

We also test the role of geographic diversification of insurers' premiums. However, as shown in Appendix Table A6, we do not find evidence that the geographical diversification can mitigate the adverse effects of liability climate risk on firm performance. A likely explanation is that insurers' business is heavily concentrated in coastal states (as shown in Figure 3(c)), where rising sea levels are widespread. Under such circumstances, geographic diversification offers limited risk reduction, as most exposures remain correlated.

Appendix Table A7 further investigates the role of diversification between coastal and non-coastal states. While climate risk is often characterized as non-diversifiable due to its pervasive and correlated nature, sea level rise risk exhibits strong spatial heterogeneity, creating opportunities for meaningful risk spreading. Consistent with this intuition, when geographic diversification is measured specifically across coastal and non-coastal regions, we find that such diversification does mitigate the negative impact of liability climate risk. This pattern indicates that the effectiveness of geographic diversification depends on whether the diversification occurs across areas with meaningfully different climate risk profiles. In other words, while spreading premiums across multiple coastal states does little to offset common climate-related shocks, allocating business across coastal and non-coastal areas reduces exposure correlation and allows diversification to operate as intended.

Appendix Table A8 examines geographic diversification across U.S. and non-U.S. markets. Regional climate hazards, such as sea-level rise, vary across countries, offering insurers some degree of cross-border risk smoothing. The results show that such international diversification

mitigates the impact of liability climate risk on firm volatility, but not on profitability. This asymmetry is consistent with the nature of cross-border insurance operations. International diversification primarily reduces exposure to correlated climate shocks and regulatory environments, thereby lowering the volatility of underwriting outcomes. However, profitability is less sensitive to this form of diversification because cross-market expansions often involve higher operating costs, regulatory frictions, and limited immediate scale economies, which dampen any potential improvement in average performance. As a result, diversification across U.S. and non-U.S. markets stabilizes outcomes without necessarily enhancing the firm's expected returns.

[insert Table 7]

The Mitigating Role of Strong Solvency Position

Table 8 examines the impact of insurers' financial strength on the relationship between climate risk exposure and firm performance. We measure insurers' financial strength using the RBC ratio. The results highlight the critical role of capital adequacy in shaping the impact of both liability and asset-side climate risks.

In the profitability regressions (columns (1) and (2) of Table 8), the interaction terms involving both $LiabCLR$ and $AssetCLR$ with the RBC ratio are statistically insignificant. This indicates that capital adequacy does not meaningfully moderate the profitability effects of climate risk on either side of the balance sheet. In other words, although insurers with higher RBC ratios are better capitalized, this additional capital does not translate into an improved ability to shield average returns from climate exposures. The influence of climate risk on profitability instead appears to reflect longer-horizon structural pressures, such as rising expected losses and declining expected investment yields, that cannot be easily mitigated through larger capital buffers.

In the volatility regressions (columns (3) and (4) of Table 8), the interaction between liability exposure and the RBC ratio is significantly negative for both SDROA and SDROE. This implies that higher RBC ratios attenuate the volatility impact of liability exposure. Insurers with stronger capital positions are better able to absorb liability shocks, including higher expected claims or greater reserve uncertainty, thereby dampening fluctuations in financial outcomes.

For asset-side exposures, the results point to a nonlinear moderating role of capital

adequacy. At lower to moderate levels of asset exposure, higher RBC ratios modestly reinforce the stabilizing effects of the asset portfolio, as reflected by the positive linear interaction term. At higher exposure levels, however, the negative interaction on the squared term dominates, indicating that stronger capital positions substantially reduce the volatility associated with heavily climate-exposed asset holdings.

Taken together, these findings underscore that solvency is a key moderating factor in the climate-finance nexus. Adequate capital buffers not only enhance insurers' resilience to liability shocks but also broaden the range of asset-side exposures over which insurers can earn positive returns. Conversely, capital inadequacy intensifies financial fragility in the face of climate risk, threatening both sides of the balance sheet.

[insert Table 8]

5.5 Transmission to Municipal Bond Market

This subsection examines how climate shocks affecting insurers' balance sheets propagate to municipal bond markets through insurers' trading behavior. When climate shocks hit insurers—either on the asset side through exposure to disaster-affected bonds or on the liability side through elevated claims—they rebalance their portfolios by reducing holdings of municipal bonds. Figure 14 shows that, on average, insurers become net sellers of municipal bonds in the quarters following climate shocks from either side of the balance sheet. This pattern indicates that both underwriting losses and asset-value deteriorations trigger portfolio contractions, reflecting insurers' attempts to restore liquidity and capital adequacy.

[insert Figure 14]

Such balance-sheet adjustments have implications for the pricing of municipal bonds. In particular, when insurers sell bonds that are themselves exposed to local climate risk, their collective sales exert additional downward pressure on bond prices, amplifying spreads in affected regions. Figure 15 focuses on insurers that experience liability-side climate shocks and provides a clean test of whether their selling behavior affects municipal bond prices. By comparing bonds sold versus unsold by the same set of affected insurers, the test isolates the price impact attributable to insurers' sales. The figure shows that, following a climate disaster in the issuing state, the spread increase is significantly larger for bonds that were sold after the liability shock. This clear divergence in spread responses demonstrates that insurers' post-shock selling has a distinct and measurable impact on municipal bond pricing, contributing to

the amplification of climate-related risk in these markets..

[insert Figure 15]

Taken together, these results reveal a transmission channel whereby climate shocks to insurers' balance sheets spill over to the broader financial system. Asset- and liability-side shocks jointly induce insurers to sell municipal bonds, which in turn depresses bond prices and widens spreads in disaster-prone areas. Hence, insurers not only absorb climate risk as underwriters and investors but also propagate it through their trading activities, linking the insurance sector's financial fragility to local public finance conditions.

5.6 Amplified Loss of Underwriting Capacity After Climate Shocks

A further consequence of climate risk exposure, beyond its immediate impact on profitability and volatility, is a contraction in insurers' future underwriting capacity. This capacity channel operates through balance-sheet tightening following climate shocks, particularly when shocks simultaneously strike both the asset and liability sides. Using the extended event-study evidence, we document systematic declines in asset growth, premium growth, capital and surplus, and equity growth in the quarters following climate-related disasters. These patterns reveal a meaningful and persistent feedback mechanism through which climate shocks weaken insurers' ability to supply coverage.

Figure 16 illustrates that, following asset- and liability-side climate shocks, insurers exhibit marked reductions in the growth of assets, premiums, capital/surplus, and equity. Liability shocks—driven by elevated catastrophe losses in high-risk states—reduce net income and strain reserves, limiting the retained earnings available to support asset accumulation and capital expansion. The decline in premium growth following liability shocks further indicates that insurers respond by slowing the expansion of their underwriting activities, especially in highly exposed lines and geographies. The resulting damage to insurers' underwriting capacity can be substantial. Taking assets as an example, at the aggregated industry level, an asset shock is associated with an average reduction of approximately $0.2 billion in total assets in the subsequent quarter, whereas a liability shock corresponds to a reduction of about $0.1 billion.

[insert Figure 16]

Figure 17 sharpens this comparison by isolating insurers that experience joint shocks—

simultaneous asset- and liability-side impacts—and contrasting them with insurers exposed to only one side of the balance sheet. By focusing on this subset, Figure 11 highlights the incremental effect of facing both shocks at once, over and above the impact observed for firms with only an asset-side or only a liability-side shock. The results show substantially larger and more persistent declines in asset growth, premium growth, capital/surplus, and equity growth among insurers jointly exposed to shocks compared to those exposed to shocks on a single side of the balance sheet. Still taking assets as an example, at the aggregated industry level, a joint shock leads to a decline of about $3.1 billion in total assets in the quarter that follows. This pattern confirms that asset-side shocks amplify the strain imposed by liability-side losses: mark-to-market declines in municipal bond portfolios reduce surplus and capital, while liquidity needs limit new investments and force net selling of securities.

[insert Figure 17]

The balance-sheet contraction following joint shocks is economically significant. The declines in capital and surplus imply that insurers face reduced risk-bearing capacity in subsequent periods, limiting their ability to write new business or renew high-risk policies without breaching internal or regulatory capital thresholds. The slowing of premium growth—which is most pronounced after joint shocks—suggests that insurers ration underwriting supply as a direct response to weakened solvency positions.

Overall, the evidence shows that climate shocks trigger a capacity-reducing feedback loop: as insurers absorb climate-related losses on both sides of the balance sheet, their weakened capital positions limit subsequent underwriting growth, ultimately affecting the availability and affordability of insurance in climate-exposed regions. This mechanism complements the profitability and volatility results presented earlier and highlights a broader financial-stability implication of insurers' climate exposures, particularly in markets where rate regulation or local hazard conditions impede effective capital rebuilding.

6 Conclusion

This paper provides comprehensive evidence on how climate risk—measured through exposure to sea-level rise and climate-related disasters—affects U.S. property-casualty insurers across both sides of their balance sheets. We show that liability-side exposure to climate-vulnerable regions consistently erodes profitability and increases earnings volatility by raising loss ratios. Asset-side climate exposure exhibits a nonlinear pattern: moderate exposure enables insurers to act as liquidity providers and earn higher returns in dislocated municipal bond

markets, but high exposure generates mark-to-market losses and amplifies downside risk. When both exposures are elevated, the adverse effects become mutually reinforcing, producing substantially weaker financial performance than either exposure alone.

Beyond these insurer-level effects, our results uncover two broader systemic mechanisms. First, we document a climate-risk transmission channel from insurers to municipal finance. Following asset- or liability-side climate shocks, insurers become net sellers of municipal bonds—particularly those issued by affected regions—placing downward pressure on prices and widening local borrowing spreads. As a result, climate shocks impair not only insurers' profitability but also local governments' capacity to fund adaptation and recovery, creating a feedback loop between insurance fragility and municipal fiscal stress.

Second, we show that climate shocks generate a capacity-reducing feedback effect. Joint shocks to insurers' assets and liabilities lead to persistent declines in asset growth, premium growth, capital and surplus, and equity. These balance-sheet contractions meaningfully constrain insurers' ability to supply coverage in subsequent periods, effectively tightening underwriting capacity. This mechanism highlights how climate-induced balance-sheet stress can propagate into real-economy outcomes through the insurance supply channel.

We also identify elements that can moderate climate-related vulnerabilities. Diversification across insurance lines attenuates the negative financial effects of liability-side climate risk, while stronger solvency positions reduce the volatility impact of both asset- and liability-side exposures. However, rate-regulation frictions can hinder insurers' ability to reprice climate risk, contributing to sustained underwriting losses in high-hazard jurisdictions. These results underscore the need for integrated climate-risk management strategies that jointly address exposures, diversification, capital adequacy, and regulatory constraints.

Taken together, our analysis demonstrates that climate risk imposes intertwined underwriting, investment, and capacity pressures on insurers, amplifying financial stress in municipal bond markets. An effective policy response requires regulators and firms to incorporate climate risk into capital planning, portfolio management, pricing frameworks, and solvency oversight. Strengthening these tools will be essential for sustaining the resilience of both the insurance sector and local public finance as climate hazards intensify.

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Tables and Figures

Table 1 Variable definition

Panel A Key independent variables	
AssetCLR	$\frac{\sum_j RSL_{j,t} \times holding_{i,j,t}}{\sum_j holding_{i,j,t}}$, where $RSL_{j,t}$ is the past 5-year (up to t) average of the relative sea level of county j, $holding_{i,j,t}$ is firm i's holding par value of municipal bond in county j in quarter t.
LiabCLR	$\sum_s RSL_{s,t} \times (\frac{DPW_{i,s,t}}{\sum_s DPW_{i,s,t}})$, where $RSL_{s,t}$ is the past 5-year (up to quarter t) average of the relative sea level of state s, $DPW_{i,s,t}$ is firm i's direct premiums written in county s in quarter t.
TotalCLR	$TotalCLR_{i,t} = LiabCLR_{i,t} \times \frac{Reserve_{i,t}}{Reserve_{i,t}+holding_{i,t}} + AssetCLR_{i,t} \times \frac{holding_{i,t}}{Reserve_{i,t}+holding_{i,t}}$, where $Reserve_{i,t}$ represents insurer i's total reserves in quarter t and $\text{holding}_{i,t}$ denotes insurer i's total holdings of municipal bonds in quarter t.
Panel B Key dependent variables	
ROA	ROA, defined as the income after taxes as a percent of average net admitted assets.
ROE	ROE, defined as the income after taxes as a percent of average capital and surplus.
SDROA	Four-quarter-rolling window of the standard deviation of ROA
SDROE	Four-quarter-rolling window of the standard deviation of ROE
Panel C Control variables	
Leverage	leverage $(\frac{liability}{asset})$
lnasset	the natural logarithm of the asset
reins	$\frac{net\ premiums\ written}{direct\ premiums\ written}$
geoh	geographic Herfindahl-Hirschman index (HHI) of direct premiums written
longtail	The proportion of direct premiums written (DPW) in long-tail lines of business in total DPW. Long-tail lines of business are farm owners' multiple peril line, homeowners' multiple perils, commercial multiple peril line, medical professional liability line, workers' compensation line, other liability line, products liability line, and auto liability line.
lobh	lines of business Herfindahl-Hirschman index (HHI).
Growth	The change rate of the quarterly total assets
Panel D Other variables	
Lossratio	Loss ratio, defined as the net loss and loss adjustment expense incurred as a percent of net premiums earned.
ROI	Return on investment
Premiumgrowth	The change rate of quarterly direct premiums written in 51 states.
Regulation	1 if a firm has positive direct premiums written in the lines of business under stringent regulation; 0 otherwise.
Geoh_coast_noncoast	Geographical Herfindahl-Hirschman index (HHI) of direct premiums written between the coastal states and the non-coastal states.
Geoh_us_nonus	Geographical Herfindahl-Hirschman index (HHI) of direct premiums written between the U.S. market and the non-U.S. market.
rbcratio	RBC ratio, the total eligible capital divided by the capital requirement.

Table 2 Descriptive statistics

	Obs.	Mean	Std.	Min.	Median	Max.
Panel A Key independent variables						
AssetCLR	58122	0.026	0.025	-0.00082	0.020	0.12
LiabCLR	58122	0.061	0.034	-0.0015	0.063	0.14
TotalCLR	58094	0.048	0.033	-0.0015	0.047	0.14
Panel B Key dependent variables						
ROA	58120	2.17	6.12	-24.4	2.17	23.3
ROE	58080	4.60	16.4	-75.6	4.27	60.7
SDROA	58087	4.22	4.85	0.054	2.63	28.7
SDROA	58066	11.0	14.9	0.073	6.22	96.9
Panel C Control variables						
Leverage	58122	0.51	0.21	0.0010	0.55	0.87
Lnasset	58122	12.0	1.68	9.32	11.8	17.0
Reins	58122	1.37	3.87	-0.48	0.77	33.3
Geoh	58122	0.49	0.38	0.040	0.37	1.00
Longtail	58122	0.61	0.38	0	0.76	1
Lobh	58122	0.61	0.31	0	0.59	1
Growth	58120	1.31	6.82	-21.6	0.93	36.3
Panel D Other variables						
Lossratio	47843	51.8	27.4	-54.0	53.8	172.1
ROI	58120	2.61	1.17	-0.23	2.55	7.50
Premiumgrowth	57680	15.8	100.1	-91.2	0.37	825.9
Regulation	58043	0.80	0.40	0	1	1
Geoh_coast_noncoast	58122	0.85	0.17	0.50	0.90	1
Geoh_us_nonus	58122	1.00	0.019	0.83	1	1
rbcratio	58122	41.8	81.2	2.06	9.91	410.9

Notes: Panels A-D report the summary statistics of the sample. All variables are censored at the 1% and 99% levels.

Table 3 Impact of asset and liability exposures to climate risk on firm profitability

VARIABLES	(1) ROA	(2) ROA	(3) ROE	(4) ROE	(5) SDROA	(6) SDROA	(7) SDROE	(8) SDROE
Panel A: asset and liability exposures								
LiabCLR	-9.164***	-8.548***	-24.91***	-22.08***	10.53***	10.60***	25.57***	25.42***
	(3.186)	(3.165)	(8.534)	(8.215)	(2.912)	(2.943)	(9.185)	(9.027)
$LiabCLR^2$		-31.63		-146.3		-2.830		8.953
		(45.90)		(124.1)		(40.04)		(124.4)
AssetCLR	-0.503	3.801	-1.253	12.71	2.758	4.734*	4.012	6.679
	(2.076)	(2.851)	(5.628)	(7.854)	(2.274)	(2.866)	(6.819)	(8.443)
$AssetCLR^2$		-97.83**		-316.8**		-45.07		-61.00
		(45.64)		(126.1)		(48.91)		(145.1)
R-squared	0.234	0.234	0.199	0.199	0.492	0.492	0.530	0.530
Panel B: total exposures								
TotalCLR	-5.858**	-3.541	-17.78***	-10.91*	11.84***	11.28***	23.82***	20.07***
	(2.516)	(2.432)	(6.833)	(6.405)	(2.565)	(2.587)	(7.649)	(7.469)
$TotalCLR^2$		-129.0***		-382.5***		31.38		209.0
		(47.64)		(136.2)		(42.22)		(135.5)
R-squared	0.234	0.234	0.199	0.200	0.493	0.493	0.531	0.531
Observations	58,081	58,081	58,041	58,041	58,051	58,051	58,030	58,030
firm FE	Y	Y	Y	Y	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y

Notes: The table reports the coefficients of OLS estimations of equation (1).

(1) This table shows how an insurer's asset and liability exposure to climate risk influences firm performance (ROA, ROE, SDROA, SDROE). We find that insurers' liability exposure to climate risk linearly reduces insurers' profitability. Asset exposure to climate risk increases insurer profitability up to about the 80th percentile, beyond which its effect turns negative. We also find that earnings volatility rises with liability exposure to sea-level rise.

(2) In columns (1)-(4), panel A, we use the linear and quadratic terms of asset and liability exposures as the main independent variables. The negative and significant coefficients of the quadratic terms of asset exposures suggest that the asset exposure to climate risk exhibits an inverted U-shape with firm profitability. The negative and significant coefficients of the linear terms of liability exposures, as well as the insignificant coefficients of the quadratic terms of liability exposures, suggest that the liability exposure to climate risk linearly reduces firm profitability.
(3) In columns (5)-(8), panel A, we use risk outcomes as dependent variables (the standard deviations of ROA and ROE (computed over rolling five-year windows)). The results suggest that the firm risk is positively and significantly associated with the RSL-based liability exposure measure, indicating that firms facing greater climate-liability pressure experience more unstable profitability.
(4) In columns (1)-(4), panel B, we show the quadratic impact of total climate exposures on insurers' profitability (ROA, ROE). The results reveal a nonlinear, concave relationship over the five-year window: the marginal impact of exposure becomes increasingly adverse at higher total risk levels.
(5) In columns (5)-(8), panel B, the results suggest that the aggregated climate exposures linearly increase the firm risk (SDROA, SDROE).
(6) To address the issue of multicollinearity, we decentralize *LiabCLR*, *AssetCLR*, and *TotalCLR*.
(7) All standard errors are clustered at the firm level.
(8) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 4 Additive effects of asset and liability exposures to climate risk

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR	-16.00**	-46.73*	23.79***	67.23***
	(8.020)	(23.87)	(6.653)	(21.19)
AssetCLR	-11.68**	-26.63**	1.121	1.371
	(4.728)	(13.49)	(4.797)	(15.12)
$AssetCLR^2$	41.97	61.09	-95.73	-76.10
	(85.06)	(240.2)	(87.44)	(262.5)
LiabCLR×AssetCLR	-454.5**	-1,797***	296.7[a]	1,172**
	(205.9)	(575.6)	(190.8)	(576.0)
LiabCLR×$AssetCLR^2$	5,305	16,450	-4,329	-18,257*
	(3,829)	(10,208)	(3,568)	(10,188)
Observations	18,060	18,035	18,049	18,029
R-squared	0.304	0.261	0.595	0.624
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

Note: (a) p-value=0.12.

(1) This table reports how the asset and liability exposure to climate risk interact to influence firm performance when both the asset and liability exposures are above their respective median levels.
(2) In columns (1)-(2), the negative and statistically significant coefficients of the interaction term of liability exposure and asset exposure suggest that there are additive effects on firm profitability between these two exposures. In columns (3)-(4), the positive coefficients of the interaction term of liability exposure and asset exposure suggest that there are additive effects on firm volatility.
(3) This table indicates that the asset exposure exacerbates the negative impact on firm performance, while the liability exposure constrains the range of asset exposure over which asset exposure enhances firm profitability.
(4) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(5) All standard errors are clustered at the firm level.
(6) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 5 Impact of asset and liability exposures on return on investment and on loss ratio

VARIABLES	(1) ROI	(2) lossratio
LiabCLR	1.528**	42.99***
	(0.640)	(16.22)
$LiabCLR^2$	6.773	587.8**
	(9.855)	(237.9)
AssetCLR	1.144**	-4.009
	(0.574)	(14.90)
$AssetCLR^2$	-17.40**	179.1
	(8.531)	(264.7)
Observations	58,081	47,716
R-squared	0.573	0.360
firm FE	Y	Y
quarter FE	Y	Y
Control variables	Y	Y

(1) This table illustrates the channel by which asset and liability exposure to climate risk affects firm performance. We find that insurers' liability exposure to climate risk reduces loss ratios. Asset exposure to climate risk increases the return on investment up to about the 80th percentile, beyond which its effect turns negative.
(2) To address the issue of multicollinearity, we decentralize *AssetCLR* and *AssetClimateRisk_3y*.
(3) All standard errors are clustered at the firm level.
(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 6 The role of rate regulation on the impact of liability exposures

VARIABLES	(1) Premiumgrowth	(2) Lossratio	(3) Lossratio	(4) Lossratio
	Full sample	HighLiabRisk =0	HighLiabRisk =1	Full sample
Regulation	-8.898*	2.366	3.623	2.241
	(5.278)	(2.251)	(3.200)	(2.291)
LiabCLR		128.9***	65.04**	139.0***
		(33.27)	(32.79)	(32.68)
LiabCLR×Regulation		-102.5***	11.14	-100.0***
		(32.58)	(37.47)	(32.67)
Regulation ×HighLiabRisk				3.213
				(3.828)
LiabCLR×Regulation ×HighLiabRisk				101.0**
				(47.36)
Observations	57,594	35,197	12,470	47,667
R-squared	0.251	0.379	0.318	0.360
Asset exposures	N	Y	Y	Y
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table illustrates that stringent rate regulation induces more cautious underwriting behavior among insurers, thereby mitigating the negative impact of liability climate risk on underwriting performance, and hence "protecting" insurers. The protective effect is particularly pronounced when liability climate risk is relatively low.
(2) Column (1) shows the effect of stringent regulation on quarterly premium growth. The result indicates that insurers facing stringent rate regulation will have a lower premium growth rate.
(3) Column (2) and (3) shows the effect of stringent rate regulation on underwriting performance in the subsamples. The variable $HighLiabRisk$ equals 1 if an insurer's mean liability exposure during the sample period is above the 75th percentile, and zero otherwise. The results in columns (2) and (3) show that the mitigating role of stringent rate regulation only exists in the subsamples where the mean liability exposures are relatively low.
(4) Column (4) interacts the mitigating role with the variable $HighLiabRisk$, confirming that when the mean liability exposures are relatively high, the mitigating role of stringent rate regulation will diminish.
(5) To address the issue of multicollinearity, we decentralize *LiabCLR* and *AssetCLR*.
(6) All standard errors are clustered at the firm level.
(7) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 7 Business diversification mitigates the negative effect of liability-side climate risk

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR	-8.655***	-23.30***	9.922***	24.94***
	(3.146)	(8.444)	(2.902)	(9.123)
LiabCLR×(1-lobh)	8.808*	27.87*	-11.12**	-11.66
	(5.207)	(14.53)	(4.684)	(14.99)
AssetCLR	3.824	12.83	4.746*	6.683
	(2.852)	(7.859)	(2.861)	(8.437)
$AssetCLR^2$	-97.25**	-316.5**	-47.26	-62.91
	(45.75)	(126.6)	(48.82)	(145.3)
R-squared	58,081	58,041	58,051	58,030
Observations	0.234	0.199	0.492	0.530
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table reports how insurers' line of business diversification mitigates the impact of liability exposures. We measure diversification as $(1-lobh)$, where a higher value of $(1-lobh)$ indicates greater diversification across business lines.
(2) In columns (1)-(2), the negative and statistically significant coefficients of the interaction term between the liability exposures and the line of business Herfindahl index suggest that when the insurers' underwriting is relatively diversified on certain lines of business, the negative impact of liability exposure on firm profitability is mitigated. In column (3), the positive and statistically significant coefficients of the interaction term suggests that when the insurers' underwriting is relatively diversified on some certain lines of business, the increasing impact of liability exposure on firm volatility is mitigated.
(3) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(4) All standard errors are clustered at the firm level.
(5) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table 8 Financial strength mitigates the negative effect of climate risk

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
AssetCLR	2.777	10.93	3.664	4.845
	(2.926)	(8.079)	(2.849)	(8.524)
$AssetCLR^2$	-82.30*	-298.2**	-31.22	-22.14
	(47.33)	(133.0)	(49.24)	(150.3)
AssetCLR×rbcratio	0.0175	0.0261	0.0754**	0.176**
	(0.0212)	(0.0523)	(0.0328)	(0.0828)
$AssetCLR^2$×rbcratio	-0.117	0.273	-0.983*	-3.398**
	(0.325)	(0.822)	(0.520)	(1.399)
LiabCLR	-8.811***	-24.33***	10.91***	26.44***
	(3.237)	(8.703)	(2.963)	(9.382)
LiabCLR×rbcratio	-0.00866	0.0393	-0.0748***	-0.188***
	(0.0160)	(0.0375)	(0.0190)	(0.0489)
R-squared	57,616	57,578	57,611	57,592
Observations	0.237	0.202	0.493	0.530
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table reports how capital requirement mitigates the impact of liability exposures.
(2) In columns (1)-(2), we don't find evidence on the mitigation role of financial strength on profitability.
(3) In columns (3)-(4), the results show that financial strength mitigates the impact of climate risk on firm volatility. The negative and statistically significant coefficients of the interaction between the liability exposures and the RBC ratio suggest that when the insurers are more solvent and financially strong, the increasing impact of liability exposure on firm volatility is mitigated. As for the asset exposure, the positive linear interaction term suggests that at lower to moderate levels of asset exposure, higher RBC ratios modestly reinforce the stabilizing effects of the asset portfolio. The negative quadratic interaction term suggests that at higher exposure levels, however, the negative interaction on the squared term dominates, indicating that stronger capital positions substantially reduce the volatility associated with heavily climate-exposed asset holdings.
(4) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(5) All standard errors are clustered at the firm level.
(6) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

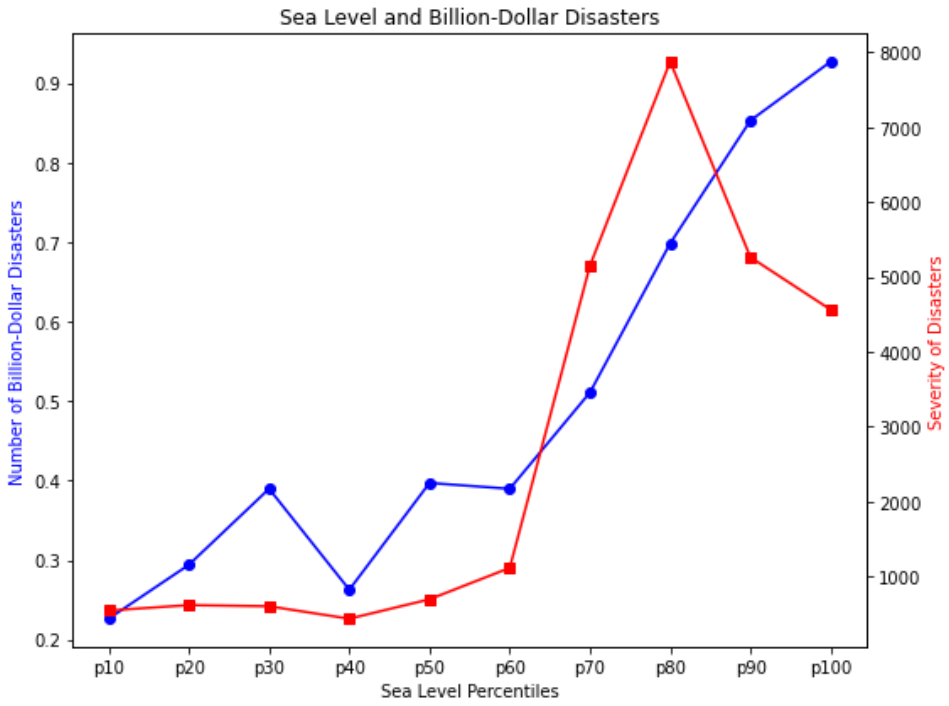
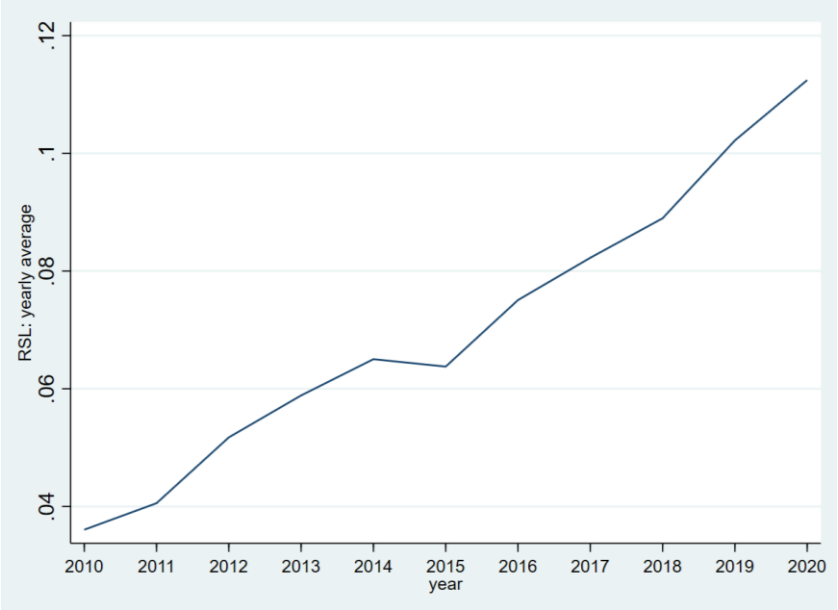
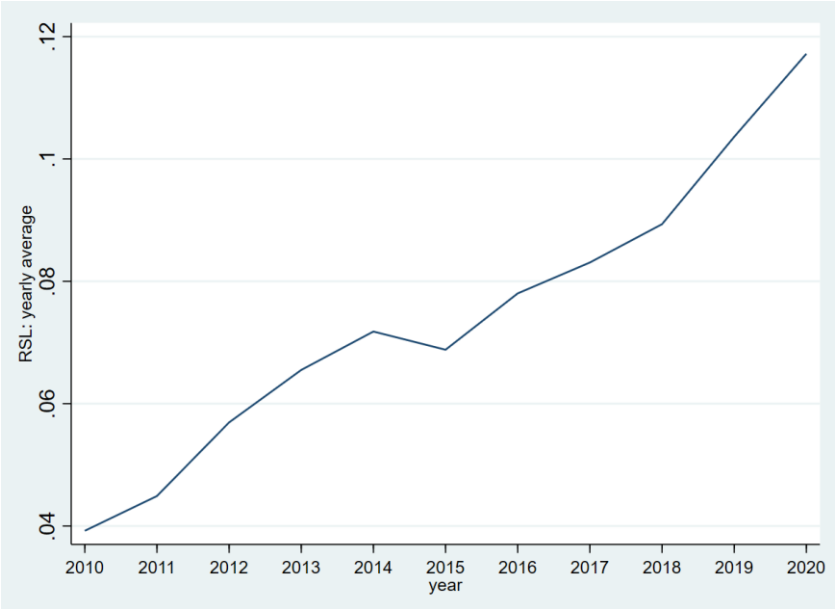


Figure 1 Sea-level and billion-dollar disasters

Figure 1 illustrates the relationship between higher sea levels and the increased frequency and severity of disasters. The figure is constructed using state–quarter observations with relative sea levels. Disaster data are obtained from NOAA's Billion-Dollar Weather and Climate Disasters database. The disasters include flooding, tropical cyclone, severe storm, and winter storm, each with CPI-adjusted costs of at least 1 billion U.S. dollars. The blue line represents the number of events affecting a state in a given quarter. The red line depicts the average severity, measured by the mean CPI-adjusted cost (million dollars) of the events affecting a state in a given quarter. Both series are plotted as mean values across 10 bins of relative sea level.



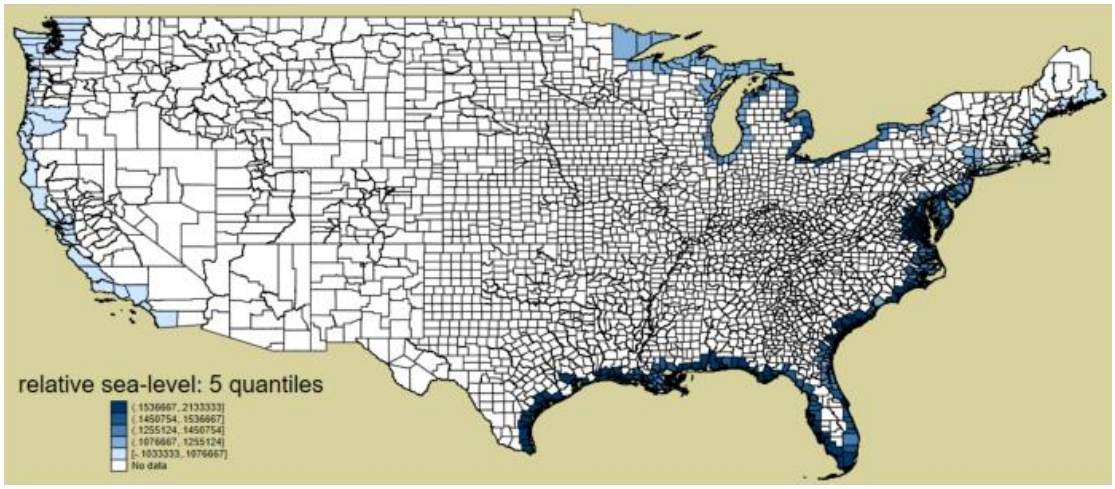
(a)



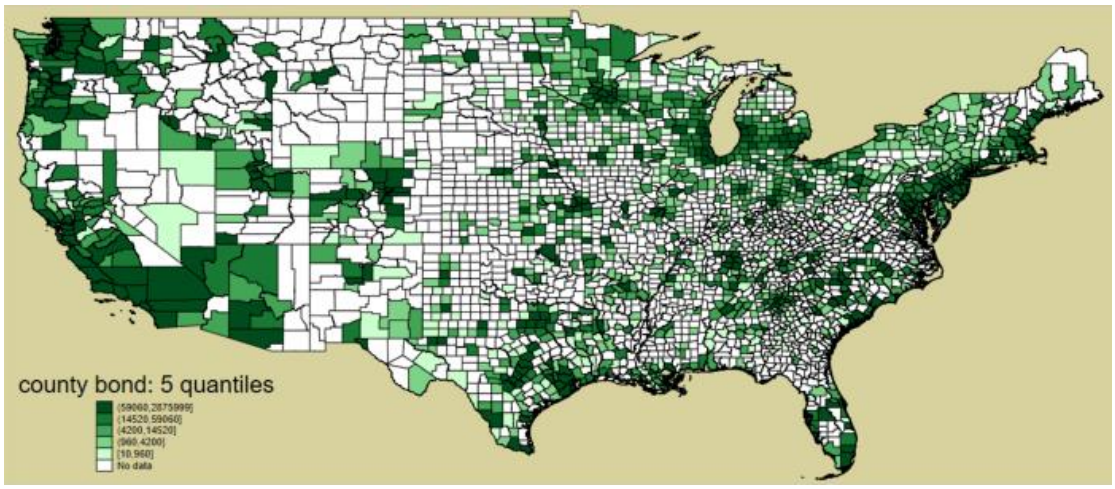
(b)

Figure 2 Time trend of sea-level

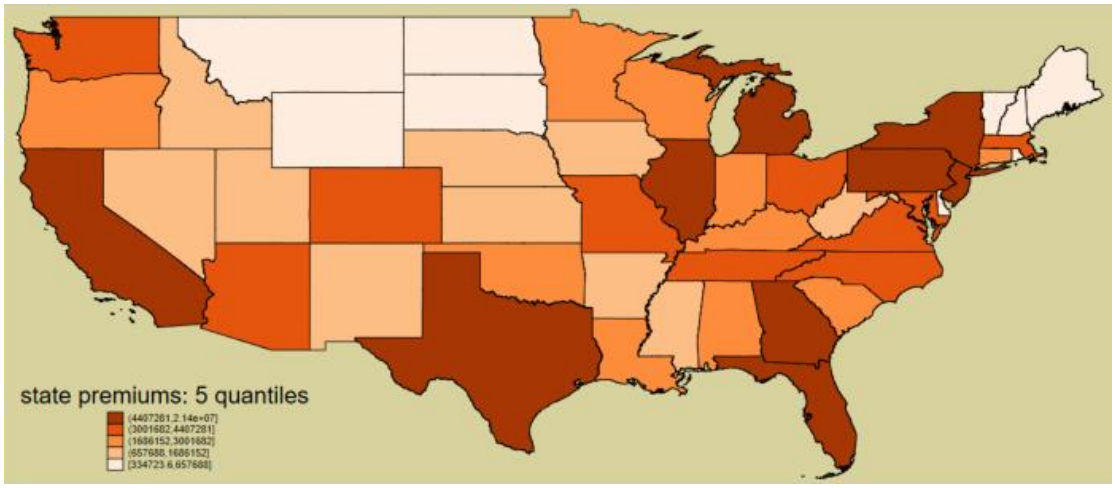
Notes: Figure 2 shows the increasing trend of relative sea level over the years. The figure (a) is produced in the firm-county-quarter sample, while figure (b) is produced in the county-quarter sample. The y-axis is the yearly average of relative sea level (*RSL*).



(a)



(b)



(c)

Figure 3 Relative sea-level, municipal bond holding, and direct premiums written

Panel (a) and (b) plots relative sea-level and insurers' municipal bond holdings in 2020Q4 across coastal counties as defined by NOAA. Panel (c) plots insurers' direct premiums written by state.

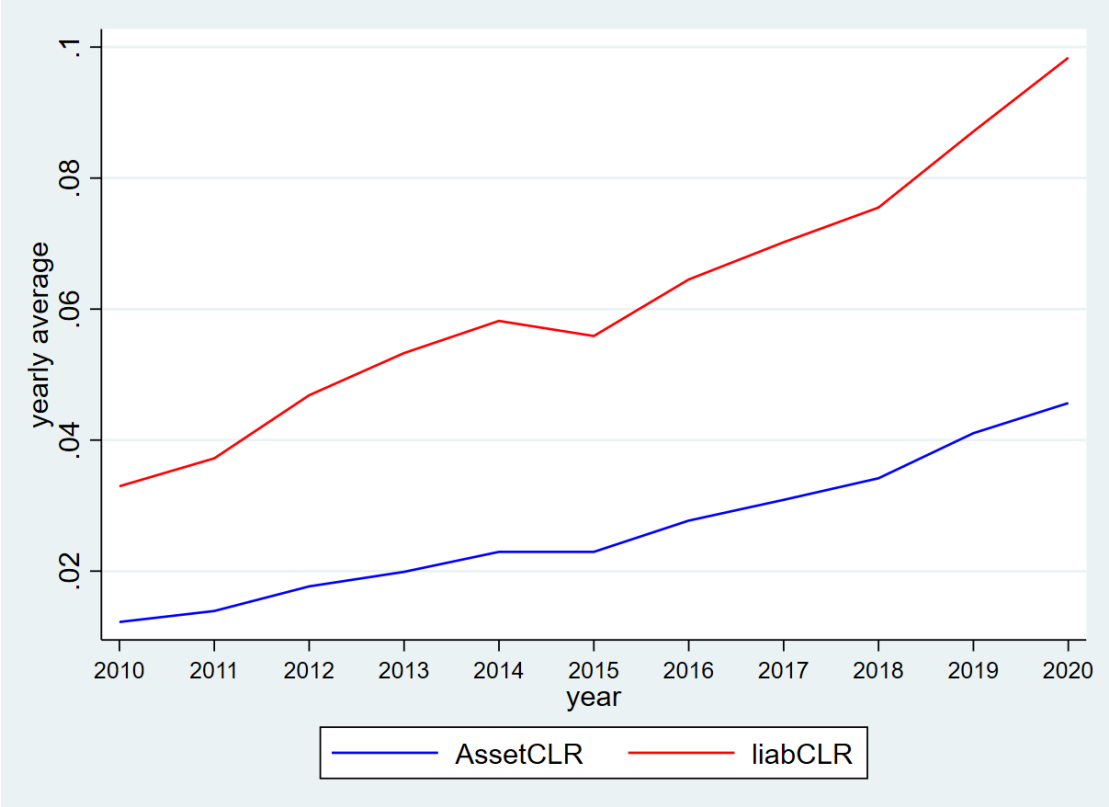


Figure 4 Time trend of asset and liability exposures to climate risk

Notes: Figure 4 presents the time trend of climate risk exposure variables. The y-axis is the yearly averages of *AssetCLR* and *LiabCLR*, respectively. Firms' climate risk exposures are generally increasing over time.

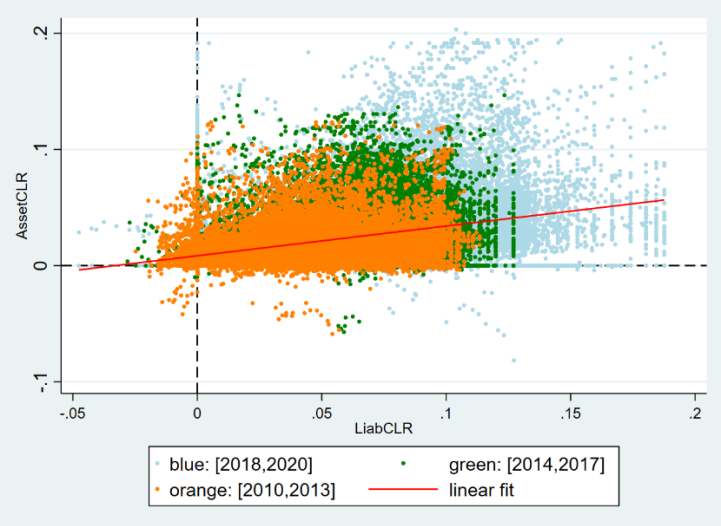
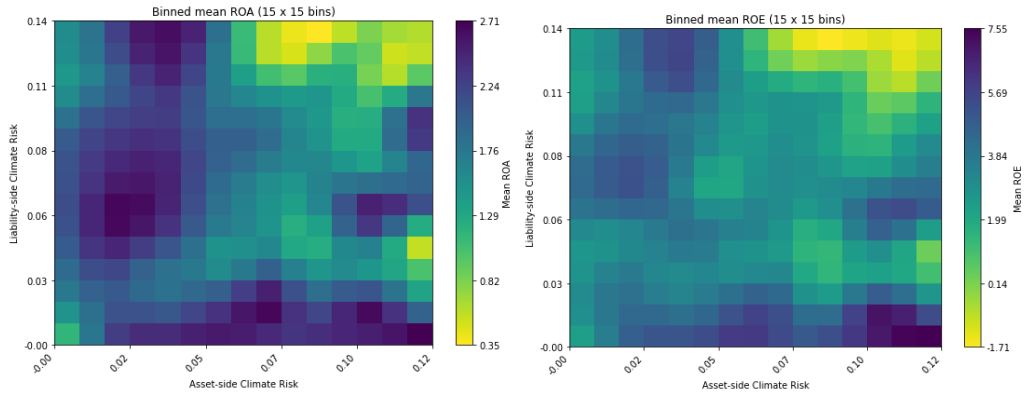
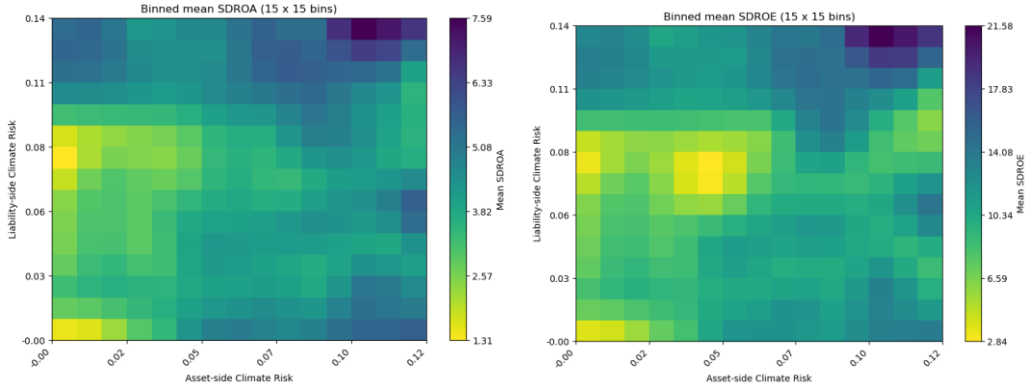


Figure 5 Positive correlation between asset and liability exposures to climate risk

Notes: Figure 5 provides a look of firms' correlated exposures, i.e. *AssetCLR* and *LiabCLR* grouped by years. We observe a positive relationship between asset- and liability-side climate risk measures. The climate risk is larger in later years compared to earlier years, consistent with Figure 3.



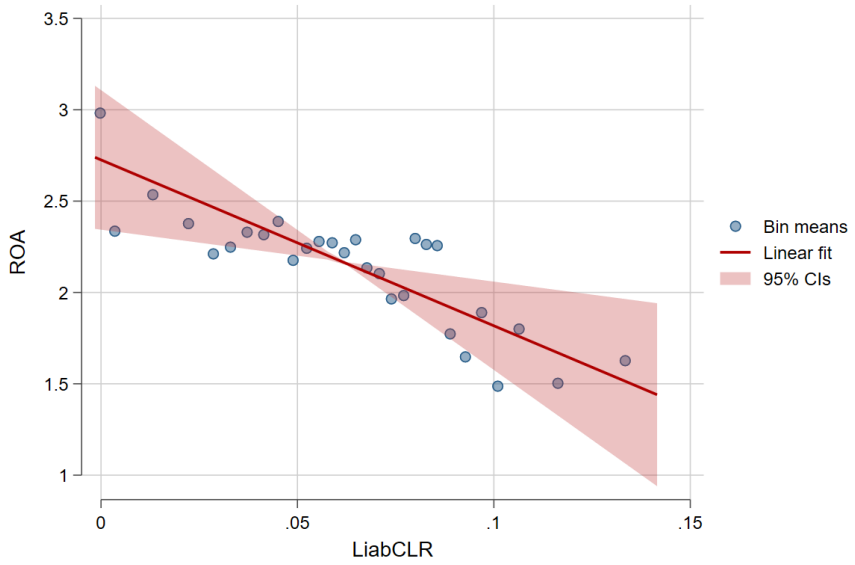
(a) ROA (b) ROE



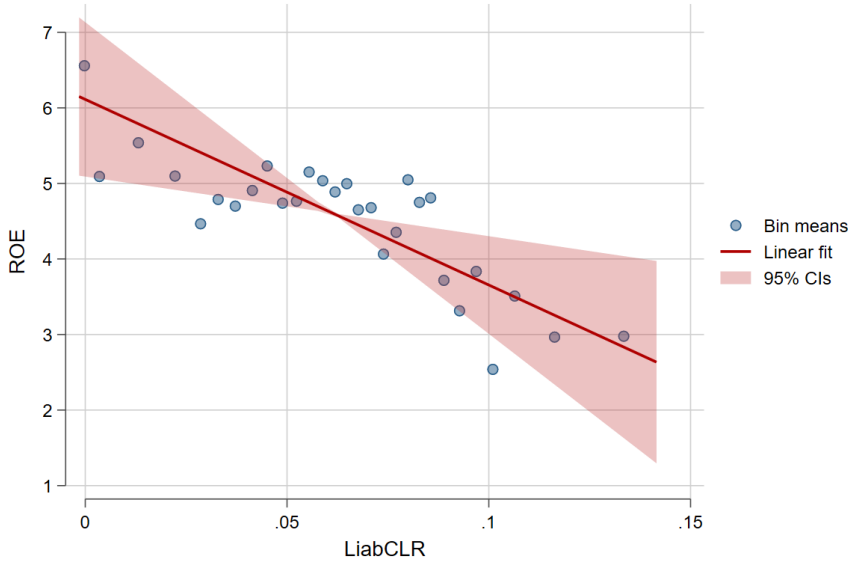
(c) SDROA (d) SDROE

Figure 6 Climate Risk Exposures and Insurer Performance

Notes: The figures show the binned mean ROA, ROE, and their respective standard deviations across asset-side and liability-side climate risks. The figure divides the two-dimensional risk space into 15×15 bins and reports the average ROA (ROE, SDROA, SDROE) within each cell. Darker shades correspond to higher mean ROA (ROE, SDROA, SDROA), whereas lighter shades indicate lower performance or volatility. The pattern suggests that firms exposed to higher levels of both asset-side and liability-side climate risks (toward the upper-right region) tend to exhibit weaker profitability and higher volatility, consistent with the hypothesis that simultaneous exposure on both sides erodes insurers' performance.



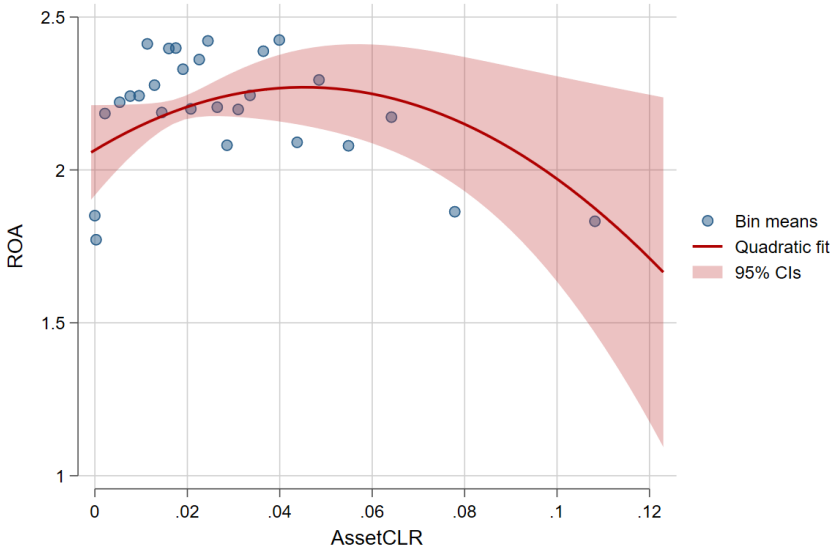
(a)



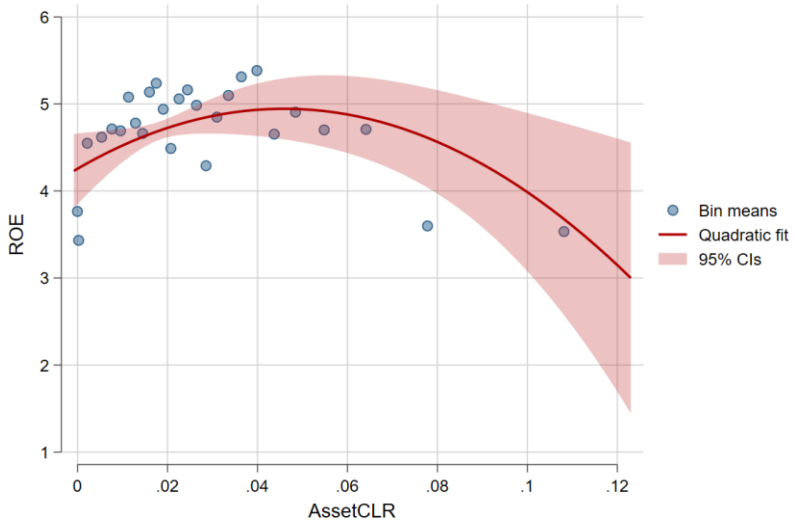
(b)

Figure 7 Negative relationship between liability exposure to climate risk and profitability

Notes: The figure illustrates the negative linear relationship between liability exposure to climate risk (*LiabCLR*) and firm profitability shown in Table 3. Asset exposure to climate risk, all control variables in Table 1 and fixed effects are controlled.



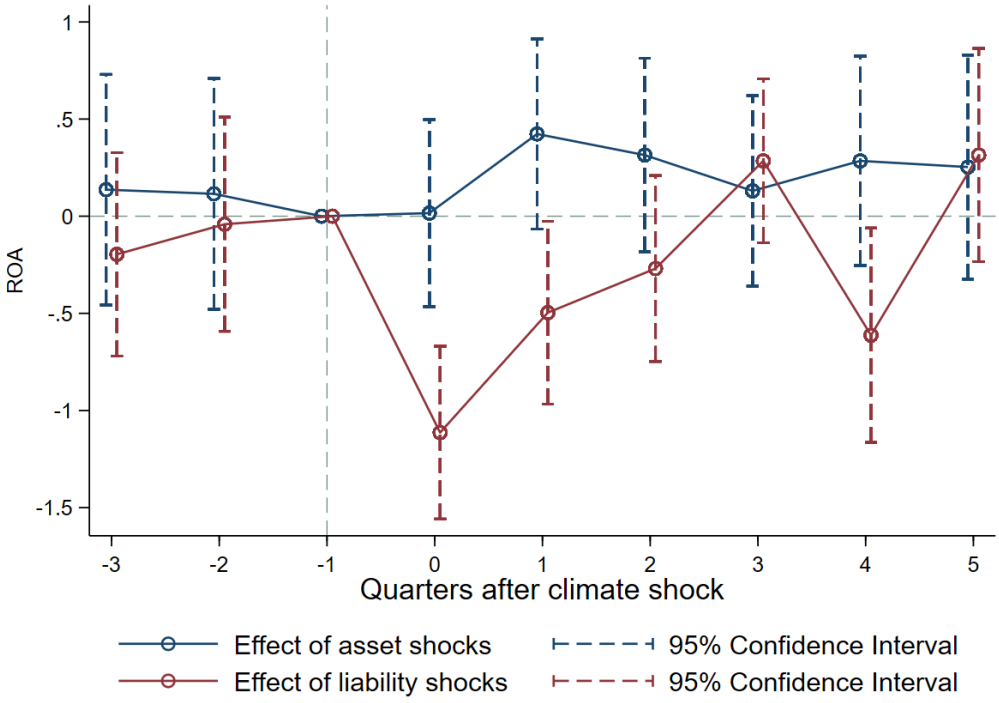
(a)



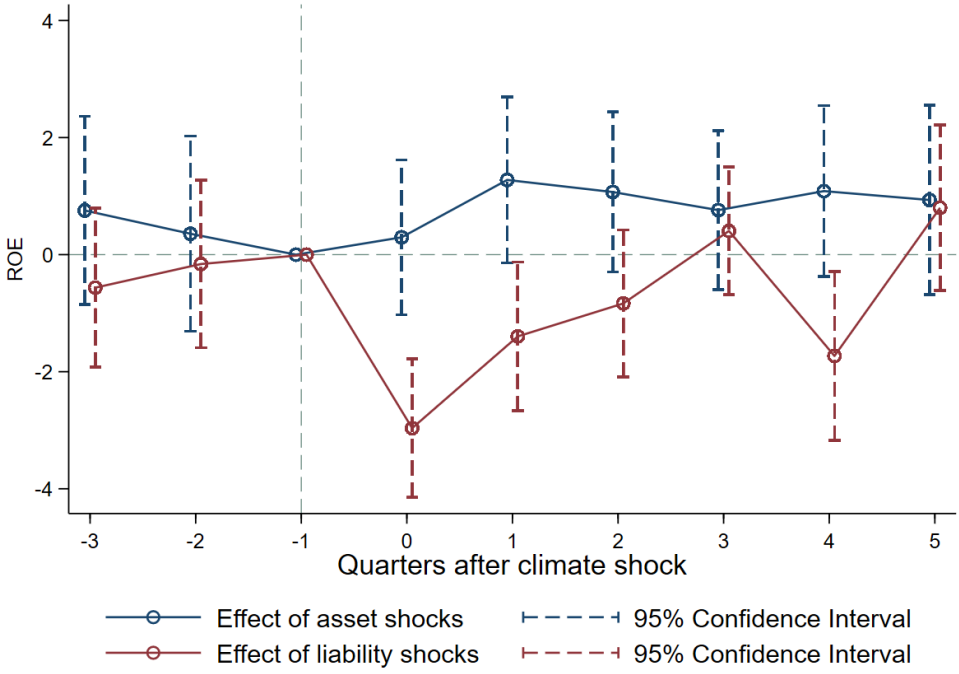
(b)

Figure 8 Inverted U-shape between asset exposure to climate risk and profitability

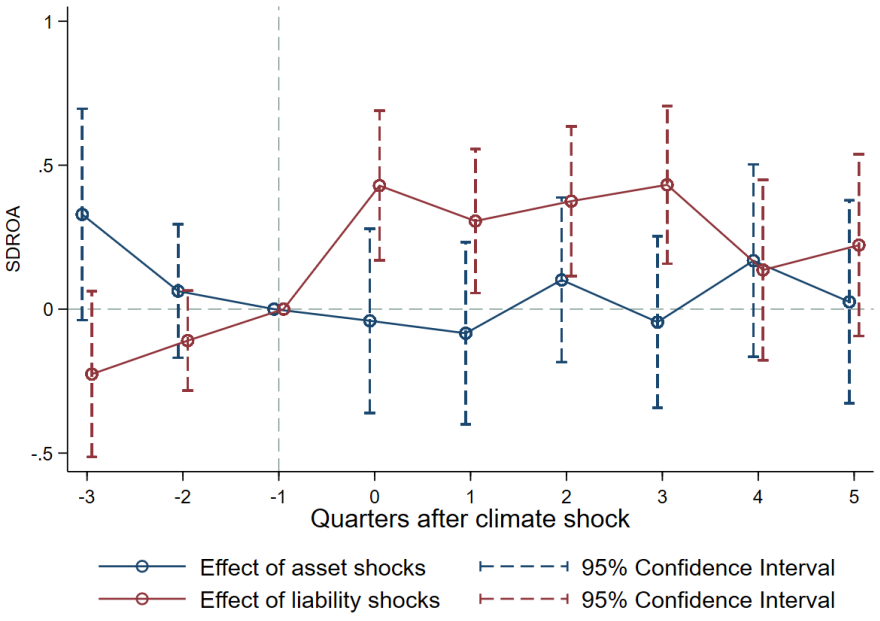
Notes: The figure illustrates the inverted U-shape relationship between asset exposure to climate risk (*AssetCLR*) and profitability shown in Table 3. Liability exposure to climate risk, all control variables in Table 3 and fixed effects are controlled.


ROA
1
.5
0
-.5
-1
-1.5
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shock
Effect of asset shocks
95% Confidence Interval
Effect of liability shocks
95% Confidence Interval

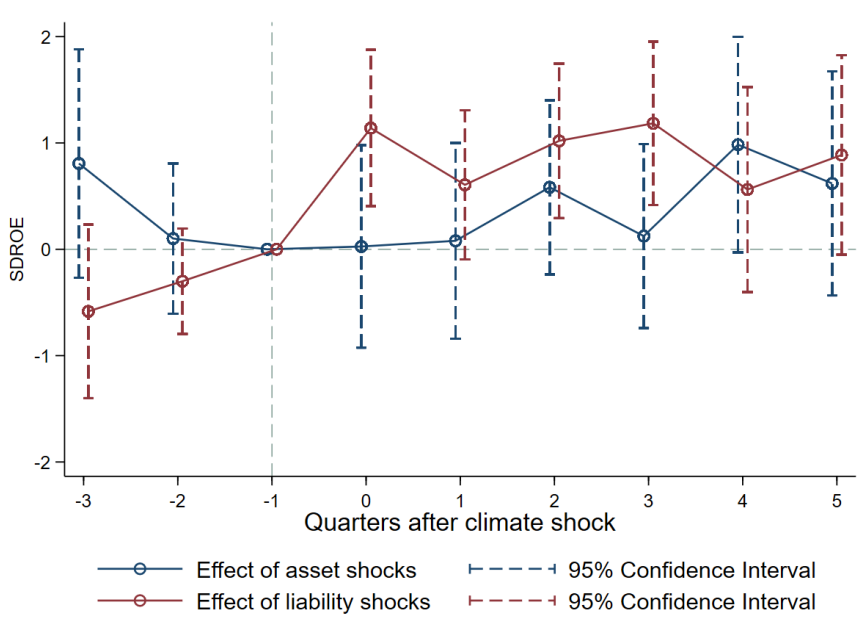
(a)


ROE
4
2
0
-2
-4
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shock
Effect of asset shocks
95% Confidence Interval
Effect of liability shocks
95% Confidence Interval

(b)



(c)



(d)

Figure 9 The performance after asset- and liability-side climate shocks

Notes: This figure presents the event study results estimated using equation (2). In Figures (a)-(d), the y-axes represent ROA, ROE, SDROA, and SDROA, respectively. The figures indicate that following an asset climate shock, insurers' profitability increases, whereas following a liability climate shock, their profitability declines and the volatility increases.

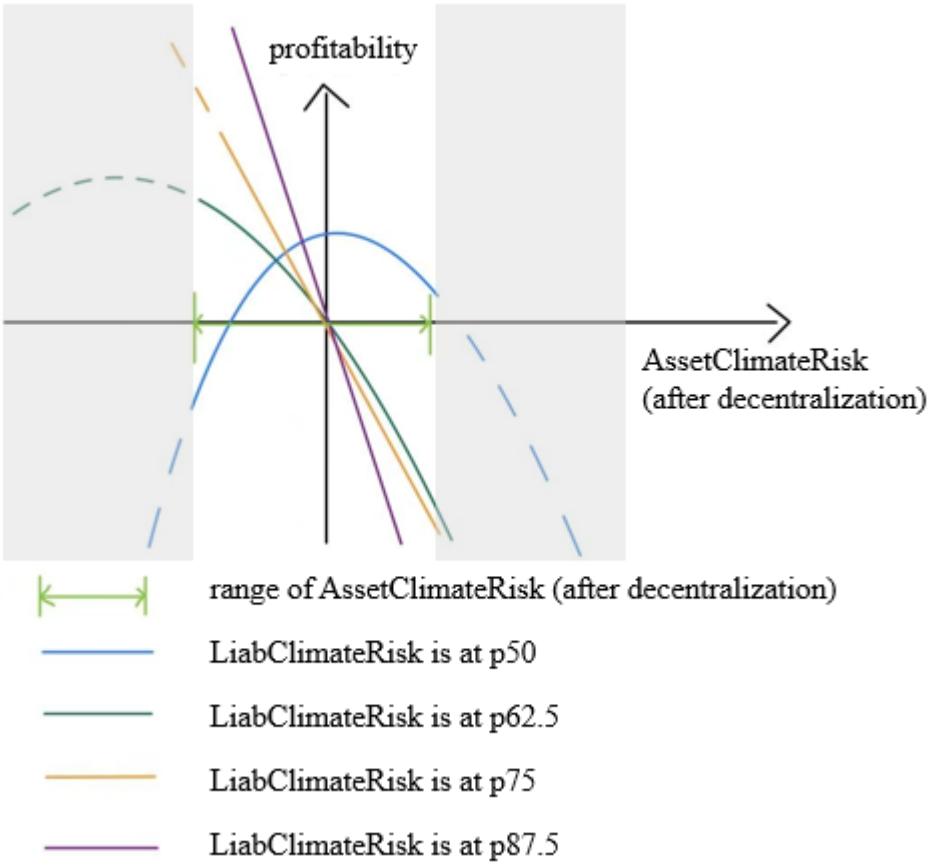
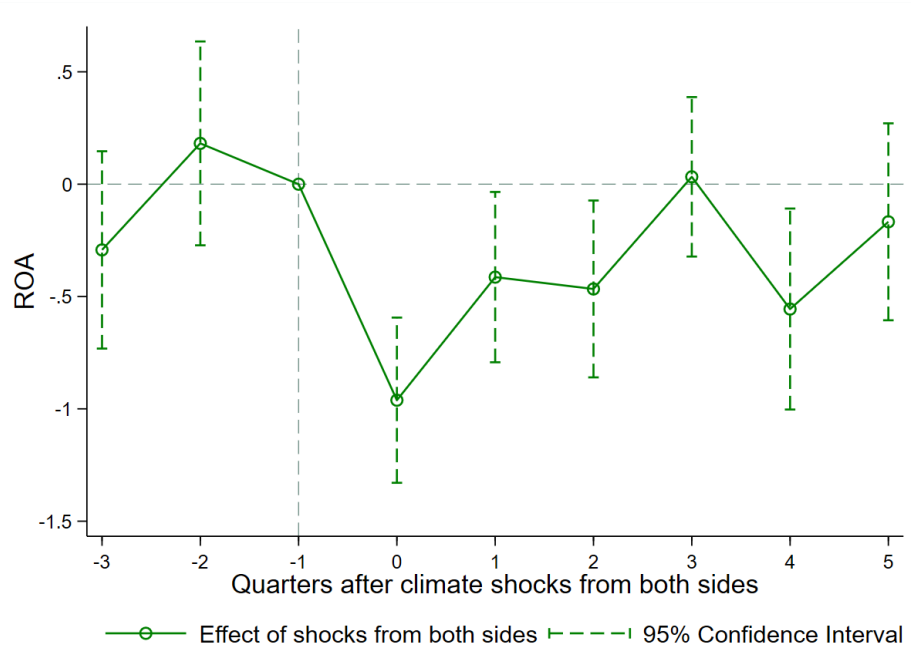
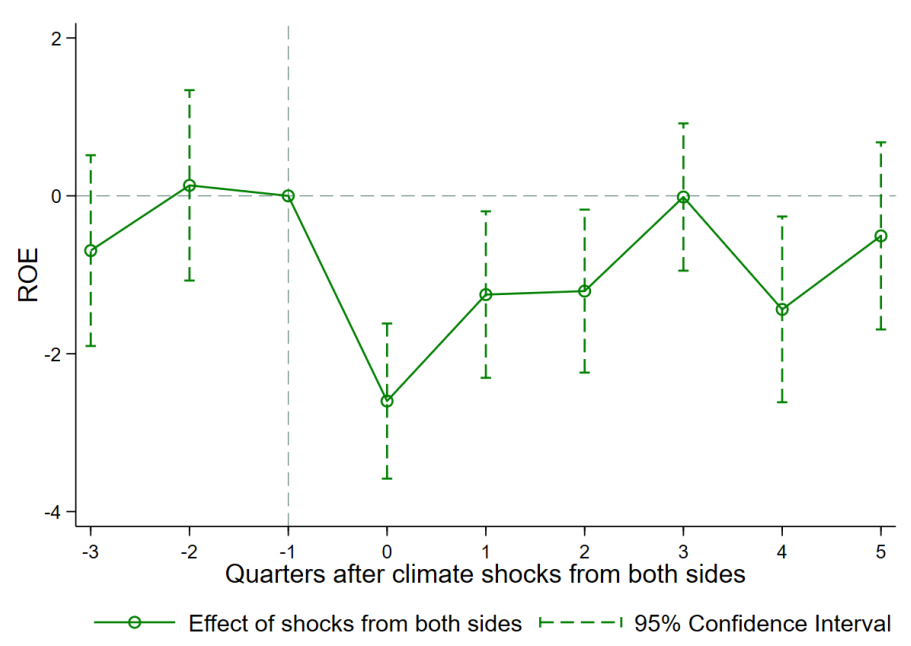


Figure 10 The benefits of asset-side climate exposure diminish as liability exposure rises

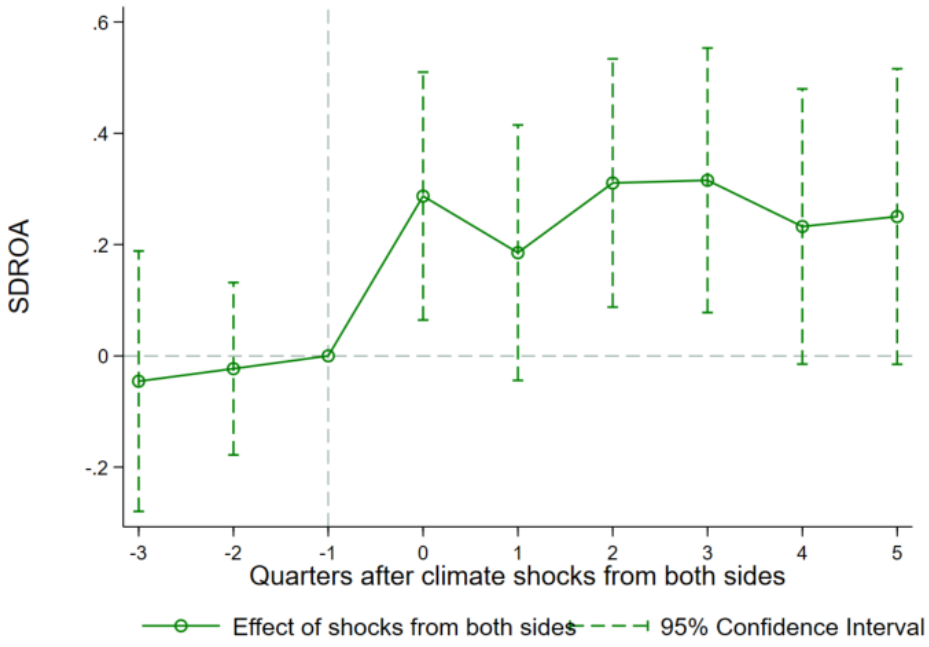
This diagram illustrates how the relationship between asset exposure and profitability changes as the liability exposure increases.


.5
0
-.5
-1
-1.5
ROA
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shocks from both sides
Effect of shocks from both sides
95% Confidence Interval

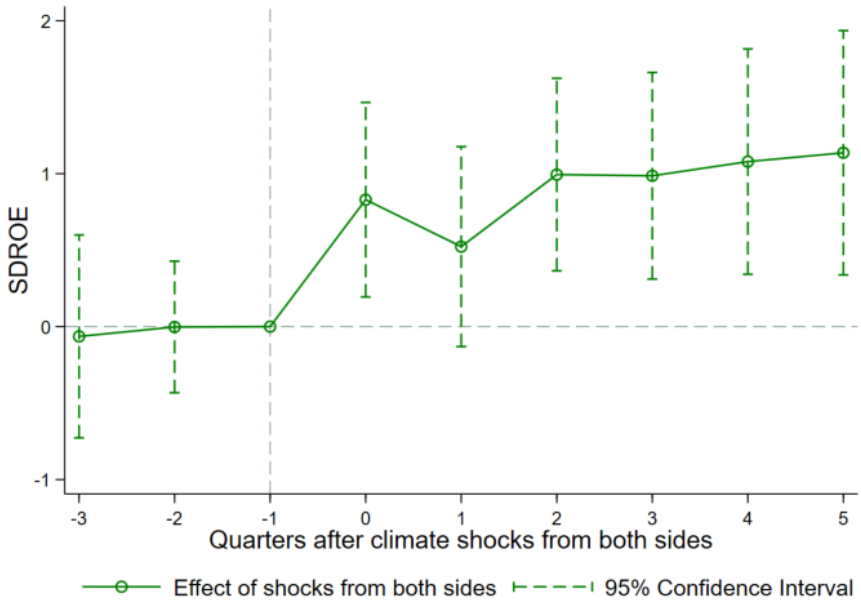
(a)


2
0
-2
-4
ROE
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shocks from both sides
Effect of shocks from both sides
95% Confidence Interval

(b)



(c)



(d)

Figure 11 The performance after climate shocks on both asset and liability sides

Note: The figure shows that firms exposed to both types of shocks exhibit lower profitability and higher volatility compared to those exposed to shocks on only one side. This figure excludes firms that have experienced neither liability-side shocks nor asset-side shocks in the past two years. That is, the sample shown in this figure includes only firms that have experienced at least one type of shock during that period.

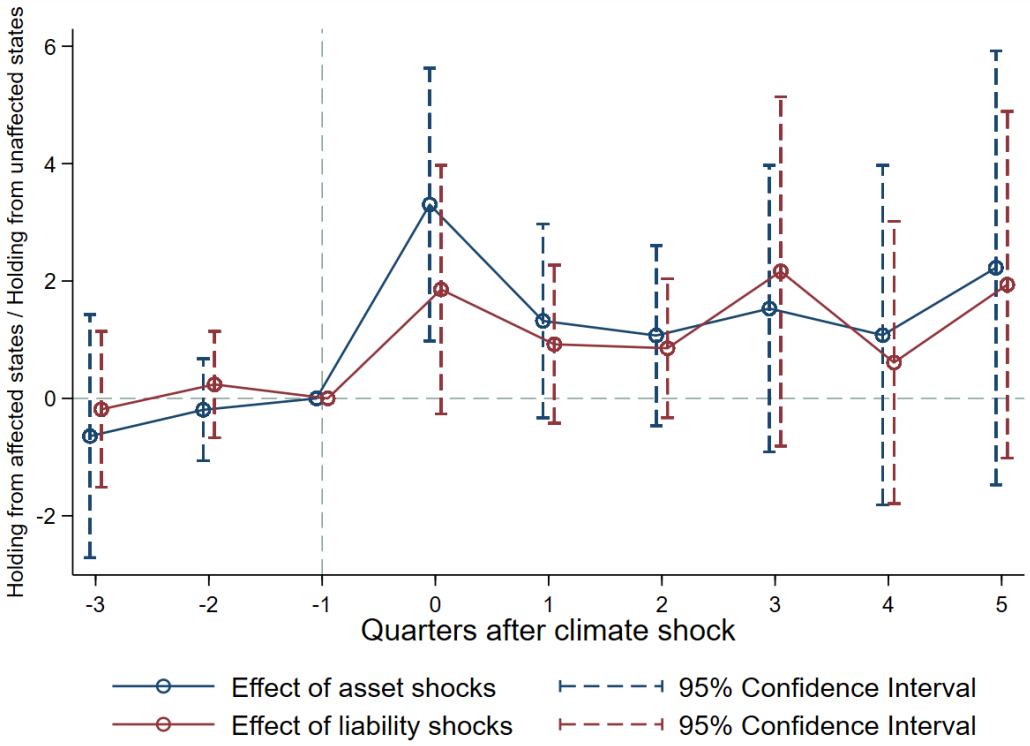


Figure 12 Higher municipal bond share in catastrophe-prone states after asset shocks

Notes: This figure shows that after asset-side climate shocks, insurers increase the share of municipal bond holdings allocated to catastrophe-affected states relative to unaffected ones. In contrast, the increasing effect of liability-side shocks is relatively weak. The y-axis is the par value of holdings from climate event–affected states divided by the par value of holdings from climate-unaffected states.

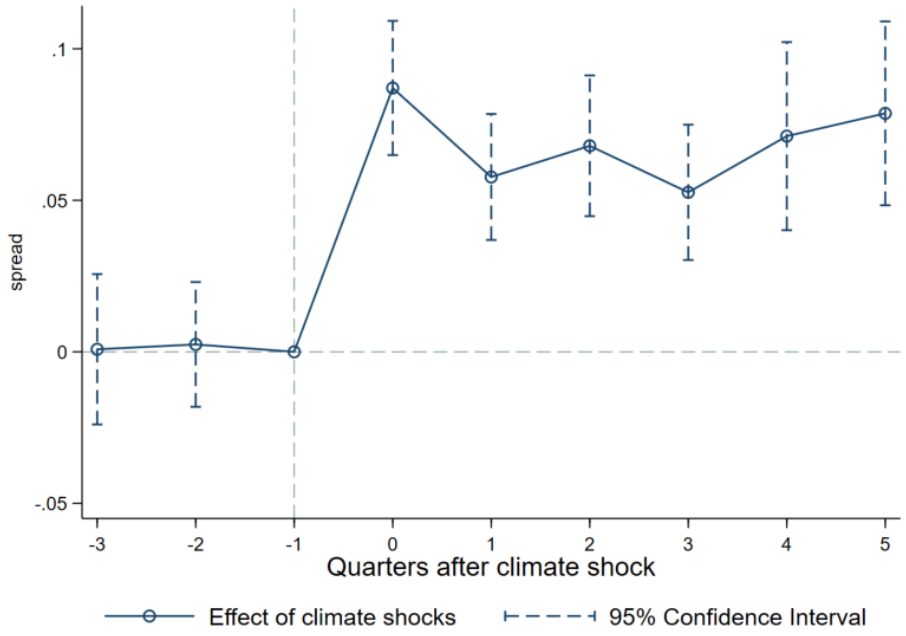


Figure 13 Higher spreads of municipal bonds after climate shocks

Notes: This figure shows that the spread of municipal bonds will increase after climate shocks, which is consistent with Painter (2020) and Goldsmith-Pinkham et al. (2023).

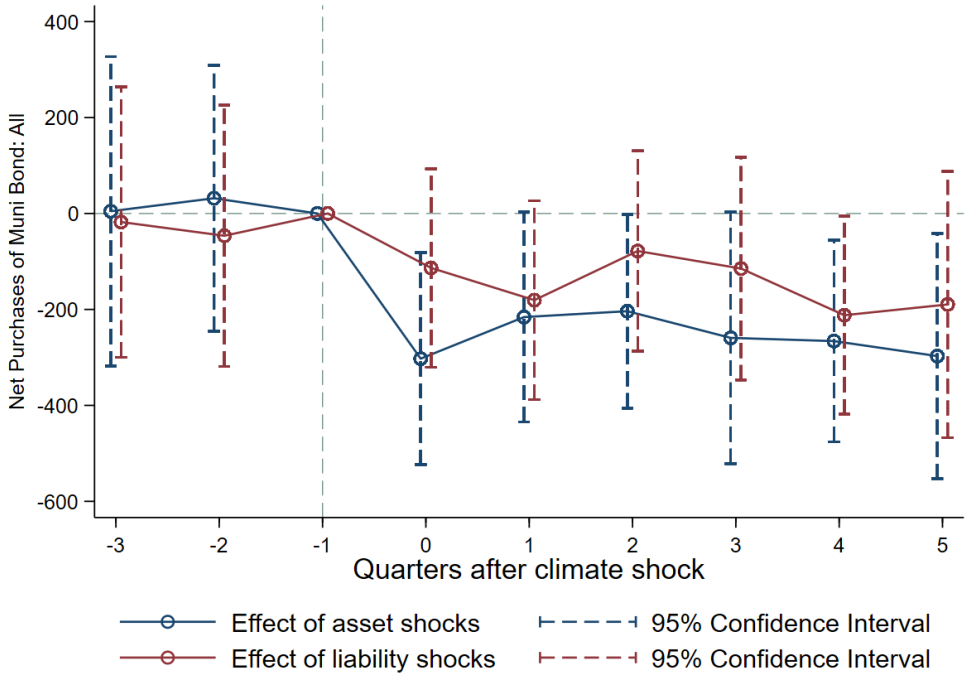


Figure 14 Selling behavior of insurers following climate shocks

Notes: This figure shows that insurers net sell municipal bonds after climate shocks from either side. The y-axis is the total net purchase of municipal bonds in each quarter.

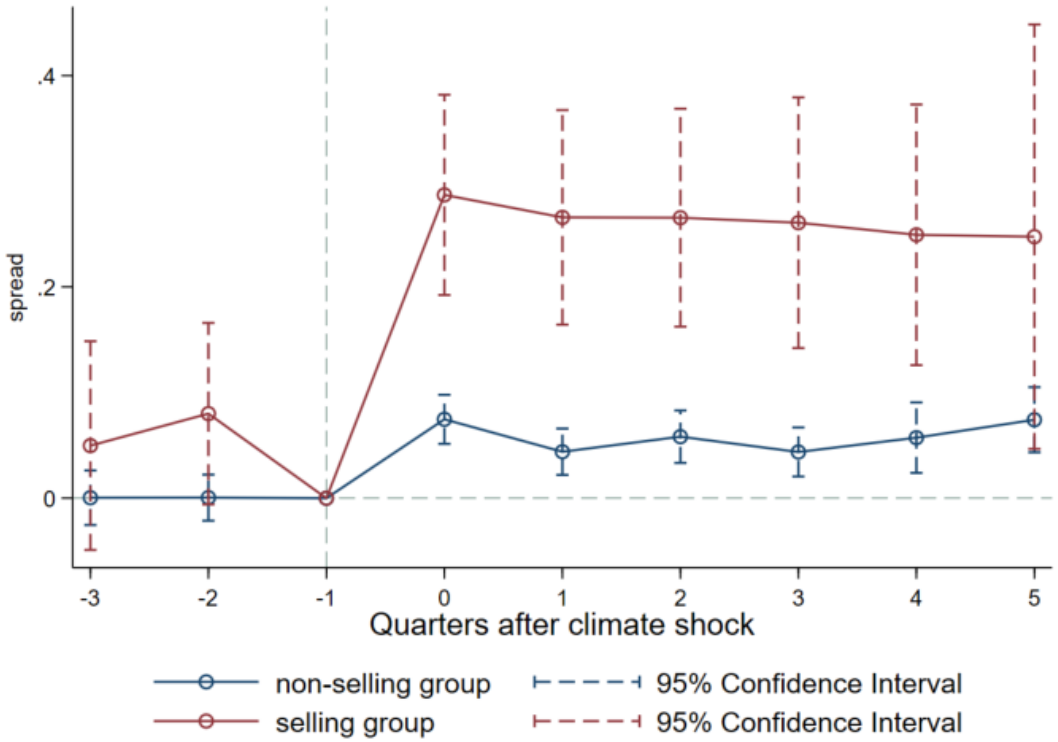


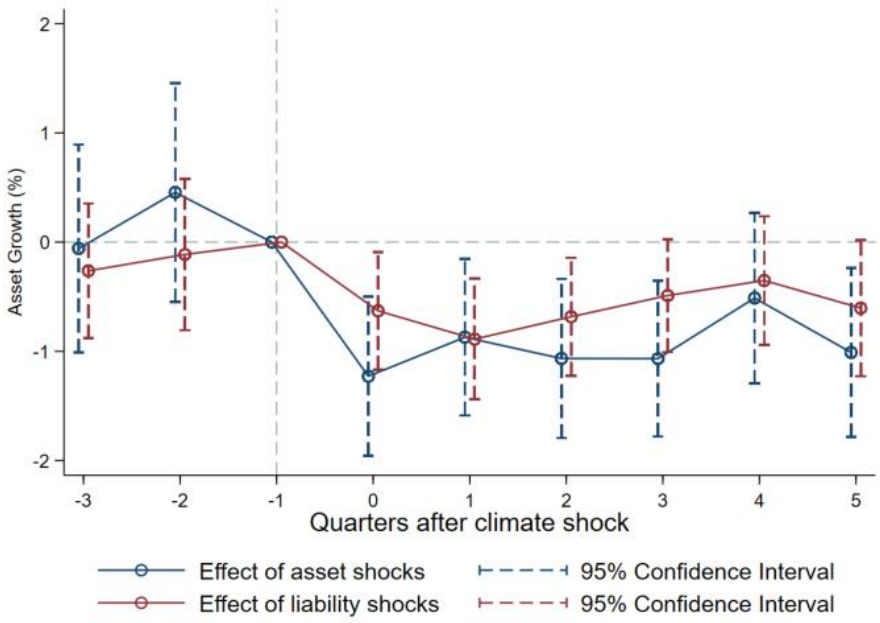
Figure 15 Differential effects of climate shocks on bond spreads: Sold vs. unsold bonds

Note: This figure shows that for bonds sold by insurers who experience a liability climate shock, the increase in spreads following a climate disaster in the issuing state is larger compared to bonds that were not sold. The figure is based on estimates from the following equation at the bond–quarter level:

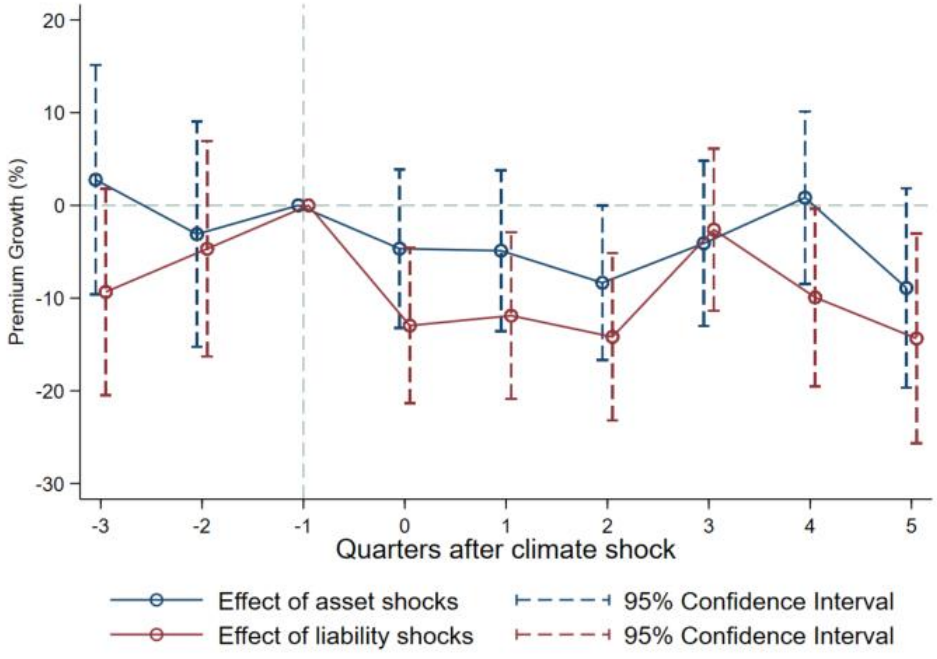
$$spread_{j,t} = \beta + \sum_{\tau=-3,\tau\neq-1}^{5} \beta_\tau^1 \boldsymbol{I}(t - t_{CLShock} = \tau) +$$

$$\sum_{\tau=-3,\tau\neq-1}^{5} \beta_\tau^2 \boldsymbol{I}(t - t_{CLShock} = \tau) \times soldafterliabshock_{j,t} + \gamma \boldsymbol{X}_{jt} + \alpha_j + \alpha_t + \varepsilon_{it}$$

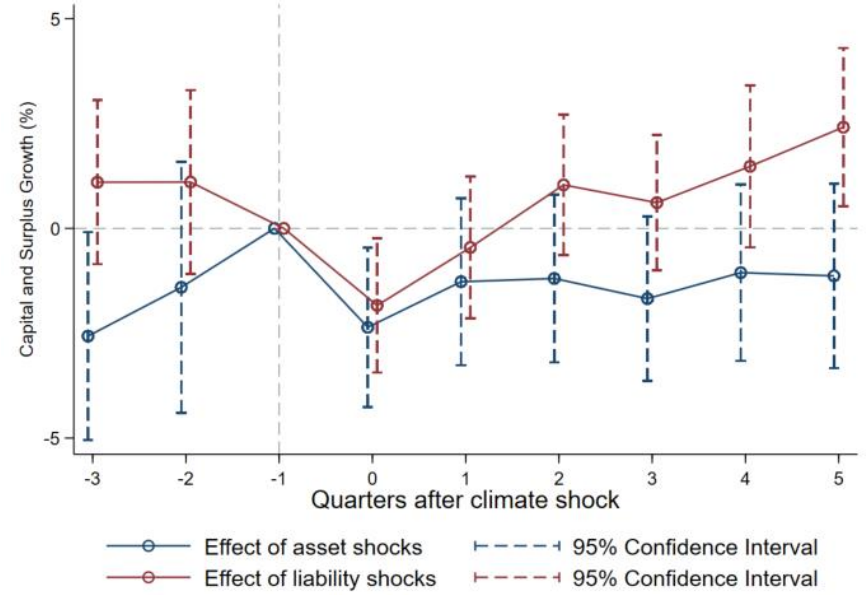
Where the $spread_{j,t}$ represents the spread of bond j in quarter t. And $soldafterliabshock_{j,t}$=1 meaning the bond j was sold in quarter *t* by an insurer affected by a liability-side climate shock. The blue line illustrates the coefficients of β_τ^1 and their confidence intervals for bonds that were not sold. The red line shows the corresponding coefficients for bonds sold after liability shocks, computed as $\beta_\tau^{sold} = \beta_\tau^1 + \beta_\tau^2$. The corresponding standard error is derived as $SE(\beta_\tau^{sold}) = \sqrt{Var(\beta_\tau^1) + Var(\beta_\tau^2) + 2Cov(\beta_\tau^1, \beta_\tau^2)}$. The 95% confidence intervals are then constructed based on these standard errors.


Asset Growth (%)
2
1
0
-1
-2
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shock
Effect of asset shocks
95% Confidence Interval
Effect of liability shocks
95% Confidence Interval

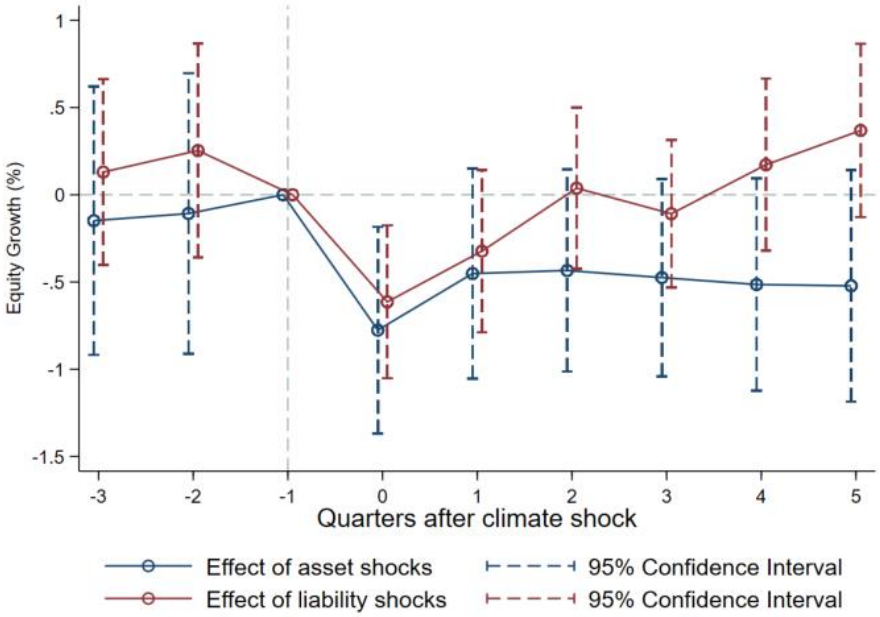
(a)


Premium Growth (%)
20
10
0
-10
-20
-30
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shock
Effect of asset shocks
95% Confidence Interval
Effect of liability shocks
95% Confidence Interval

(b)



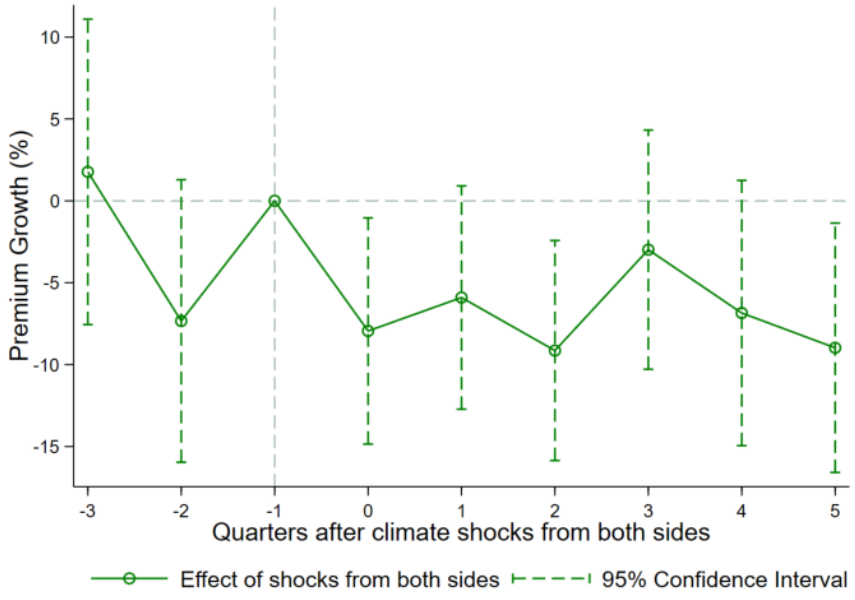
(c)



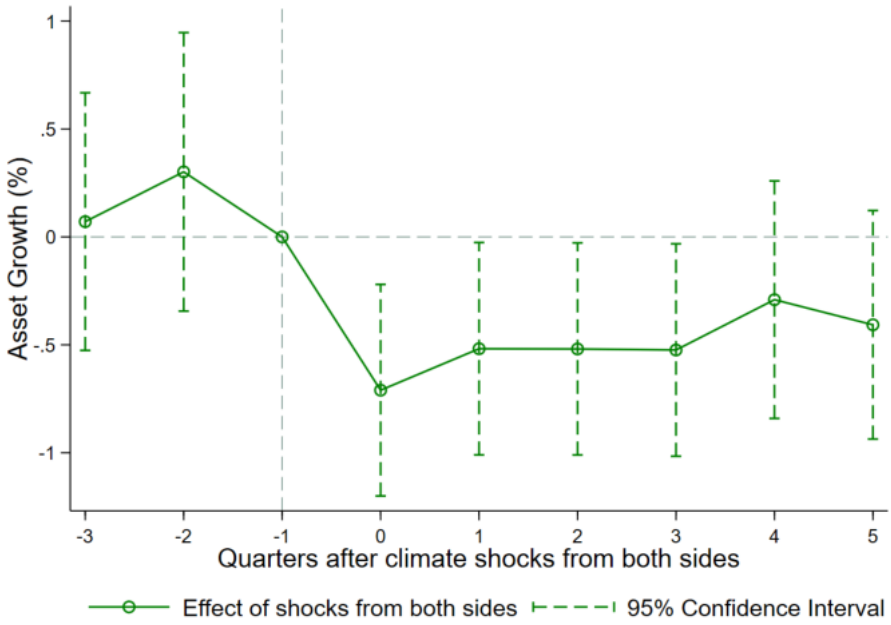
(d)

Figure 16 The performance after asset- and liability-side climate shocks

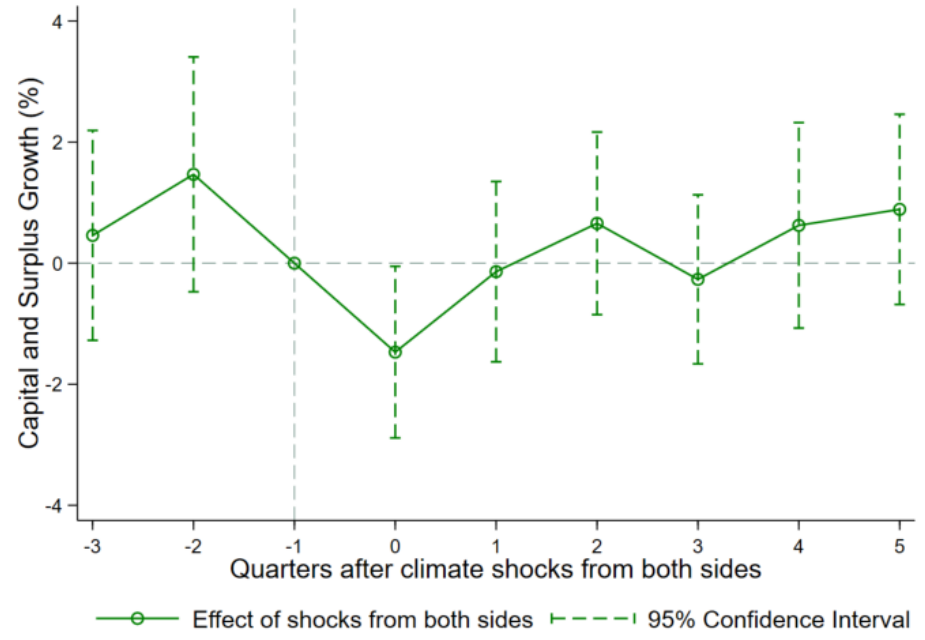
Notes: This figure presents the event study results estimated using equation (2). In Panels (a)- (d), the y-axes are asset growth, premium growth, capital and surplus growth, and equity growth.


Premium Growth (%)
10
5
0
-5
-10
-15
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shocks from both sides
Effect of shocks from both sides
95% Confidence Interval

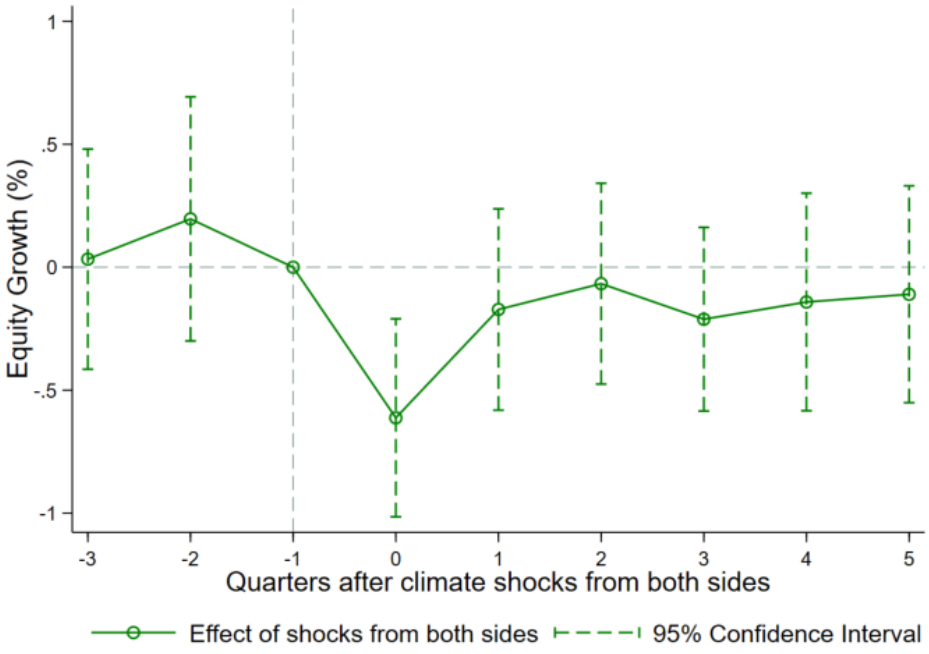
(a)


Asset Growth (%)
1
.5
0
-.5
-1
-3
-2
-1
0
1
2
3
4
5
Quarters after climate shocks from both sides
Effect of shocks from both sides
95% Confidence Interval

(b)



(c)



(d)

Figure 17 The performance after climate shocks on both asset and liability sides

Note: Similar to Figure 11, this figure excludes firms that have experienced neither liability-side shocks nor asset-side shocks in the past two years. That is, the sample shown in this figure includes only firms that have experienced at least one type of shock during that period.

Appendix

Table A1 Robustness test: using 3-year relative sea level to generate asset and liability exposures

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROA
LiabCLR_3Y	-5.021**	-11.78*	5.131**	11.49
	(2.418)	(6.270)	(2.324)	(7.221)
LiabCLR_3Y^2	25.10	21.52	4.780	29.04
	(33.41)	(89.10)	(30.76)	(95.96)
AssetCLR_3Y	3.319	11.43*	5.058*	8.405
	(2.490)	(6.915)	(2.615)	(7.572)
AssetCLR_3Y^2	-74.30**	-236.0**	-66.54*	-134.3
	(36.13)	(101.1)	(39.62)	(117.4)
Observations	58,081	58,041	58,051	58,030
R-squared	0.233	0.198	0.491	0.528
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table shows how an insurer's asset and liability exposure to climate risk influences firm performance (ROA, ROE, SDROA, SDROA). This table is a robustness test of Table 3.
(2) We find that insurers' liability exposure to climate risk linearly reduces insurers' profitability. Asset exposure to climate risk increases insurer profitability up to about the 80th percentile, beyond which its effect turns negative.
(3) We use the linear and quadratic terms of asset and liability exposures as the main independent variables. The negative and significant coefficients of the quadratic terms of asset exposures suggest that the asset exposure to climate risk exhibits an inverted U-shape with firm profitability. The negative and significant coefficients of linear terms of liability exposures as well as the insignificant coefficients of quadratic terms of liability exposures suggest that the liability exposure to climate risk linearly reduces firm profitability.
(4) To address the issue of multicollinearity, we decentralize *LiabCLR*, *LiabClimateRisk_3y*, *AssetCLR*, *AssetCLR_3y*, *TotalCLR* and *TotalCLR_3y*.
(5) All standard errors are clustered at the firm level.
(6) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A2 Robustness test: Impact of asset and liability exposures to climate risk on firm performance

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR_10_20	-0.172	-0.528	0.588***	1.522**
	(0.252)	(0.639)	(0.215)	(0.640)
LiabCLR_20_30	-0.214	-0.666	0.499**	1.375*
	(0.271)	(0.683)	(0.235)	(0.713)
LiabCLR_30_40	-0.227	-0.481	0.559**	1.508**
	(0.289)	(0.717)	(0.252)	(0.762)
LiabCLR_40_50	-0.228	-0.408	0.740***	1.710**
	(0.299)	(0.748)	(0.258)	(0.785)
LiabCLR_50_60	-0.296	-0.597	0.886***	2.118**
	(0.312)	(0.777)	(0.275)	(0.831)
LiabCLR_60_70	-0.390	-0.895	0.891***	2.198**
	(0.317)	(0.782)	(0.283)	(0.860)
LiabCLR_70_80	-0.370	-0.945	1.155***	2.968***
	(0.335)	(0.822)	(0.293)	(0.890)
LiabCLR_80_90	-0.776**	-2.092**	1.016***	2.466***
	(0.344)	(0.855)	(0.303)	(0.920)
LiabCLR_90_100	-0.773**	-2.066**	1.442***	3.691***
	(0.391)	(0.994)	(0.344)	(1.072)
AssetCLR_0_10	-0.505***	-1.538***	-0.201	-0.283
	(0.166)	(0.454)	(0.163)	(0.485)
AssetCLR_10_20	-0.256	-0.964*	-0.171	0.148
	(0.205)	(0.538)	(0.192)	(0.569)
AssetCLR_20_30	-0.116	-0.590	-0.211	-0.0563
	(0.149)	(0.406)	(0.156)	(0.439)
AssetCLR_30_40	-0.0601	-0.450	-0.208	-0.131
	(0.138)	(0.366)	(0.141)	(0.407)
AssetCLR_40_50	0.0261	-0.189	-0.192	-0.264
	(0.118)	(0.315)	(0.130)	(0.384)
AssetCLR_50_60	-0.0235	-0.358	-0.107	-0.0433
	(0.119)	(0.312)	(0.128)	(0.380)
AssetCLR_60_70	-0.191*	-0.602**	-0.0683	0.0563
	(0.106)	(0.291)	(0.101)	(0.308)
AssetCLR_80_90	-0.204*	-0.568*	0.0541	0.101
	(0.114)	(0.312)	(0.118)	(0.323)
AssetCLR_90_100	-0.376**	-1.291***	0.0338	0.209
	(0.153)	(0.419)	(0.154)	(0.481)
Observations	58,081	58,041	58,051	58,030
R-squared	0.234	0.199	0.492	0.529
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table shows how an insurer's asset and liability exposure to climate risk influences firm performance (ROA, ROE, SDROA, SDROE). This table is a robustness test of Table 3, confirming the result that insurers' liability exposure to climate risk linearly reduces insurers' profitability and increases insurers' volatility, while asset exposure to climate risk increases insurer profitability up to about the 80th percentile, beyond which its effect turns negative.

(2) For asset and liability exposures, we use decile dummies in the regression. We omit the 7th decile dummy of asset exposure and the 1st decile dummy of liability exposure as the reference group in the regression. The significant and negative coefficients of the dummies of asset exposures further confirm the inverted U-shape relationship between asset exposures and profitability. And the negative coefficients of the dummies of liability exposures further confirm the linearly negative relationship between liability exposures and profitability.

(3) All standard errors are clustered at the firm level.

(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A3 Robustness test: Impact of asset and liability exposures to climate risk on firm profitability

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR_z	-0.555***	-1.463***	0.544***	1.240**
	(0.169)	(0.446)	(0.156)	(0.482)
AssetCLR_z	0.240	0.842*	0.311*	0.474
	(0.160)	(0.448)	(0.162)	(0.479)
AssetCLR_z^2	-0.305**	-1.112***	-0.208	-0.317
	(0.149)	(0.418)	(0.154)	(0.472)
Observations	58,081	58,041	58,051	58,030
R-squared	0.233	0.198	0.491	0.529
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table shows how an insurer's asset and liability exposure to climate risk influences firm performance (ROA, ROE, SDROA, SDROE). This table confirms the result that insurers' liability exposure to climate risk linearly reduces insurers' profitability, while asset exposure to climate risk increases insurer profitability up to about the 80th percentile, beyond which its effect turns negative.

(2) For asset and liability exposures, we substitute the original measures with the Z-score measures as below:

$$AssetCLR_z_{i,t} = \sum_j RSL_z_{j,t} \times \left(\frac{holding_{i,j,t}}{\sum_j holding_{i,j,t}}\right)$$

$$LiabCLR_z_{i,t} = \sum_s RSL_z_{s,t} \times \left(\frac{DPW_{i,s,t}}{\sum_s DPW_{i,s,t}}\right)$$

Where RSL_z is the Z-score of the original sea-level measures defined as the following formula. $Historical_j$ is the mean value of the quarterly relatively sea-level in county j over the past 30 years, i.e. from 1980 through 2009, and SD_j is the corresponding standard deviation. For state-level relative sea-level z-scores, we simply replace j with s.

$$RSL_z_{j,t} = \frac{RSL_{j,t} - Historical_j}{SD_j}$$

(3) All standard errors are clustered at the firm level.

(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A4 Impact of asset and liability exposures to climate risk on firm profitability

VARIABLES	(1) ROA	(2) ROA	(3) ROE	(4) ROE	(5) SDROA	(6) SDROA	(7) SDROE	(8) SDROE
TotalCLR	-11.32***	-9.336***	-31.76***	-24.23***	8.706***	9.821***	24.62***	24.78***
	(3.073)	(2.929)	(8.288)	(7.567)	(2.707)	(2.681)	(8.618)	(8.331)
$TotalCLR^2$		-89.12*		-337.3**		-49.89		-7.339
		(52.11)		(150.0)		(42.85)		(142.2)
Observations	58,081	58,081	58,041	58,041	58,051	58,051	58,030	58,030
R-squared	0.234	0.234	0.199	0.200	0.492	0.492	0.530	0.530
firm FE	Y	Y	Y	Y	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y	Y	Y

(1) This table is a robustness test of Table 3, Panel B.

(2) The total climate risk is redefined as:

$$TotalCLR_{i,t} = LiabCLR_{i,t} \times \frac{DPW_{i,t}}{DPW_{i,t} + holding_{i,t}} + AssetCLR_{i,t} \times \frac{holding_{i,t}}{DPW_{i,t} + holding_{i,t}}$$

where $DPW_{i,t}$epresents insurer i's total direct premiums written in quarter t and $\text{holding}_{i,t}$ denotes insurer i's total holdings of municipal bonds in quarter t.

(3) In columns (1)-(4), we show the quadratic impact of total climate exposures on insurers' profitability (ROA, ROE). The results reveal a nonlinear, concave relationship over the five-year window: the marginal impact of exposure becomes increasingly adverse at higher total risk levels.

(4) In columns (5)-(8), the results suggest that the aggregated climate exposures linearly increase the firm risk (SDROA, SDROE).

(5) To address the issue of multicollinearity, we decentralize *LiabCLR*, *AssetCLR*, *TotalCLR*.

(6) All standard errors are clustered at the firm level.

(7) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A5 Additive effects in the subsamples where either asset or liability exposures are below the median level

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
Panel A: liability exposure≤median, asset exposure≤median				
LiabCLR	-12.69	-16.05	14.33	21.69
	(9.656)	(27.37)	(9.129)	(27.96)
AssetCLR	21.58	41.90	15.54	19.77
	(13.27)	(39.18)	(12.36)	(35.87)
$AssetCLR^2$	-2,286	-3,464	-2,350	-6,484
	(1,856)	(5,415)	(1,820)	(5,269)
LiabCLR×AssetCLR	209.4	566.4	184.6	326.0
	(618.5)	(1,769)	(476.9)	(1,399)
LiabCLR×$AssetCLR^2$	103,064	113,637	-90,754	-304,000
	(86,500)	(254,253)	(83,135)	(238,841)
Observations	18,044	18,038	18,037	18,037
R-squared	0.307	0.274	0.572	0.605
Panel B: liability exposure>median, asset exposure≤median				
LiabCLR	6.703	24.63	20.25*	37.59
	(12.34)	(31.69)	(11.16)	(32.68)
AssetCLR	15.05	36.88	-15.02	-29.01
	(19.90)	(51.73)	(18.56)	(54.98)
$AssetCLR^2$	-378.1	-3,435	268.9	-925.3
	(2,635)	(6,998)	(2,612)	(7,829)
LiabCLR×AssetCLR	-7.351	-620.6	872.0	972.9
	(726.4)	(1,951)	(644.1)	(2,009)
LiabCLR×$AssetCLR^2$	25,726	-56,475	-72,532	-107,513
	(128,756)	(327,150)	(105,969)	(279,679)
Observations	10,821	10,820	10,814	10,814
R-squared	0.277	0.249	0.630	0.647
Panel C: liability exposure≤median, asset exposure>median				
LiabCLR	17.58*	44.83*	11.77	40.10
	(10.00)	(27.13)	(7.966)	(25.90)
AssetCLR	7.023	15.40	-2.921	-15.83
	(6.940)	(18.60)	(6.640)	(19.89)
$AssetCLR^2$	-63.49	-95.22	199.1	487.7
	(146.3)	(366.1)	(140.1)	(405.9)
LiabCLR×AssetCLR	144.5	147.5	327.2	1,704*
	(304.3)	(782.7)	(307.1)	(982.8)
LiabCLR×$AssetCLR^2$	-8,461	-21,961	5,512	7,734
	(5,643)	(14,178)	(5,719)	(15,542)
Observations	17.58*	44.83*	11.77	40.10
R-squared	(10.00)	(27.13)	(7.966)	(25.90)
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) This table reports how the asset and liability exposure to climate risk interact to influence firm performance when either the asset or liability exposures are not more than their respective median levels.
(2) The results suggest that there are little additive effects between these two exposures.
(3) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(4) All standard errors are clustered at the firm level.
(5) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A6 Geographical diversification cannot mitigate the negative effect of liability-side climate risk

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR	-9.940***	-24.83***	9.323***	25.22***
	(3.169)	(8.693)	(2.916)	(9.345)
LiabCLR×(1-geoh)	-3.327	0.0922	-5.111	-1.531
	(4.935)	(12.83)	(4.615)	(13.61)
AssetCLR	3.750	12.86	4.612	6.633
	(2.846)	(7.866)	(2.861)	(8.409)
$AssetCLR^2$	-97.24**	-321.8**	-42.65	-59.94
	(45.63)	(126.6)	(48.93)	(145.2)
R-squared	58,081	58,041	58,051	58,030
Observations	0.234	0.199	0.492	0.530
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

(1) We don't find evidence from this table that insurers' geographical diversification can mitigate the impact of liability exposures.
(2) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(3) All standard errors are clustered at the firm level.
(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

Table A7 Geographical diversification across coastal states and non-coastal states

VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR	-7.552**	-18.46**	8.582***	19.31**
	(3.070)	(8.059)	(2.986)	(9.227)
LiabCLR× (1-geoh_coastal_non-coastal)	18.47[a]	76.35**	-19.49*	-52.16[b]
	(11.48)	(31.31)	(10.95)	(31.75)
AssetCLR	3.862	12.98*	4.695	6.519
	(2.853)	(7.859)	(2.865)	(8.436)
$AssetCLR^2$	-98.82**	-321.4**	-45.02	-59.38
	(45.75)	(126.5)	(48.91)	(145.1)
R-squared	58,081	58,041	58,051	58,030
Observations	0.234	0.200	0.492	0.531
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

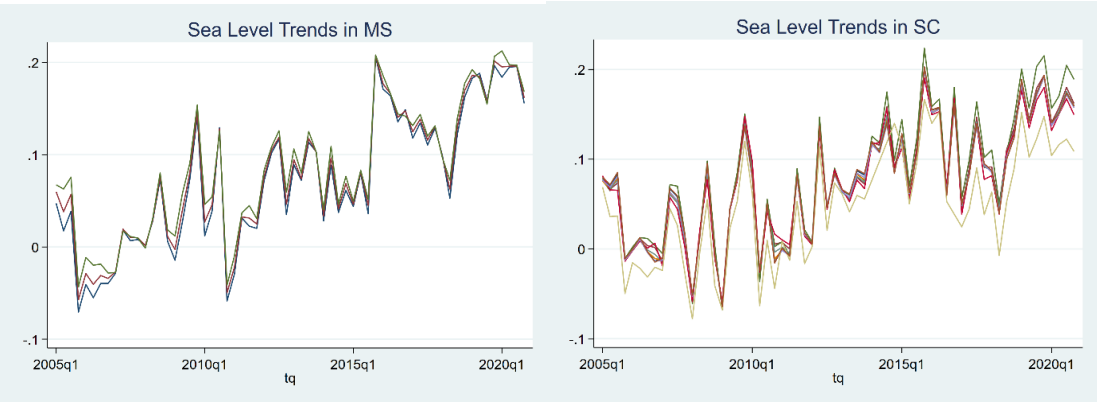
Note: [a] p-value=0.108; [b] p-value=0.101

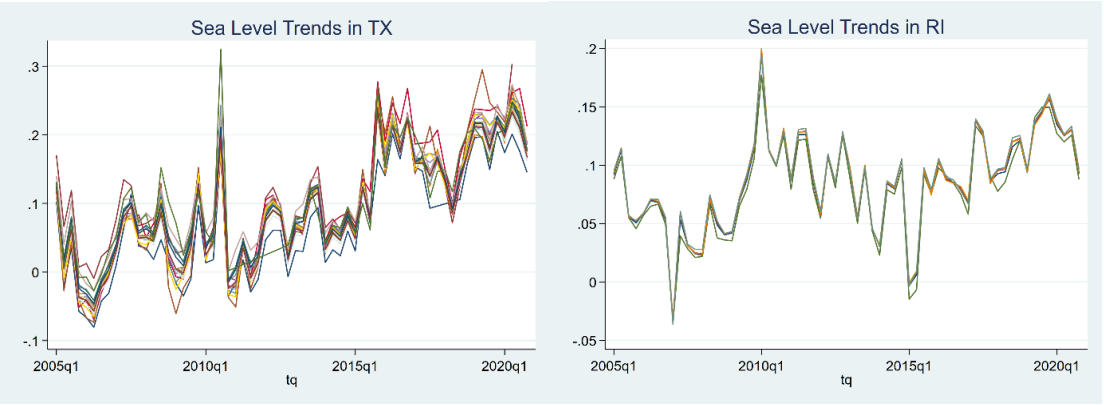
(1) This table shows that insurers' geographical diversification between coastal and non-coastal states can mitigate the impact of liability exposures.
(2) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(3) All standard errors are clustered at the firm level.
(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

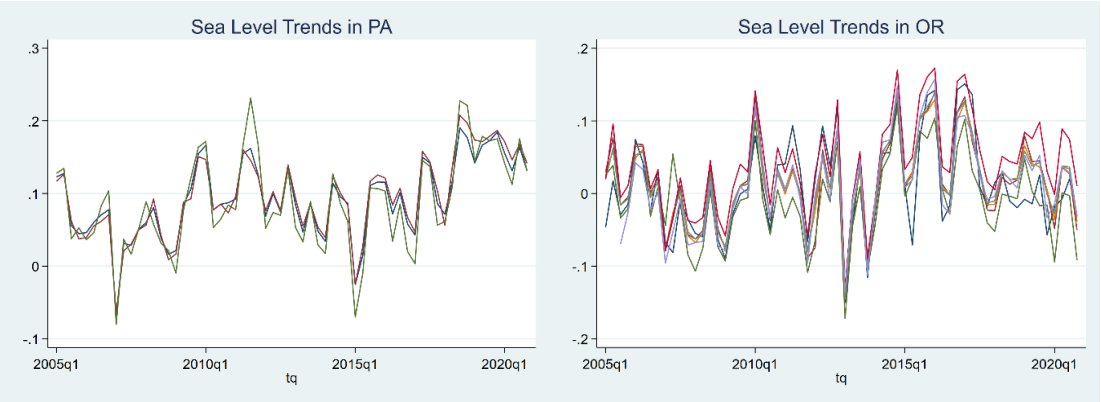
Table A8 Geographical diversification across U.S. market and non-U.S. market

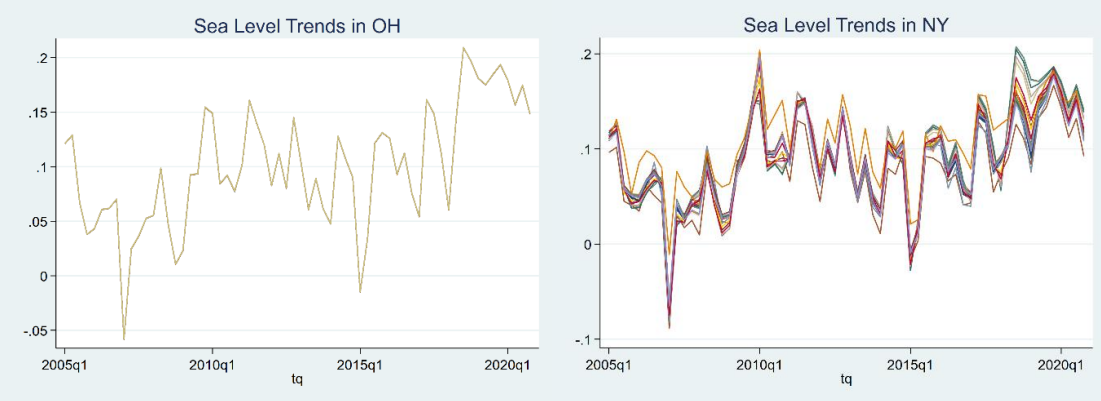
VARIABLES	(1) ROA	(2) ROE	(3) SDROA	(4) SDROE
LiabCLR	-9.181***	-24.96***	10.51***	25.52***
	(3.179)	(8.511)	(2.907)	(9.168)
LiabCLR× (1-geoh_us_non-us)	24.82	61.98	-191.3**	-562.9***
	(67.81)	(146.8)	(79.31)	(195.8)
AssetCLR	3.884	13.03*	4.918*	7.135
	(2.858)	(7.870)	(2.856)	(8.422)
$AssetCLR^2$	-98.94**	-322.0**	-46.15	-63.46
	(45.77)	(126.6)	(48.77)	(144.9)
R-squared	58,081	58,041	58,051	58,030
Observations	0.234	0.199	0.492	0.531
firm FE	Y	Y	Y	Y
quarter FE	Y	Y	Y	Y
Control variables	Y	Y	Y	Y

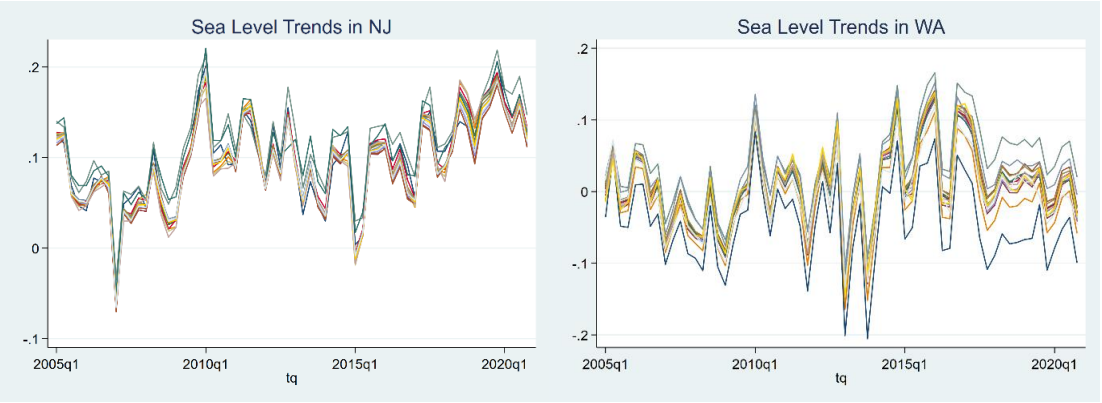
(1) This table shows that insurers' geographical diversification between U.S. market and non-U.S. market can mitigate the impact of liability exposures on firm volatility.
(2) In the interaction results, to address the issue of multicollinearity, we decentralize all the asset and liability exposure variables.
(3) All standard errors are clustered at the firm level.
(4) ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

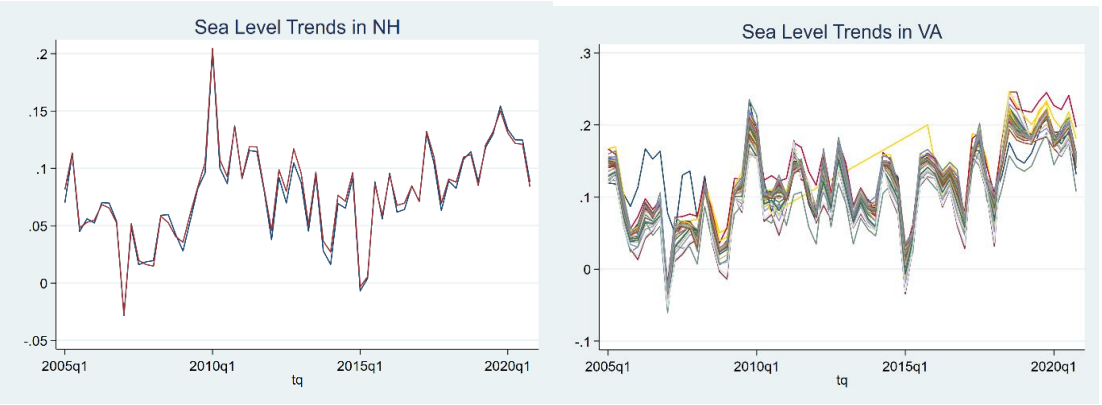

Sea Level Trends in MS
.2
.1
0
-.1
2005q1
2010q1
2015q1
2020q1
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Sea Level Trends in SC
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2010q1
2015q1
2020q1
tq

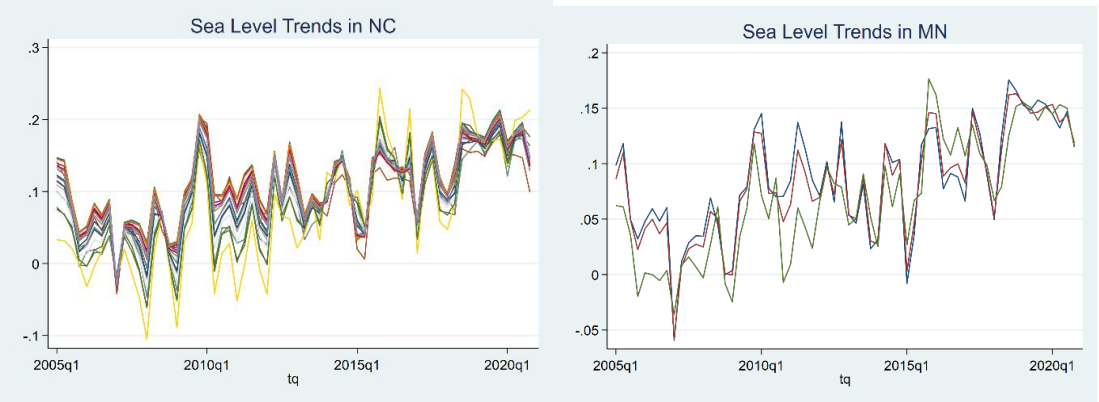

Sea Level Trends in TX
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2005q1
2010q1
2015q1
2020q1
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Sea Level Trends in RI
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-.05
2005q1
2010q1
2015q1
2020q1
tq

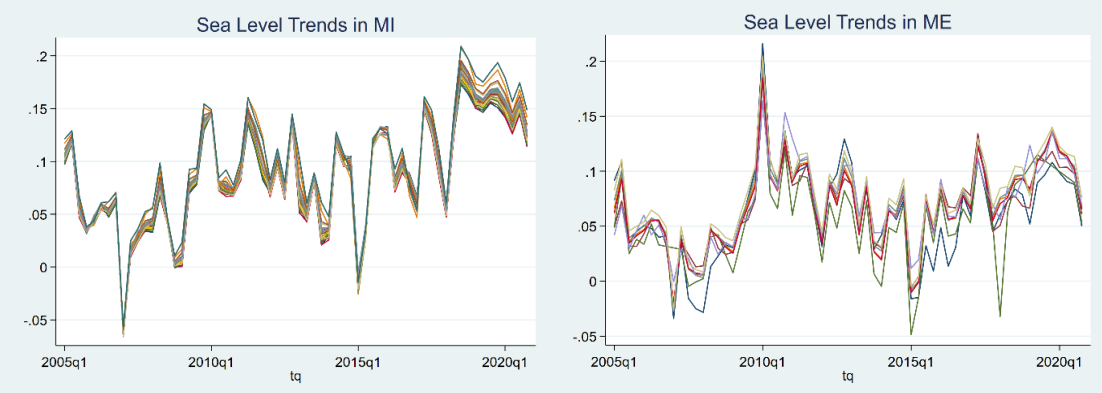

Sea Level Trends in PA
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2005q1
2010q1
2015q1
2020q1
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Sea Level Trends in OR
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2005q1
2010q1
2015q1
2020q1
tq

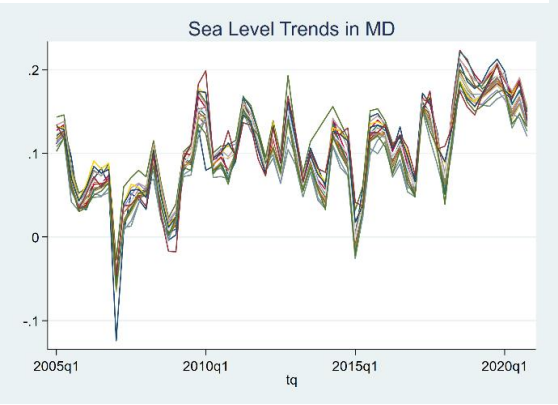

Sea Level Trends in OH
.2
.15
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.05
0
-.05
2005q1
2010q1
2015q1
2020q1
tq
Sea Level Trends in NY
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2010q1
2015q1
2020q1
tq

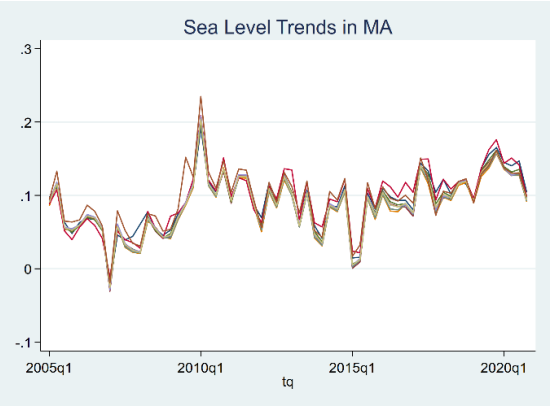

Sea Level Trends in NJ
.2
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2010q1
2015q1
2020q1
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Sea Level Trends in WA
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2010q1
2015q1
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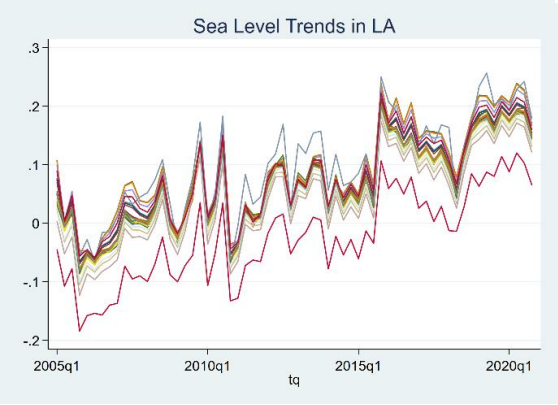

Sea Level Trends in NH
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Sea Level Trends in VA
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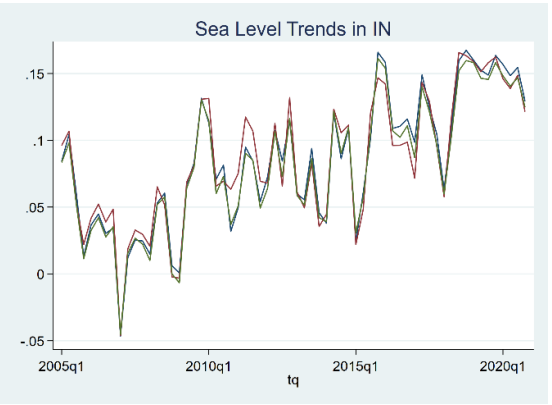

Sea Level Trends in NC
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2005q1
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2015q1
2020q1
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Sea Level Trends in MN
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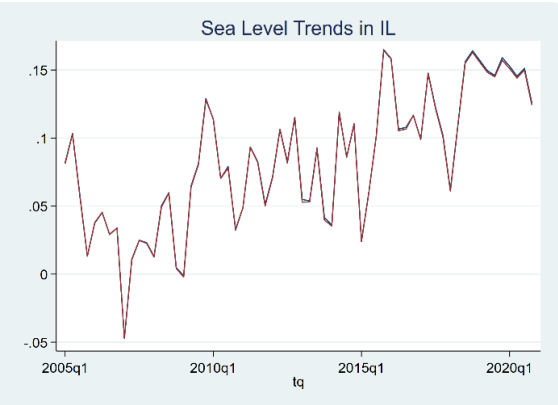

Sea Level Trends in MI
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Sea Level Trends in ME
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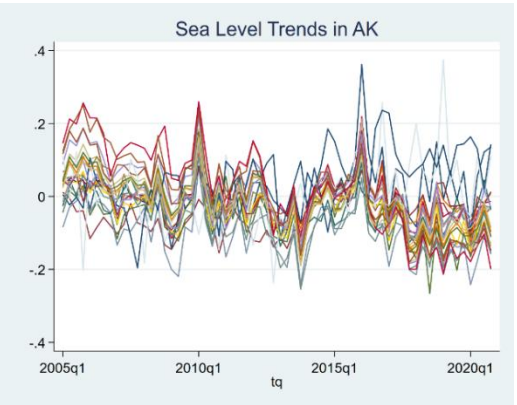

Sea Level Trends in MD
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2010q1
2015q1
2020q1
tq

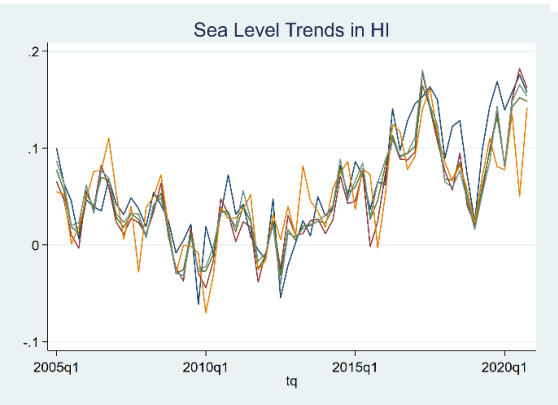

Sea Level Trends in MA
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2010q1
2015q1
2020q1
tq

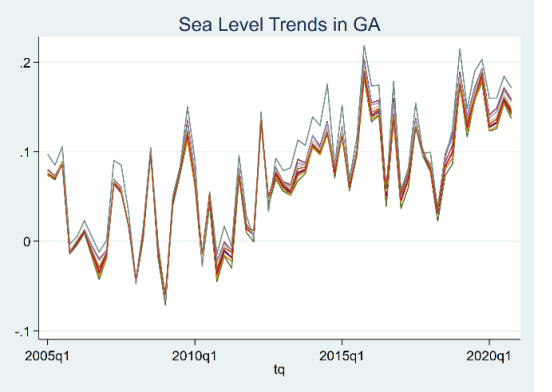

Sea Level Trends in LA
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2005q1
2010q1
2015q1
2020q1
tq


Sea Level Trends in IN
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.05
0
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2005q1
2010q1
2015q1
2020q1
tq


Sea Level Trends in IL
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2005q1
2010q1
2015q1
2020q1
tq


Sea Level Trends in AK
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2005q1
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2015q1
2020q1
tq


Sea Level Trends in HI
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2005q1
2010q1
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Sea Level Trends in GA
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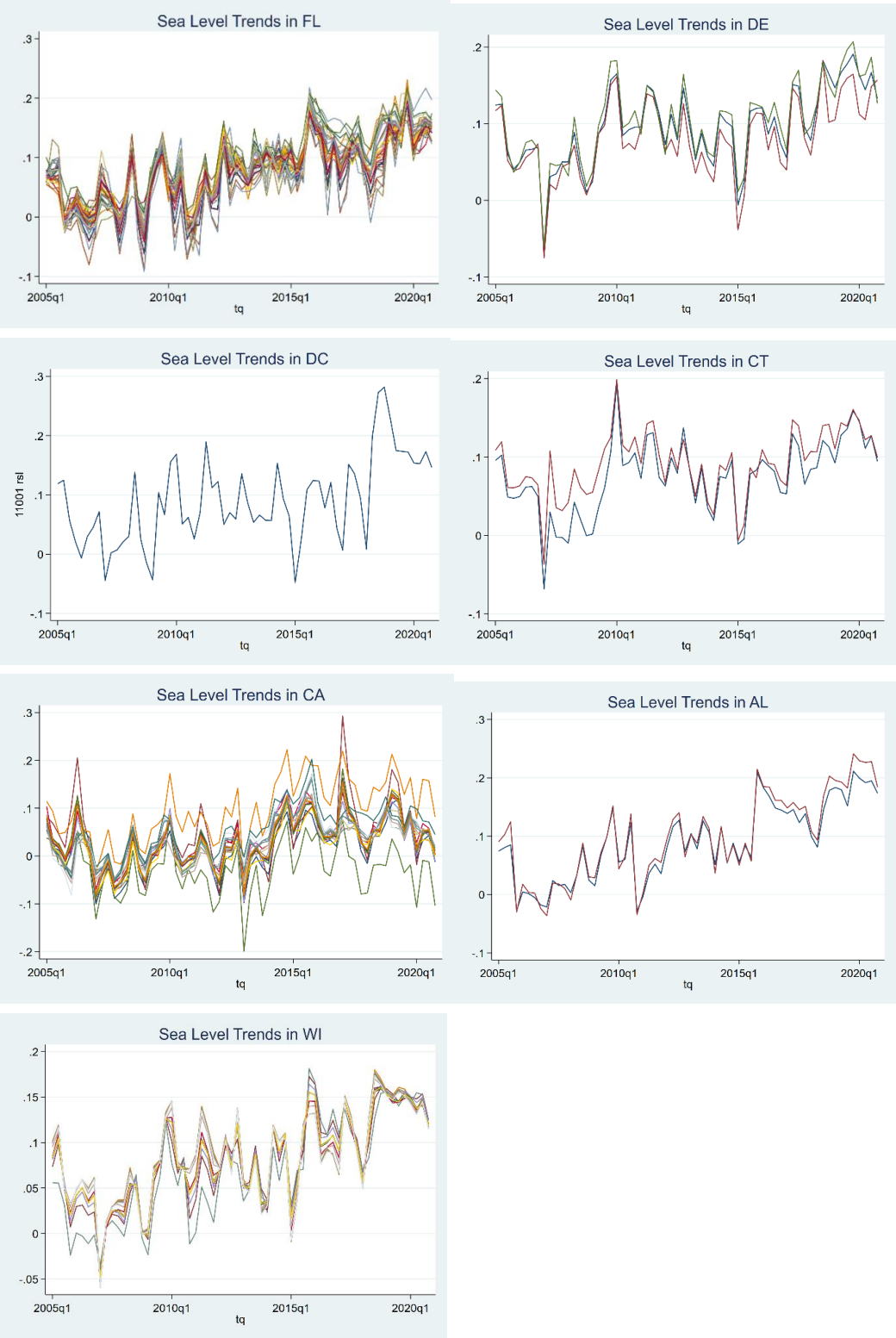


Figure A1 County-level relative sea-level in each state

These figures present relative sea-level trends for 31 coastal states, with each figure plotting all coastal counties (as defined by NOAA) within a state. They show that (i) sea levels have generally risen in recent years, (ii) the patterns of increase vary across states, and (iii) within each state, coastal counties exhibit highly correlated trends.