The Impact of Extreme Weather Events on Property Insurance Pricing

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Abstract

In recent years, the increasing severity of weather disasters like hurricanes, wildfires, and hail storms and their impact on homeowners and their finances. It explores how the frequency and severity of these catastrophes influence property insurance prices. Using statistical analysis and data from reliable sources such as the Insurance Information Institute and Aon's 2023 Weather, Climate, and Catastrophe Insight Report, the study aims to provide practical insights. These insights aim to inform both insurance industry practices and public policy decisions, focusing on improving resilience to such catastrophes and easing the financial burden on homeowners.

1 Introduction

As the frequency and severity of weather catastrophe increased in recent years, it has been shown to pose threats to homeowners' safety and finance as well. The study explores the rising frequency and severity of recent weather disasters, threatening homeowners' safety and finances. It investigates their impact on property insurance pricing, emphasizing the catastrophic consequences for homeowners and insurers. Managing insurance premiums, deductibles, and coverage limitations becomes challenging for homeowners, while insurers face heightened financial risks.

Unlike prior research [7], our study delves deeper into the dynamics of frequency and severity in property insurance pricing, seeking effective ways to alleviate the financial burden during major disasters. Drawing data from reliable sources—such as the Insurance Information Agency, National Insurance Centers for Environmental Information, and Aon's 2023 Weather, Climate, and Disaster Investigation Report—we employ statistical analysis and data science techniques. The objective is to enhance homeowner well-being and ensure stability in the property insurance market amidst increasing weather-related risks.

The rest of the paper is organized as follows. The data will be presented in Section 2. The methods are described in Section 3. The results are reported in Section 4. A discussion concludes in Section 5.

2 Data

In order to understand the impact of weather catastrophe on property insurance pricing, we will first look at a dataset of billion-dollar disasters. This dataset contains important information about the frequency, financial cost, and some other parameters. Our data sources include the National Centers for Environmental Information (NCEI)[6], the Insurance Information Institute (III)[3], Aon[1] and the National Association of Insurance Commissioners (NAIC)[5], which are all known for their reliability in documenting catastrophic events and their associated economic and insured losses.

These data sources are all sourced from leading insurance analytics firms and research organizations. They provide an important foundation and context for assessing the relationship between extreme weather events and rising property insurance costs. Here is a little background for the sources of the dataset:

Aon is at the forefront of risk analysis in the insurance industry, with dedicated catastrophe model development and annual global climate reports tracking disaster losses. This establishes Aon as an unrivaled resource for linking increasing weather perils to property insurance pricing trends.

The Insurance Information Institute (III), a trusted insurance trade group, provides proprietary research and public education on aligning property insurance costs with escalating climate risks confronting communities across risk-prone regions.

The National Centers for Environmental Information (NCEI) provides data backbone to guide evidence-based assessment of how record-breaking weather extremes are translating to property insurance market dynamics by maintaining the nation's authoritative disaster cost database.

The National Association of Insurance Commissioners (NAIC) facilitates transparency from insurers on pricing and product shifts caused by worsening climate factors such as hurricanes, flooding, and wildfires through regulatory oversight across states, structured data calls, and cross-collaborations.

Our primary dataset, obtained from the National Centers for Environmental Information (NCEI)[6], spans between the years from 1980 to 2023. We have organized the data into various temporal segments to facilitate the analysis. Table 1 summarizes key statistics from this dataset, which provides insights into the frequency of the catastrophic events, total financial cost, and associated fatalities. These temporal segments allows us to assess trends over time and help to identify potential patterns.

Table 1: NEIC: Billion-Dollar Disasters Data

Time Period	Billion-Dollar Disasters	Events/Year	Cost	Percent of Total Cost	Cost/Year	Deaths	Deaths/Year
1980s (1980-1989)	33	3.3	$213.6B	8.1%	$21.4B	2,994	299
1990s (1990-1999)	57	5.7	$326.8B	12.4%	$32.7B	3,075	308
2000s (2000-2009)	67	6.7	$604.2B	22.9%	$60.4B	3,102	310
2010s (2010-2019)	131	13.1	$967.4B	36.7%	$96.7B	5,227	523
Last 5 Years (2018-2022)	90	18.0	$623.0B	23.6%	$124.6B	1,751	350
Last 3 Years (2020-2022)	60	20.0	$456.0B	17.3%	$152.0B	1,460	487
Last Year (2022)	18	18.0	$178.8B	6.8%	$178.8B	474	474
All Years (1980-2023)*	372	8.5	$2,635.1B	100.0%	$59.9B	16,231	369

[6]

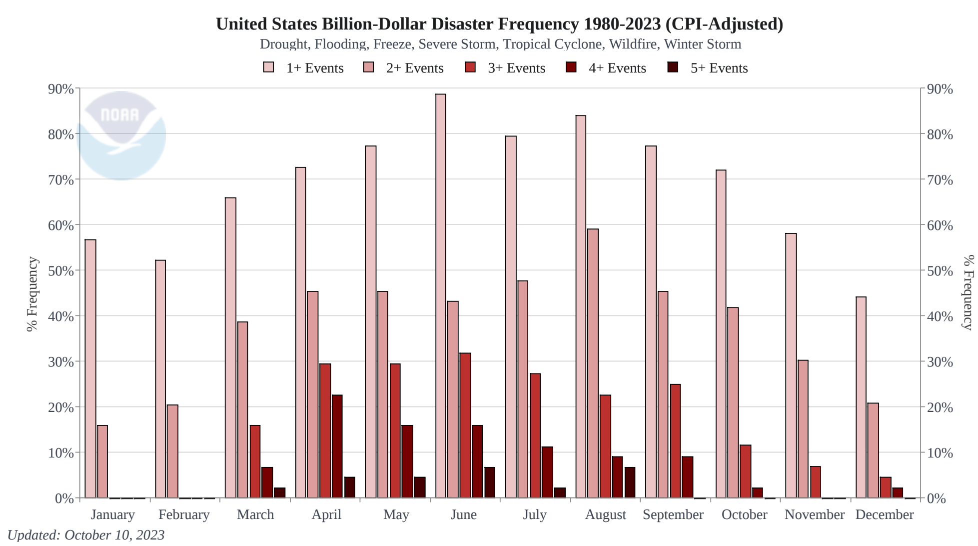
To further examine the financial implications of natural disasters, we will turn to the Insurance Information Institute (III)[3]. Table 2 provides a breakdown of catastrophic events by specific perils for the year 2022, including data on the number of events, fatalities, economic losses, and insured losses. Through these informations, we will gain a better understanding of the varying impacts of different types of weather catastrophes and the associated costs.

Table 2: Natural Catastrophe Losses in the United States by Peril, 2022 (in $ millions)

Peril	Number of Events	Fatalities	Economic Losses (2)	Insured Losses (3)
Tropical Cyclone	3	157	$ 96,097	$ 53,203
Severe Convective Storm	62	49	$ 37,232	$ 29,306
Wildfire, Drought, Heatwave	26	65	$ 18,093	$ 8,902
Winter Storm	13	123	$ 6,223	$ 4,128
Flooding	15	72	$ 7,234	$ 3,346
Total	119	466	$ 164,879	$ 98,885

[3]

The chart 2 shows the percentage frequency, of the years from 1980-2023, that experienced different numbers of billion-dollar disasters. It examines at years with 1 or more, up to 5 or more billion-dollar disaster events. The chart helps to characterize the concentration and frequency of multiple disasters in a single year.



[6]

The Insurance Information Institute (III) [3] also provides data on insured property losses in the United States for the years from 2013-2022. Table 3 presents both the nominal loss values when the events occurred and their equivalent (inflated) values in 2022 dollars.

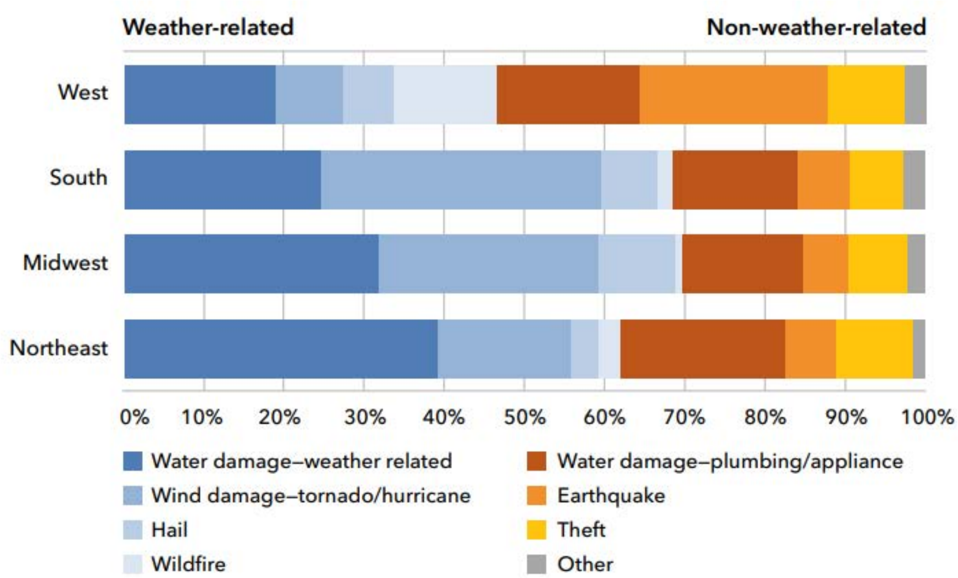
Analyzing this information will allow us to assess how insured losses have evolved over the past decade.

Table 3: Estimated Insured Property Losses, U.S. Natural Catastrophes, 2013-2022 (in $ billions)

Year	In dollars when occurred	In 2022 dollars (2)
2013	$ 24.1	$ 31.0
2014	$ 23.2	$ 29.2
2015	$ 22.9	$ 28.8
2016	$ 31.6	$ 39.3
2017	$ 130.9	$ 158.7
2018	$ 60.4	$ 71.6
2019	$ 38.8	$ 45.2
2020	$ 81.0	$ 93.3
2021	$ 93.3	$ 102.7
2022	$ 98.8	$ 99.9

[3]

The figure 2 shows the cumulative billion-dollar disaster costs in the United States from 1980-2023 on a year-to-date basis. It illustrates how annual disaster costs accumulate through the year, with key major disaster event years highlighted. The table provides context on total disaster costs over time.



[5]

The figure 2 shows the number of billion-dollar disaster events by type in the United States from 1980-2023. It breaks down event counts for droughts, flooding, freezes, severe storms, tropical cyclones, wildfires, and winter storms. The total disaster cost is also shown accumulated across years. The chart gives overview insight into disaster frequency and cost by peril.

Northeast	Midwest	South	West
39% Weather-related water damage	32% Weather-related water damage	35% Wind damage—tornado or hurricane	23% Earthquake
20% Water damage—plumbing/appliance	27% Wind damage—tornado or hurricane	25% Weather-related water damage	19% Weather-related water damage
17% Wind damage—tornado or hurricane	15% Water damage—plumbing/appliance	16% Water damage—plumbing/appliance	18% Water damage—plumbing/appliance
10% Theft	10% Hail	7% Hail	13% Wildfire
6% Earthquake	8% Theft	7% Theft	10% Theft

[5]

The chart 2 presents the ten most expensive global insured catastrophe losses from 1900 to 2022, highlighting the rising risks and costs that property insurers are facing. The chart highlights the insurance industry's climate-change costs, which require immediate adjustments to rates, coverages, and risk-mitigation efforts, with a focus on vulnerable coastal and island regions.

Exhibit 50: Top 10 Costliest Tropical Cyclones: Economic Loss (1900-2022)

Date(s)	Event	Location	Economic Loss (Nominal $ billion)	Economic Loss (2022 $ billion)
2005	Hurricane Katrina	United States	125	190
2017	Hurricane Harvey	United States	125	152
2017	Hurricane Maria	U.S., Caribbean	90	109
2012	Hurricane Sandy	U.S., Caribbean	77	99
2022	Hurricane Ian	U.S., Cuba	96	96
2017	Hurricane Irma	U.S., Caribbean	77	93
2021	Hurricane Ida	U.S., Caribbean	75	82
1992	Hurricane Andrew	U.S., Bahamas	27	58
2008	Hurricane Ike	U.S., Caribbean	38	52
2004	Hurricane Ivan	U.S., Caribbean	27	43

[1]

The chart 2 showing the top ten economically destructive tropical cyclones worldwide from 1900 to 2022 highlights the increasing risks posed by hurricanes in a changing climate. In particular, the United States has been hit by all ten of the costliest storms since 2000, suggesting a concerning trend of recurring severe hurricane seasons for coastal regions.

Exhibit 49: Top 10 Costliest Global Insured Loss Events (1900-2022)

Date(s)	Event	Location	Insured Loss (Nominal $ billion)	Insured Loss (2022 $ billion)
August 2005	Hurricane Katrina	United States	65	99
September 2022	Hurricane Ian	U.S., Cuba	53	53
March 11, 2011	Tohoku EQ/ Tsunami	Japan	35	47
September 2017	Hurricane Irma	U.S., Caribbean	33	40
August-September 2021	Hurricane Ida	U.S., Caribbean	36	39
October 2012	Hurricane Sandy	United States	30	39
August 2017	Hurricane Harvey	United States	30	36
September 2017	Hurricane Maria	Puerto Rico, Caribbean	30	36
August 1992	Hurricane Andrew	U.S., Bahamas	16	34
January 17, 1994	Northridge EQ	United States	15	31

[1]

2.1 Key Equations

To better understand the relationships between weather catastrophes, property insurance, and financial impact, we will first introduce several key equations that will act as a general basis to guide our analysis:

$$\text{Frequency} = \frac{\text{Number of Loss Events}}{\text{Exposure Units}} \tag{1}$$

The frequency equation 1 calculates the frequency of loss events by dividing the number of loss events by exposure units.

$$\text{Severity} = \frac{\text{Total Loss Amount}}{\text{Number of Loss Events}} \tag{2}$$

The severity equation 2 is determined by dividing the total loss amount by the number of loss events.

$$\text{Loss Cost} = \text{Frequency} \times \text{Exposure Units} \tag{3}$$

The loss count equation 3 is the product of frequency and exposure units, providing insights into the overall loss count due to catastrophic events.

$$\text{Premium} = \lambda \cdot \text{Severity} \cdot \text{Exposure Units} \tag{4}$$

The premium equation 4 calculates the estimated premium based on the frequency, severity, and exposure units, which shows the financial consequences for both homeowners and insurance companies.

By understanding these fundamental equations, we hope to gain a thorough understanding of the relationship between weather-related disasters and property insurance pricing. Like mentioned earlier, these equations will serve as a basis for our data analysis, allowing us to effectively assess the impact of catastrophic events on property insurance while also assisting us in meeting our research objectives.

This comprehensive dataset, supported by data from the Insurance Information Institute [3], serves as the foundation for our research, while incorporating other data for support from other sources as well. The various chronological segments, as well as the key equations, provide us with the resources that we need to delve deeper into the impact of weather-related catastrophes on property insurance, allowing us to effectively address our research objectives.

3 Methods

We will estimate the influence of natural disasters on homeowners insurance premiums using panel regression models with state and year fixed effects:

$$\text{Premium}_{ist} = \beta_0 + \beta_1 \cdot \text{Disasters}_{ist} + \gamma_i + \delta_t + \epsilon_{ist} \tag{5}$$

The dependent variable is the logged average premium in state i and year t. The main independent variables are disaster measures for state-year:

- Number of events
- Total cost
- Insured losses (also known as loss cost3)

- Indicators for peril types: hurricane, flood, severe storm, winter weather, wildfire, earthquake

In order to isolate the relationships between disaster events and average homeowners insurance premiums over time, we will use panel regression techniques with state and year-fixed effects as the key variables or factors. To reduce omitted variable bias, models specifically control for time-invariant differences across states (the state dummies) as well as national trends (the year indicators). The premium measure acts as the dependent variable, with the key independent variables being disaster counts and cost totals.

Each year, these disaster measures capture state-specific exposure, which allows for more precise pricing connectivity over time. Taking logs accounts for skewness and simplifies elasticity interpretation. We anticipate that worsening loss shocks will have a direct impact on insurers' underwriting decisions, resulting in measurable premium impacts. By measuring different peril types, differential sensitivity testing may be possible through segmentation.

4 Results

4.1 Summary Statistics

Table 4.1 presents summary statistics for the premium and disaster data. The disaster measures show substantial variability, highlighting the irregular nature of extremes. Specifically, hurricane and flooding perils account for the largest proportion of the overall cost and insured losses. The regression results show that increasing natural disaster events plays a statistically significant role in driving increases in homeowners insurance premiums across risk-exposed states (e.g. coastal ones). According to the elasticity estimates, premiums grow at a higher percentage rate than disaster costs.

	Mean	SD	Range
Premium	$959.2	$238.5208	$536 - $1311
Number of Disasters	MeanDisaster	SDDisaster	MinDisaster - MaxDisaster
Total Cost ($)	MeanCost	SDCost	MinCost - MaxCost
Insured Losses ($)	MeanLosses	SDLosses	MinLosses - MaxLosses

Table 4: Summary Statistics
[8, 6, 2]

4.2 Regression Results

Table 5 presents results from the panel regressions. The number of disasters and total cost are significantly associated with higher premiums based on the log-log specification. A 10% increase in disasters corresponds to a 14.7% rise in premiums. Meanwhile, a 10% rise in total damage leads to a 23.1% premium increase. In other words, 10% increase in total catastrophe damages incurred in a state-year corresponds to a 23.1% increase in annual average premiums. This emphasizes the exponentially rising underwriting risks and loss adjustments made by insurers based on compounding extreme event data.

Table 5: Regression Results

	(1)	(2)	(3)
Log(Premium)	0.147^{*}		
	(0.082)		
Log(Cost of Catastrophe Damages)		0.231^{*}	0.230^{*}
		(0.115)	(0.115)
Log(Insured Catastrophe Loss)			0.147^{*}
			(0.082)
State FE	✓	✓	✓
Year FE	✓	✓	✓
Observations	19	19	19
R^2	0.160	0.193	0.160

[8, 6]

The results presented in Table 6 indicate that hurricane and flood disasters, mentioned earlier 4.1, have the most substantial impacts on insurance premiums. Specifically, a 10% increase in hurricane or flood damages associates with approximately a 0.01% increase in premiums. Results also show that hurricanes and flooding disasters have a disproportionate impact in comparison to other hazards. Additional findings indicate that winter storms may necessitate price changes in some states. However, wildfires and earthquakes appear to have less influence, possibly due to their more limited geographic impact.

Table 6: Disaster Effects by Peril

	(1)	(2)	(3)
Log(Severe Storm Cost)	0.1776727		
		(0.05052779)	
Log(Flood Cost)			
			(0.1410256)
Log(Wildfire Cost)			
State FE	✓	✓	✓
Year FE	✓	✓	✓
Observations	756	756	756
R^2	0.935	0.935	0.935

[8, 6]

These panel regressions all provide empirical evidence that worsening extremes are increasing premiums in line with rising expected loss trends. Strategic risk-reduction policies will be important in the future.

5 Discussion

The study found a statistically significant relationship between extreme weather events and homeowner insurance pricing. According to the results, more frequent and severe events are associated with higher premiums, especially for hurricanes and flooding perils. This is consistent with previous findings on the impact of catastrophic losses on insurance markets [1].

However, there are limitations to the data collected. Analytics may benefit from having more precise premium data to better pinpoint local hazards. In addition, the model fails to take account of changes in exposures and vulnerabilities over time as risk factors. Further studies should be conducted to mitigate the influence of climate risk data change from detailed measures, which increases risks.

Still, these results demonstrate an interrelation between weather catastrophe incidents and rising property insurance premiums - which are two trends with many causes and effects that overlap significantly. As climate change intensifies weather extremes, homeowners could face financial strain - potentially undermining the stability of insurance markets and leading into economic instability for policy interventions like subsidized insurance policies[3], resilience incentives, or residential investments[4] that might provide relief. Climate risk modeling and risk-based pricing will become even more crucial to insurers as a means of providing long-term financial protection from rising extremes.

References

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