Assessing Insurance Market Stress under Climate Risk: Evidence from the United States

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Abstract

The growing frequency of climate-related hazards is testing the insurance markets in every region of the United States, and instilling fears of availability, affordability and duration of insurance. While there is sufficient research on disaster risk and insurance pricing, little attention has been paid to the measures that account for how physical risk, market responses, and household economic capacity influence stress in the insurance market. This study addresses this gap by creating a Catastrophe Insurance Stress Index (CISI) to measure insurance market stress at the state level. Using data on the frequency of climate disasters, insurance premiums, and the median household income of average homeowners, CISI aggregates the long-run risk of hazard, pressure on insurance rates, and affordability into an open composite indicator. The results demonstrate significant variation in insurance market stress across states, with high CISI values concentrated in disaster-prone and coastal areas. Correlation analysis reveals that insurance price pressure is highly correlated with CISI, and that accidents will reveal the center of gravity in the market stress caused by climate risk.

Keywords: Affordability, CISI, Climate risk, Insurance markets.

Introduction

Rapid climate change in the last decade has considerably changed the frequency and intensities of extreme weather events across the globe. Warming temperatures have an impact on many processes including the hydrological cycle, melt of ice and large-scale weather patterns. Rapid climate change has caused more and more extreme weather events. In the United States, however, escalating danger from climate change has affected heightened pressure on property insurance markets, especially by the seaside dwellers. More frequent severe weather occurrences and an increased number of people in places along the coasts have created greater economic loss and also an increase in insured loss (Swiss Re, n.d.). Insurers have vied by raising premiums, limiting cover and withdrawing from certain markets. As insurance costs increase, pressures on the affordability of insurance grow, placing uneven stresses on the insurance market with Florida, Louisiana, and Texas experiencing some of the largest impacts.

Existing research links climate change and the natural disasters that result to increased economic costs, especially in coastal areas, and documents physical risks associated with extreme weather events. Insurance-oriented studies investigate market behaviors such as pricing and underwriting (Gray, 2021) while studies on coasts investigate vulnerabilities from sea-level rise and erosion and their implications to policy-based public programs such as the National Flood Insurance Program (Leatherman, 2018). However, these strands are typically studied individually and are not typically explored within an integrated framework. Present approaches provide a partial picture of the difficulties in the insurance market. Hazard-based

measures capture physical risk but not its distribution in the market (Kousky, 2018), whereas pricing studies or studies focusing on specific programs do not consider affordability or cross-state variation (Dixon et al., 2006). As a result, there is no consistent, transparent way to assess insurance market stress across regions (Born & Klein, 2016), reducing the possibility of systematic comparisons and the identification of states with disproportionate vulnerabilities due to climate-related risks.

This paper addresses how to systematically measure stress in the US coastal states' insurance markets using readily available data and what these measurements reveal about variation in climate-related insurance vulnerability across states. To do so, it proposed a composite indicator of exposure to the climate hazards, insurance pricing pressures, and household insurance affordability limits, which it calls the Catastrophe Insurance Stress Index (CISI). The paper contributes to the existing research by providing a transparent, replicable framework for measuring stress in the insurance market and enabling comparisons across regions. The rest of the paper is organized as follows: a review of relevant literature, a description of the data and methodology, a presentation of the results of the empirical analysis, and a discussion of implications for insurance stability and future research.

Literature review

A large body of literature documents a significant rise in the occurrence and intensity of climate-related natural disasters over the past couple of decades, as well as a marked increase in both economic and insured losses. Climate science research has established that rising global temperatures are intensifying extreme weather events, including floods, hurricanes, wildfires, and heat waves, particularly in coastal and low-lying areas (Intergovernmental Panel on Climate Change (IPCC), 2023). Empirical inventories of disaster losses also suggest that events with at least one billion dollars in damages have become increasingly common in the United States since the 1980s, with frequency much higher in recent decades than in previous decades (NOAA, 2023).

From an economic perspective, research emphasizes that growth in disaster losses results from changes in hazard characteristics and from increased exposure due to population growth and the concentration of assets in vulnerable areas (PielkeJr. et al., 2008; Kahn et al., 2019). Insurance and reinsurance studies also show that insured losses have been increasing significantly over time, and in some cases faster than economic losses, thus putting increasing pressure on the risk-transfer mechanisms and capital adequacy of insurance systems (Swiss Re, n.d.; Kousky, 2018). This literature lays the foundation for an evolving climate-risk environment in which there is an increased frequency and severity of losses, and a dramatically increased concentration of exposures, posing great challenges to the long-term sustainability of insurance markets.

The theoretical literature on catastrophe insurance highlights that markets in which risk is low-probability and severity is high have structural characteristics that set them apart from standard insurance. Classic economic theory emphasises the importance of having a risk pool and diversification to provide effective insurance, however, such catastrophe risks tend to have a high degree of correlation across policyholders and geographic locations, and as such insurance companies are unable to share losses effectively (Boomhower et al., 2024). In addition, fat-

tailed loss distributions and deep uncertainty add complexity to the area of actuarial pricing and capital allocation and expose insurers to extreme downside (Froot, 2001). These characteristics tend not only to cause higher premiums, more stringent underwriting, or market atrophy, but also to make reinsurance capacity tighter. The literature further asserts that asymmetric information (information asymmetries), moral hazard and adverse selection may increase such pressures, especially when it comes to areas with high risks of loss, and therefore decrease incentives for private insurers to provide coverage (Kunreuther et al., 2011). In response, purely private insurance solutions may be unstable in the face of sustained increases in catastrophe risk, leading to public intervention in the form of government-backed insurance programs, reinsurance facilities or risk sharing arrangements (Cummins & Mahul, 2009).

There is increasingly available evidence from empirical research which reveals that rising climate-related risk has produced measurable responses in terms of stress in property insurance markets, especially in catastrophe-prone areas. A large body of research provides evidence that insurers respond to increasing disaster risk by not offering new, affordable, underwriting requirements but through raising premiums, raising deductibles, and more restrictive underwriting requirements, particularly after major losses (Born & Klein, 2016; Kousky & Kunreuther, 2014). A similar state-level analysis for the United States also found that repeating disasters such as hurricanes, floods and wildfire are linked to insurance company retreat from the market and weaker competition and more use of residual or state-back insurance for these areas (Nevitt & Pappas, 2024). Empirical insight also suggests there is a lag between insurance price adjustments and changes in the underlying risk and that this may cause periods of very sharp premium increases as losses accumulate, or when the cost of reinsurance increases sharply. These dynamics contribute to unequal outcomes across states in the market for insurance products, as areas equally exposed to hazards may have very different insurance conditions based on their regulatory environment, income levels, and loss experience. Taken together, these studies prove that stress in insurance markets is a measurable, regionally differentiated phenomenon, which is determined by an interaction between climate-related exposure to hazards, the behaviour of insurers, and institutional and regulatory conditions.

A growing body of literature supports the notion that rising cost of insurance are limiting the ability of households to maintain adequate insurance and that we are seeing the forces of the market contributing to the socioeconomic vulnerability (Kousky & Kunreuther, 2014). Studies have found insurance affordability barriers present when the growth of insurance premiums outpaces income growth resulting in households not being able to afford insurance coverage, have to pay more in deductibles, or have to withdraw from insurance markets entirely (Kousky, 2018; Kousky et al., 2017). In the United States, such challenges are being experienced particularly in areas along the country's floodplains, the repeated exposure to such losses and regulations have lead to continued reliance on public insurance mechanisms, most notably the National Flood Insurance Program (NFIP). Research under the aegis of the NFIP has chronicled problems concerning underpricing, cross-subsidization, fiscal sustainability and uselessness of NFIP to incentivize risk mitigation on the part of policyholders (Michel-Kerjan, 2010; Dixon et al., 2006). At the level of households, the empirical evidence is suggestive of how shrinking housing demand after the rise in costs of insurance, along with the escalating level of mortgage financing difficulties and the resulting inequality are especially strong in high hazard areas (Gordy, 2016; Kahn et al., 2019). Overall, it is clear from the literature on insurance minds how

affliction in insurance markets can trickle outside the balance sheets of insurers and become a pressure on affordability with important ramifications for household resiliency, housing markets, and the long-term sustainability of insurance systems.

Despite the extensive research conducted on trends in climate risks, the behaviour of the insurance market and the affordability to households, there is neither a unified empirical approach in the literature to measure insurance market stress as a multidimensional phenomenon. Existing studies tend to take isolated indicators like exposure to hazards measures, premium features of insurers or participation rates or household income reflections building only one dimension of the insurance system performance. Climate vulnerability indices focus on physical exposure and adaptive capacity, whereas analyses that include a portfolio of cost-study, insurance-focused analyses primarily focus on price dynamics, certain or unusual programs, and surgically enhancing classic affordable or cross-national results in comparison. As a result, these approaches provide limited insight into the interactions among physical risk, market responses, and socioeconomic vulnerability that determine overall insurance market conditions. This fragmentation complicates researchers' and policymakers' ability to diagnose where insurance markets are under the most stress, compare the degree of stress across geographic areas, families, or other groups, or identify differences between increased climate risks and broader market instability. To help fill this missing link, a replicable, transparent measuring and reporting framework, incorporating hazard exposure, pricing pressure in the insurance market and household affordability, could be contained in one tool to offer a comprehensive, comparable measure of insurance market stress.

Data and Methodology

Data Overview and Scope

This research is centered around the susceptibility of insurance markets from various US states, which are exposed to disaster risk and are under pressure to constructively price and are part of households facing affordability. The analysis involves creating an insurance market stress index with data already available at the secondary level, at state level as shown in **Table 1**. The empirical framework combines three dimensions, namely the exposure to climate hazards, insurance price pressure and the household economic capacity to capture the response of different actors in the face of the physical risk, the insurance price pressure and the affordability constraint. Focusing on states allows comparisons to be made efficiently across states without being affected by local anomalies. Premiums and income are averaged for 2018-2022, reflecting the absence of short-term risk experience and disaster exposure for 1980-2024, which is reflected in the long-term risk experience. This design places less emphasis on shocks in short-term markets and more on structural stress in the insurance market.

Table 1: ***Data sources***

Variable	Description	Source	Period
Disaster Frequency	Count of billion-dollar disasters by state	NOAA	1980–2024
Average Homeowners Premium	Inflation-adjusted annual premium	Insurance Information Institute	2018–2022
Median Household Income	ACS 5-year estimate	U.S. Census Bureau	2018–2022
Affordability Ratio	Premium / income	Author calculation	2018–2022
CISI	Composite stress index	Author calculation	-

Data Sources

Insurance pricing pressure is calculated from the average homeowners' insurance premiums for each state, as reported by the Insurance Information Institute (2018-2022), *(Archived Tables | III, n.d.)*. Household economic capacity is measured by median household income from the U.S. Census Bureau's ACS 5-Year estimates (2018-2022) *(Bureau, n.d.)*. These publicly available datasets represent insurers' pricing behavior, underlying risk, and regulation, and offer uniform, replicable measures at the state level.

The effect of climate hazards on one is quantified using state-based disaster-frequency measures obtained from the National Oceanic and Atmospheric Administration (NOAA), specifically the Billion-Dollar Weather and Climate Disasters dataset at the National Centers for Environmental Information. This dataset provides a standardized record of major climate-related disasters in the United States from 1980 through 2024 and is widely used in climate risk and insurance research, as illustrated in **Figure 1.**

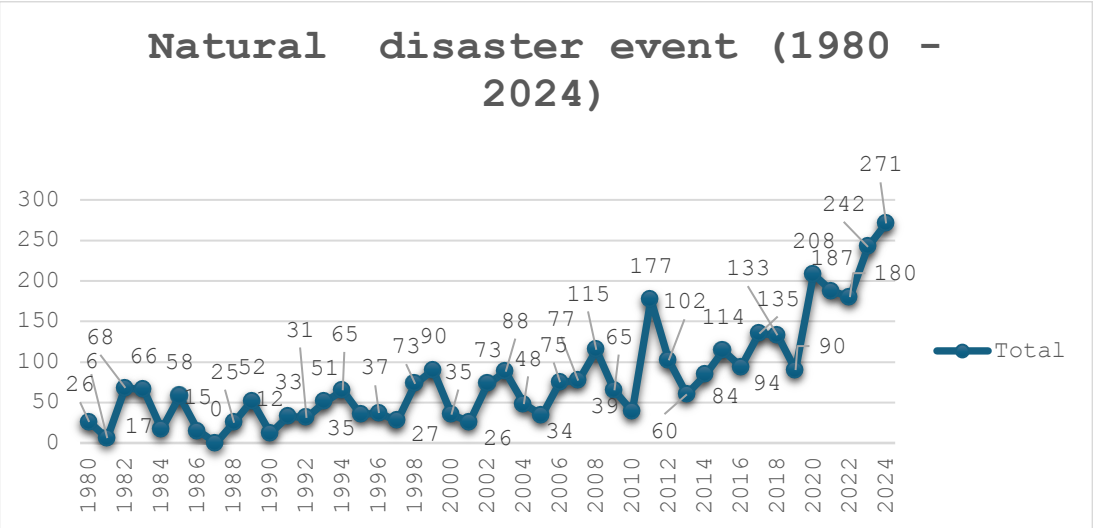


Figure 1. ***Natural Disaster Count by Years*** *("U.S. Billion-Dollar Weather and Climate Disasters, 1980 - Present," 2020)*

Climate Hazard Exposure Measurement

Climate hazard exposure is measured as the cumulative number of major climate-related disasters at the state level from 1980 - 2024. This is a long window of historical context for actual exposure to extreme events and long-run vulnerability, rather than short-term variation or modelled projections. The measure is in line with the reliance by insurers on aggregate loss experience and the expectation of long-term risk. Disaster frequencies of the states are normalized using min-max transformation for the sake of comparison, shown in Equation (1).

$$D_s = \frac{D_s - \min(D)}{\max(D) - \min(D)}$$

Insurance Market Pricing Pressure

Insurance market pressure, based on average homeowners insurance premiums for 2018-2022 for states. Premiums are adjusted in line with inflation and averaged over five years to reduce sensitivity to short-term shocks from outlier years caused by a single disaster, regulations, or reinsurance cycles. Premiums are adjusted on a normalized basis (house-years), that is, are made comparable across states with different housing stocks and populations. Average premiums are proxies for insurers' reaction to underlying risk in terms of pricing, underwriting, and capital costs; Higher premiums indicate Existing risk in the marketplace. The measure is standardized before it is included in the composite index, as illustrated in Equation (2):

$$P_s = \frac{\overline{Premium_s} - \min(P)}{\max(P) - \min(P)}$$

Household Affordability and Economic Capacity

Household affordability calculations exclude percentiles, and total-housing affordability measures are based on the state-level median household income, using data from the 2018-2022 American Community Survey (ACS) 5-year estimates, from which stable measures of longer-term economic capacity are derived. An indication of affordability pressure is the premium-to-income ratio, which reflects the burden of insurance costs on households; the higher the ratio, the greater the risk of underinsurance or leaving the insurance market. The ratio is normalized so that it is included in the composite index, as shown in Equation (3):

$$A_s = \frac{\overline{Premium_s}}{Median\ Income_s}$$

Construction of the Catastrophe Insurance Stress Index (CISI)

The Catastrophe Insurance Stress Index (CISI) is a composite index that combines climate-hazard exposure, insurance pricing pressure, and household affordability. Each component is normalized to the 0-1 scale using a min-max transformation. CISI is defined as an unweighted average of these three dimensions and it represents joint physical, market, and affordability stress. Higher values of CISI mean higher insurance market stress:

$$CISI_s = \frac{D_s + P_s + A_s}{3}$$

The summary statistics in **Table 2** pertain to key theoretical dimensions in the literature on catastrophe risk, insurance market behavior, and affordability. Median household income is a measure of economic ability to have insurance (Kunreuther et al., 2011). Disaster frequency proxies the long-run climate hazard exposure which influences the risk assessment by insurers (PielkeJr. et al., 2008; Intergovernmental Panel on Climate Change (IPCC), 2023). Average homeowner's insurance premiums reflect insurance pricing responses to risk, reinsurance costs and uncertainty (Froot, 2001; Born & Klein, 2016). The affordability ratio relates premiums to income using to draw attention to the insurance burden on households (Kousky & Kunreuther, 2014; Mills, 2005). CISI incorporates these elements, the combined impact of physical risk, market responses, and household vulnerability on the stress of an insurance market (Kunreuther et al., 2011).

Table 2: ***Summary Statistics***

Variables	Mean	Standard Dev.	Min	Max
Household Income	$74266.7	$11942.43	$52985	$98461
Disaster Count	71	41	2	190
Avg. Homeowners Premium	$1318.49	$374.88	$779.75	$2265.5
Affordability Ratio	0.0184	0.0067	0.0093	0.0384
CISI	0.3983	0.1375	0.1493	0.781

Results

Distribution of Insurance Market Stress Across States

This section presents the results of the CISI for states across the United States and shows substantial variation in insurance market stress, driven by differences in disaster exposure, pricing pressures, and households' ability to afford insurance. As shown in **Table 3**, the CISI ranges from 0.15 to 0.78, with a mean of 0.40, indicating moderate stress but high dispersion (standard deviation of 0.14). The lack of equality reflects the importance of state-level analysis in assessing climate-related insurance challenges.

State-Level Patterns in Insurance Market Stress

Figure 2 shows apparent geographic aggregation of CISI, with higher insurance market stress in disaster-prone areas and large-population areas, especially along the Gulf Coast and in the Northeast. As shown in **Table 3**, the states with the highest CISI are Texas (0.78), followed by Colorado and Florida (0.61), and the other high-stress states include Massachusetts (0.60) and Maryland (0.58). In contrast, those states with low disaster exposure and a weaker affordability pressure have the lowest CISI values, with West Virginia (0.15), Maine (0.19), and Idaho, New Mexico and Nevada (approx. 0.20). These patterns indicate that insurance market stress is

conditioned partly on the exposure to climate hazards, as well as regional variation of the costs of insurance and household economic capacity.

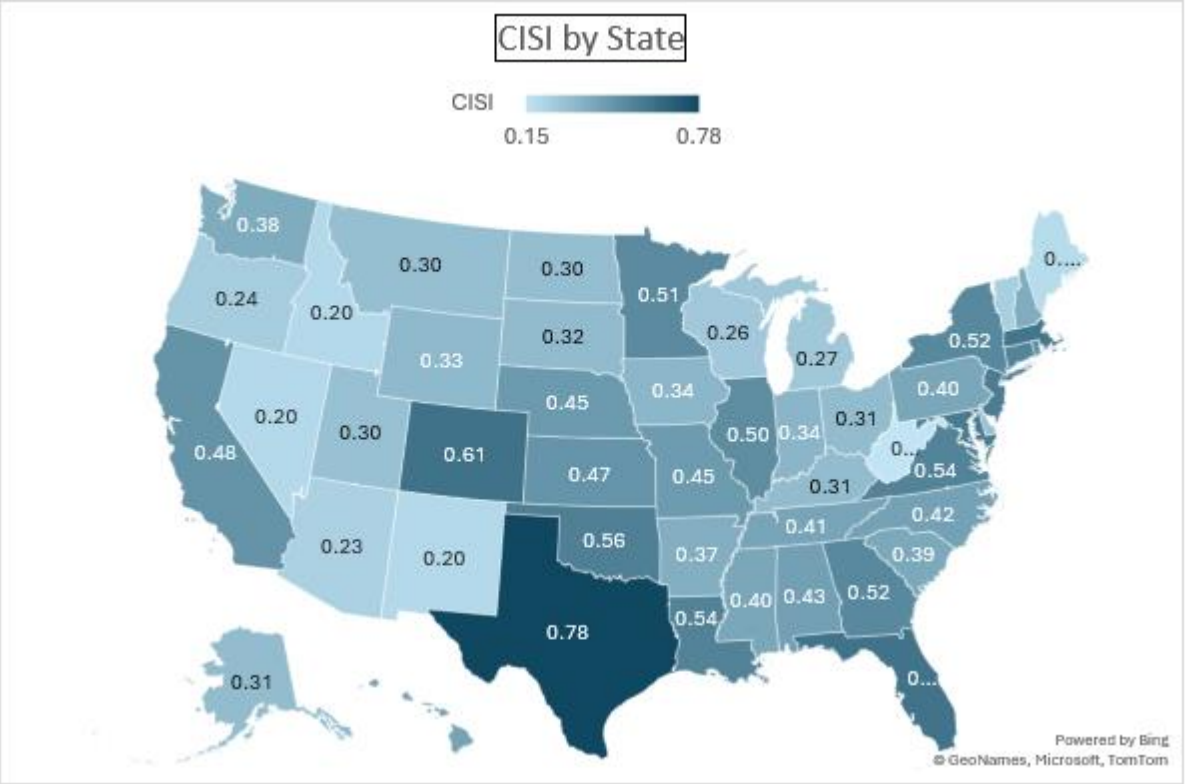


Figure 2. ***CISI by State***

Table 3 identifies the 5 highest- and lowest-scoring CISI states. High-CISI states are predominantly disaster-prone or coastal, where the combination of frequent disasters, premiums, and affordability constraints is driving higher stress in the sector. Low-CISI states are less prone to disasters, experience less affordability stress, and therefore have less stressed insurance markets. The contrast demonstrates that hazard exposure is a key driver of physical risk and insurance responses, and that the composite CISI is an effective way to identify stressed markets that single risk measures cannot capture.

Table 3. ***Top 5 highest and lowest states***

Highest		Lowest	
State	CISI	State	CISI
Texas	0.78	Idaho	0.20
Colorado	0.61	New Mexico	0.20
Florida	0.61	Nevada	0.20
Massachusetts	0.60	Maine	0.19
Maryland	0.58	West Virginia	0.15

Source: Author's calculations based on NOAA Billion-Dollar Disaster data, Insurance Information Institute homeowners insurance premiums, and U.S. Census Bureau American Community Survey data.

Associations Between CISI and Key Insurance Stress Drivers

Correlations between CISI and its important constituents are shown in **Table 4.** The correlation analysis suggests the impact of its components on the stress in the insurance market. Premium dynamics show the strongest direct relationship with CISI, while exposure to disasters and affordability are conditionally or indirectly related to stress outcomes.

Using a correlation cutoff of 0.6, average homeowners insurance premiums show a strong link with CISI (correlation coefficient of 0.76), suggesting that pricing pressure is the most significant observable stressor on the insurance market across states. The correlation between the frequency of disasters and CISI is 0.58, which is slightly below the threshold for strong correlation, indicating that long-run exposure to climate-related disasters contributes to insurance market stress but does not, on its own, account for much of the variation in CISI across states. Moreover, CISI is positively correlated with the affordability ratio (0.46), indicating a rising household burden as premiums capture a larger share of household income, thereby contributing to insurance market stress. However, the direct statistical association between these factors is less pronounced than that with pricing pressure. Affordability constraints are likely to increase stress after premiums rise, contributing to underinsurance, lower coverage demand, or policy non-renewal, but this will depend on premium levels and regional income structures.

Table 4. ***Correlation Between CISI and Key Variables***

Variables	Correlation with CISI
Disaster count	0.58
Homeowners Premium	0.76
Affordability Ratio	0.46

Discussion

Interpretation of CISI Patterns Across States

These findings make it clear that there is considerable heterogeneity in insurance market stress across the United States of America, hence the need for a multidimensional approach to measuring climate-related insurance concerns. The variation in CISI values was found to be a result of an interaction of long-run exposure to a disaster, insurance market pricing, and household economic capacity, not due to a single factor.

The states with higher CISI values are not uniformly the most frequent but rather an increased stress factors is evident with constant exposure of hazards associated with rising insurance rates and limited client ability. This finding implies that the stress that insurance markets are under most acutely felt when physical climate risks translate into insurance price increases that exceed the growth in household incomes. On the other hand, the CISI value in moderate disaster-exposure states is low since insurance premiums and their economic capacity to bear insurance costs are fairly constant, which buffers the stress in a market.

Notably, the CISI framework shows that reliance on hazard-based metrics may be insufficient for identifying insurance market vulnerability in some areas. Using pressure on pricing and

affordability helps the index capture dimensions of stress closely related to the availability and sustainability of insurance. These trends support the usefulness of a composite indicator for gauging the state of insurance markets amid rising climate risk.

Pricing Pressure as a Central Driver of Insurance Market Stress

The results demonstrate that insurance pricing pressure is the primary driver of how insurance market stress varies across states in the US. CISI is most strongly correlated with average homeowners' insurance premiums, suggesting that changes in premiums are the most important way climate risk is transmitted into market stress. Rising premiums reflect continually occurring losses, higher reinsurance expense and greater uncertainty, and are the main tool of the insurers to transfer risk to the policyholders. This highlights the discrepancy between exposure to physical hazards and market outcomes: premiums reflect insurers' expectations, regulatory and capital constraints, and, as a result, are more direct measures of market stress than hazard measures. All in all, premium dynamics stand out as a key mechanism linking climate risk to the stability of insurance markets.

The Role of Affordability and Household Economic Capacity

In addition to pricing pressure, affordability considerations are a major source of stress in the insurance market, especially in coastal states. The positive relationship between CISI and the affordability ratio is moderate, indicating that when premiums are high and households are impoverished, stress is compounded, particularly when repeated hurricanes and floods lead to sustained premium increases. These conditions put pressure on household budgets and lead to the risk of underinsurance and exit from the market (Kunreuther et al., 2011; Kousky & Kunreuther, 2014). Differences in CISI across coastal states with similar hazard exposure highlights the fact that market stress does not always depend on hazard exposure, but also on differences in income and premium, in line with past studies on socioeconomic vulnerability (Mills, 2005; Kousky, 2018). Increasing premiums in areas most at risk may further reduce coverage and increase public reliance on disaster relief, underscoring the need to factor affordability, risk, and price into efforts to address insurance market stress (Kunreuther et al., 2011).

Implications for Insurance Market Stability and Policy

The results indicate that stress in the insurance market points to issues not only in hazard exposure but also in insurers' pricing behaviour and households' affordability, rendering CISI more informative than hazard-only. The close association between CISI and premiums indicates that pricing pressure is an early warning sign of market stress in the emerging market and could guide regulatory oversight before a decline in coverage. High CISI values in Coastal states indicate the need for special regional oversight, as hazards have been frequent, premiums have increased, and affordability has been low. This has put a combined strain on the markets, with higher prices, low coverage, and insurer exits. More broadly, CISI offers a transparent stress-and-risk analysis for comparing insurance market resilience across states and over time, using integrated modelling of physical risk, market response, and household vulnerability, and is thus useful for informed discussion of insurance resilience to climate change.

Limitations and Directions for Future Research

Although this research can be considered a systematic evaluation of the state of stress in U.S. insurance markets, several limitations should be noted. First, CISI relies on a proxy variable for disaster frequency (disaster exposure and severity are not considered directly) and may benefit from integrating economic or insured-mayhem parameters to evaluate risk intensity. Second, the index assigns the same weight to disaster exposure, insurance price pressure, and affordability, which increases transparency but does not necessarily reflect their relative importance; future research could test different or data-driven weighting schemes. Third, the conclusions are not causal and thus cannot establish the relationship among climate risk, insurance prices, and affordability; longitudinal data and econometric or quasi-experimental designs are necessary to establish causality. Lastly, state-level averages might mask considerable heterogeneity within states and expanding the analysis to cover smaller geographic units of analysis or including more market-specific variables, such as insurer concentration or reinsurance dependency, are other promising avenues for future research.

Conclusion

This paper discusses changes in insurance market stress in U.S. states that are more vulnerable to climate-related changes in the face of simultaneously assessing disaster exposure, insurance pricing stresses, as well as household affordability by using the catastrophe Insurance Stress Index (CISI), which integrates these three dimensions of insurance market stress systems into one measure of analogous insurance market stress at the state level.

The findings indicate that stress in insurance markets varies considerably across states and does not appear to be explained by exposure to disaster. States with similar levels of climate-related hazard exposure often have very different levels of stress regarding insurance premiums and household economic resources. Notably, insurance pricing pressure is the best gauge of overall market stress and suggests that premium increases will be the primary driver of a tight insurance market in a climate-risk landscape. While disaster exposure is a stress factor, price reactions and affordability-related decisions help mitigate it. Additionally, low CISI rates are mostly found in states that face frequent hazards and have long-term, uneven income distribution between households. These patterns point to increasing weaknesses in insurance markets, as costs are outstripping households' ability to pay and pressure on insurance affordability is building to an even greater degree, even where there is some similarity in the physical risks involved. As a result, stress levels in insurance markets, particularly where market reactions and household vulnerability are critical, are likely underestimated if assessments are based on hazard exposure alone.

Overall, the results point to a need to move from hazard-based measures for assessing the positive and negative effects of stress on insurance markets to integrated measures that consider the multidimensional nature of stress because of the rising climate risk.

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