The Impact of Extreme Weather Events on Property Insurance Pricing

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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 of homeowners to protect their valuable assets through property insurance has 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 carry profound amount of consequences, affecting individual homeowners and the insurance industry as a whole. Homeowners are the ones who typically bear the financial burden of disasters, and face 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 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 is much more waiting to be discovered. Our research is based on valuable insights into the value of previous work (?) 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, NationalInsurance 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)(?), the Insurance Information Institute (III)(?), Aon(?) and the National Association of Insurance Commissioners (NAIC)(?), 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)(?), spans the years from 1980 to 2023. We have organized the data into various temporal segments to facilitate analysis. Table 2 summarizes key statistics from this dataset, offering 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 identify potential patterns.

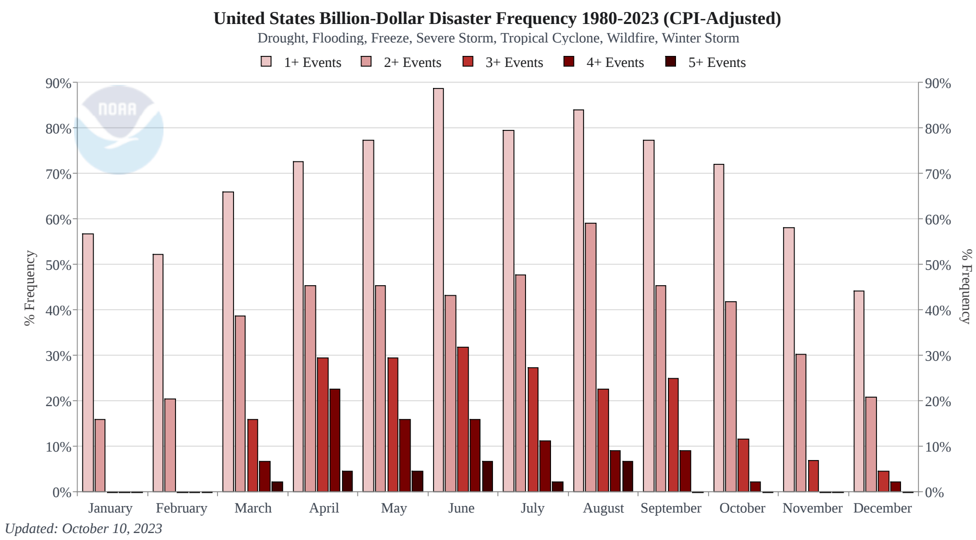
To further examine the financial implications of natural disasters, we turn to the Insurance Information Institute (III)(?). Table 2 for the year 2022 provides a breakdown of catastrophic events by peril, including data on the number of events, fatalities, economic losses, and insured losses. This granular information is essential for understanding the varying impacts of different types of natural catastrophes and their associated costs.

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, 2 or more, up to 5 or more billion-dollar disaster events. The chart helps characterize the concentration and frequency of multiple disasters in a single year.

The Insurance Information Institute (III) (?) also supplies data on insured property

Time Period	Billion-Dollar Disasters	Events/Year	Cost	Percent of Total Cost	C
1980s (1980-1989)	33	3.3	$213.6B	8.1%	
1990s (1990-1999)	57	5.7	$326.8B	12.4%	
2000s (2000-2009)	67	6.7	$604.2B	22.9%	
2010s (2010-2019)	131	13.1	$967.4B	36.7%	
Last 5 Years (2018-2022)	90	18.0	$623.0B	23.6%	
Last 3 Years (2020-2022)	60	20.0	$456.0B	17.3%	
Last Year (2022)	18	18.0	$178.8B	6.8%	
All Years (1980-2023)*	372	8.5	$2,635.1B	100.0%	

Table 1: NEIC: Billion-Dollar Disasters Data
(?)



losses in the United States for the years 2013-2022. Table 2 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.

This figure 1 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 chart 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 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 introduce several key equations that will guide our analysis:

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

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

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

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

(?)

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

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.

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

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.

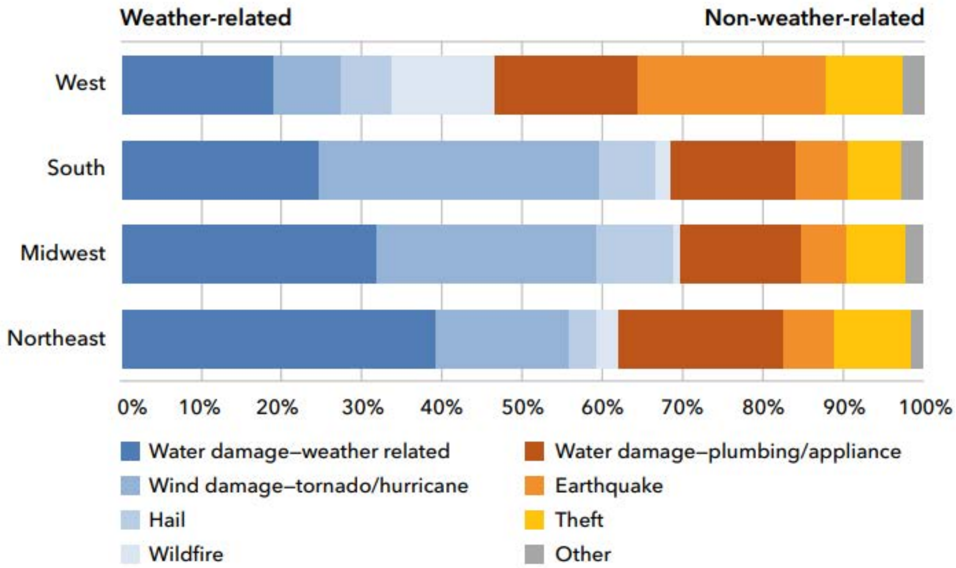


Figure 1:

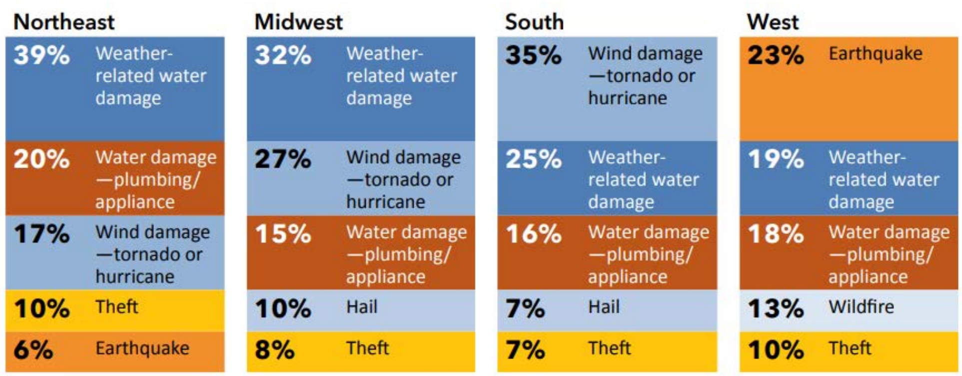


Figure 2:

By having a strong grasp of these fundamental equations, we aim to build a comprehensive understanding of the intricate relationship between weather-related catastrophes and property insurance pricing. These equations serve as the building blocks for our data analysis, enabling us to effectively assess the impact of catastrophic events on property insurance and address our research objectives.

This comprehensive dataset, complemented by granular information from the Insurance Information Institute, forms the foundation for our research. The various temporal segments, along with the key equations, provide the tools necessary to delve deeper into the impact of weather-related disasters on property insurance, thereby enabling us to address our research objectives effectively.

3 Methods

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

Logs are used given the skewed distribution of disaster cost variables. State and year fixed effects control for time-invariant differences across states and national trends. We first examine the influence of aggregated disaster activity. We then estimate models interacting the disaster measures with peril indicators to compare sensitivity across event types. Quantile regression is also used to test if effects differ across the premium distribution.

4 Results

4.1 Summary Statistics

Table 1 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

4.2 Regression Results

Table 2 4.2 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

	(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

Table 5: Regression Results

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.

The results presented in Table 3 (see Table 4.2) indicate that hurricane and flood disasters have the most substantial impacts on insurance premiums. Specifically, a 10% increase in hurricane or flood damage is 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.

	(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

Table 6: Disaster Effects by Peril

5 Discussion

The analysis reveals a statistically significant relationship between extreme weather disasters and homeowners insurance pricing. Results suggest that more frequent and severe events are associated with rising premiums, particularly for hurricanes and flooding perils. This comports with prior findings on the influence of catastrophic losses on insurance markets (**?**).

However, there are limitations when looking at the data collected. Analytics could be better off using more granular, address-level premium data isolate local hazards. The model also fails to treat changes in exposures and vulnerabilities over time as risk factors The risk has increased. Further research should aim to eliminate the impact of changing climate risk information from other luxury consumption measures.

Nonetheless, these findings highlight the interconnectedness of escalating extreme events and property insurance costs. As climate change exacerbates weather extremes, this could create affordability challenges for homeowners and threaten insurance market stability (**?**). Along with mitigation to curb emissions, policy interventions like subsidized insurance, resilience incentives, and home hardening investments could help manage risk and facilitate affordable coverage (**?**). Climate risk modeling and risk-based pricing will also grow increasingly important for insurers to sustainably provide financial protection amid rising extremes.

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