The Impact of Extreme Weather Events on Property Insurance Pricing

Carol Li

University of Connecticut

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Abstract

Weather catastrophes, like hurricanes, wildfires, hail storms, etc., have become more common and severe in recent years, which poses significant risks to homeowners and has significant financial consequences. The purpose of this research paper is to look into the impact of weather catastrophe frequency and severity on property insurance policy prices, and also, to identify strategies for easing the financial burden on homeowners. This research combines statistical analysis and data science techniques, drawing on data from reliable sources such as the Insurance Information Institute and Aon's 2023 Weather, Climate, and Catastrophe Insight Report. The research aims to provide helpful insights into the relationships between the frequency and severity of weather catastrophes and property insurance pricing in order to inform insurance industry practices and public policy decisions to improve resilience to catastrophes.

1 Introduction

In recent years, weather catastrophes have become more frequent and severe, which poses a potential threat to homeowners' safety as well as financial impacts. As the frequency and severity of disasters increase, the significance of the ability of homeowners to protect their homes using property insurance also increases. This research will focus on exploring the relationship between the frequency and severity of weather catastrophes and the pricing of property insurance.

Climate disasters have become more frequent and severe in recent years. These incidents not only put homeowners' safety at risk but also have significant economic consequences. As weather-related risks increase in frequency and severity, the ability for homeowners to protect their valuable assets through property insurance has also become increasingly important This paper aims to explore the relationship between the frequency and severity of weather hazards and property insurance policies and prices.

The importance of this study is the fact that weather disasters can carry profound amount of consequences, which affects the individual homeowners and the insurance industry as a whole. Homeowners are the ones who typically bear the financial burden of disasters, and face the finance of all the insurance premiums, deductibles, and coverage limitations at the same time. On the other hand, the insurance company is tasked to manage the increased risks associated with these events, which can also have a significant impact on their financial stability.

While previous research has examined different aspects of this complex issue, including the impact of weather risks on insurance prices, there are much more waiting to be discovered. Our research is based on valuable insights into the value of previous work [7] aimed at assets that have provided insurance pricing of weather frequency and severity. It provides a general understanding of how frequency and severity affect the pricing of property insurance. We are also trying to identify effective strategies that can reduce the financial burden of homeowners in the face of these major disasters.

This research has used several methods, including statistical analysis and data science methods. To achieve our goals, we will draw data from reliable sources, such as the Insurance Information Agency, National Insurance Centers for Environmental Informations, and Aon's

2023 Weather, Climate and Disaster Investigation Report. This study is not only timely but critically important at a time of increasing weather-related risks, with the goal of contributing to homeowner well-being and the stability of the property insurance market.

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

To comprehend the impact of weather-related catastrophic events on property insurance pricing, we will begin by examining a dataset of billion-dollar disasters. This dataset provides crucial information on event frequency, financial cost, and other key parameters. Our data sources include the National Centers for Environmental Information (NCEI)[6], the Insurance Information Institute (III)[4], Aon[2] and the National Association of Insurance Commissioners (NAIC)[1], all are recognized for their reliability in documenting catastrophic events and their associated economic and insured losses.

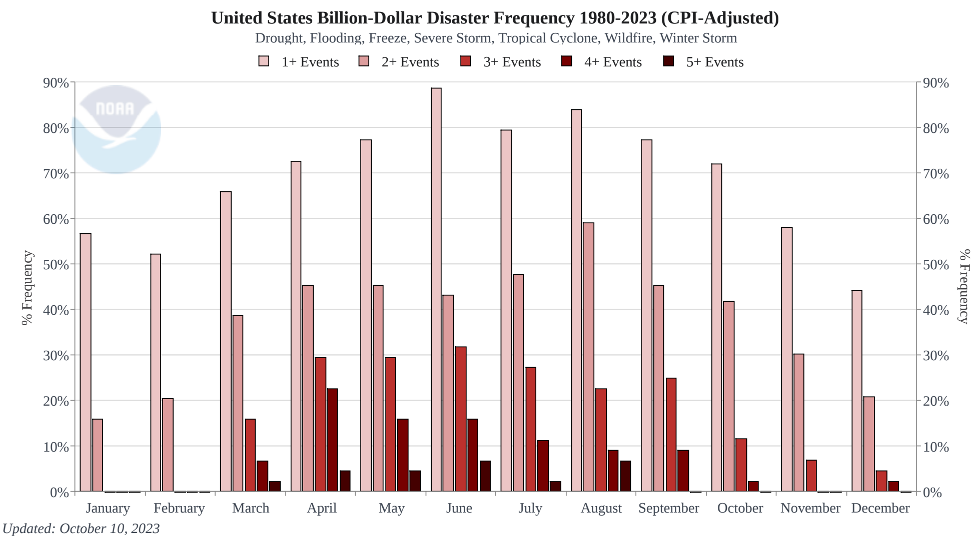
Our primary dataset, obtained from the National Centers for Environmental Information (NCEI)[6], spans between the years from 1980 to 2023. We have organized the data into various temporal segments to facilitate analysis. Table 1 summarizes key statistics from this dataset, which provides insights into the frequency of catastrophic events, total financial cost, and associated fatalities. These temporal segments, ranging from the 1980s to the present day, enable 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 turn to the Insurance Information Institute (III)[4]. Table 2 for the year 2022 provides a breakdown of catastrophic events by peril, including data on the number of events, fatalities, economic losses, and insured losses. This granular information is essential for understanding the varying impacts of different types of natural catastrophes and their associated costs.



[6]

This chart 2 shows the percentage frequency of years from 1980-2023 that experienced different numbers of billion-dollar disasters. It looks 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.

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

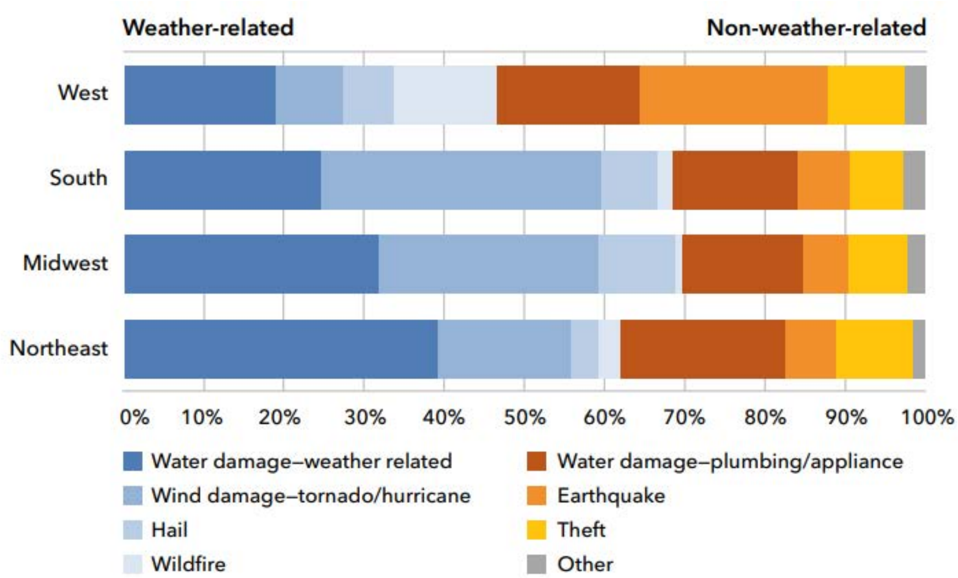
[4]

The Insurance Information Institute (III) [4] also supplies data on insured property losses in the United States for the years 2013-2022. Table 3 presents both the nominal loss values when the events occurred and their equivalent 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

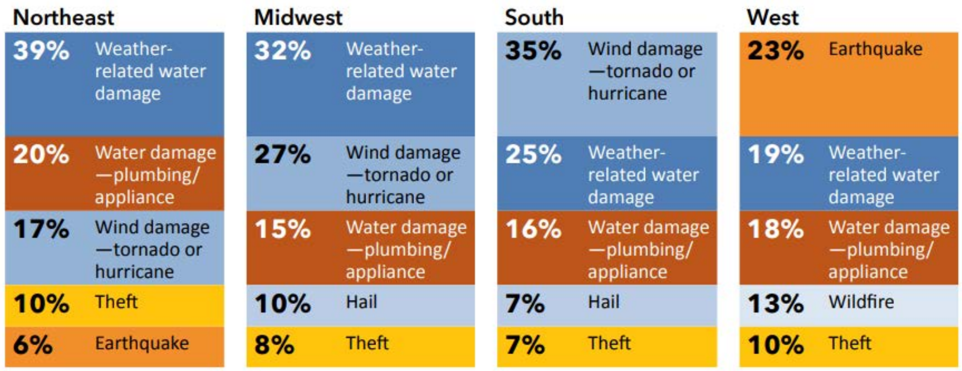
[4]



[1]

This 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.

This 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



[1]

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.

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 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. This reflects the financial implications for homeowners and insurers.

We hope to gain a thorough understanding of the complex relationship between weather-related disasters and property insurance pricing by understanding these fundamental equations. 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 granular data from the Insurance Information Institute [4], serves as the foundation for our research. 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

Given the skewed distribution of disaster cost variables, logs are used. Fixed effects by state and year account for time-dependent differences between states and national trends. We begin by looking at the impact of aggregated disaster activity. The models are then estimated by interacting the disaster measures with peril indicators in order to compare the sensitivity across event types. Quantile regression was also used to determine whether or not effects differ across the premium distribution.

4 Results

4.1 Summary Statistics

Table 4 4.1 presents summary statistics for the premium and disaster data. The disaster measures show substantial variability, highlighting the irregular nature of extremes. Hurricane and flooding perils account for the largest share of overall cost and insured losses.

	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, 3]

4.2 Regression Results

Table 5 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.

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 6 indicate that hurricane and flood disasters have the most substantial impacts on insurance premiums. Specifically, a 10% increase in hurricane or flood Damages are associated with approximately a 0.01% increase in premiums. Severe storms and winter weather also exhibit positive effects on premiums. 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]

5 Discussion

The study found a statistically significant link 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 [2].

However, there are limitations to the data collected. Analytics may benefit from having more granular, address-level 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 catastrophic incidents and rising property insurance premiums - 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 to economic instability for policy interventions like subsidized insurance policies[4], resilience incentives, or residential investments[5] 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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