

# Catastrophe Insurance Modeling: An analytical Approach to Property preservation

## Summary

In a world increasingly affected by extreme weather, the insurance industry's role is vital. Yet, property insurance faces challenges, including a significant protection gap and rising costs against catastrophic claims. Our project targets this underwriting decision making and pricing issues, offering measurable standards for property development and strategies for preserving historic buildings.

Firstly, we established a set of assumptions regarding the definitions of the catastrophe insurance and its details settings for the following construction of the pricing model. This model is predicated on the evaluation of insured loss risk, considering the frequency and intensity of relevant disasters. A “small profit but quick turnover” oriented diversified underwriting strategy is used for limiting idiosyncratic risk, thereby reducing potential costs to maintain the long-term cash flow of the insurance company. Considering the bargaining power of the property owner, we introduced Rubinstein equilibrium pricing to determine an appropriate price and make underwriting decisions. Historical climate data is tested for setting the approximate boundary of premium through regression model testing.

Secondly, to make our insurance pricing model positively influences the property developers' asset developing decisions, we introduce the PR ratio. This ratio is derived by dividing the total potential estimated profit by the adjusted insurance premium. It measures the potential return for each additional unit of risk. Our approach involves comparing the PR ratio of a specific project to those of analogous projects, and we recommend the construction of projects with PR ratios above the industry median.

Thirdly, we employ the Analytic Hierarchy Process to determine whether the property requires protection. If protection is deemed necessary, we utilize time series prediction to analyze historical data, aiming to identify specific events and their frequencies. Based on the nature of these events and the specific impairments they cause, we then formulate a corresponding protection plan. Then, we use all the models and approaches formulated above to propose a comprehensive plan for the Forbidden City.

Finally, the advantages and disadvantages of the model are described and summarized, for further improving proposed models.

**Keywords:** Insurance pricing; Bargaining model; Risk sharing and exposure; Underwriting decision; Property preservation

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# 1 Introduction

## 1.1 Background

Climate has always been a major factor influencing human production and life. Over the past few decades, the frequency of extreme weather and natural disasters has increased significantly due to greenhouse gas emissions, change in land usage and many other factors. Extreme weather events cause enormous property damage. Statistics show that from 1980 to 2023, economic losses caused by extreme weather accounted for 59.22% of the total economic losses caused by the world's top 10 natural disasters [1]. Meanwhile, the Americas suffered 79.53% of the total economic losses from the natural disasters that will cause the most economic damage globally in 2022 [2]. From above information, the Americas have one of the worst situations in the world in terms of property damage due to the effect of extreme weather.

Insurance, on the other hand, can be a financially effective response to a changing climate by estimating and pricing climate risk, encouraging risk sharing, and releasing recovery funds when facing a disaster caused by extreme weather [3]. However, property insurance is also bearing an increasing burden of claims due to the frequency of extreme weather. According to statistics, insured losses from natural disasters around the world increased by 25.23% every five years between 1990 and 2023 [4]. The increasing burden of claims has led to a tendency for property insurance to become more expensive and less available.

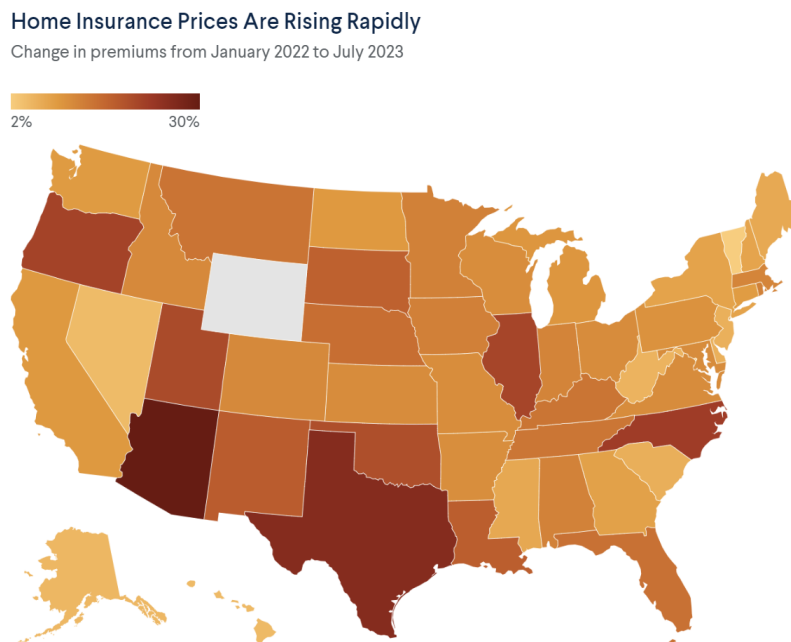


Figure 1: the souring rate of American insurance premium price [5]

Statistics have shown that the Americas accounted for 89.94% of the total insurance payouts in the world's most expensive catastrophes in insurance industry between 1900

and 2022 [6]. Given that the Americas are among the most severely impacted regions globally by extreme weather, such as hurricanes, our research focuses on catastrophe insurance underwriting, pricing strategies, and risk control advisory assessments specific to the Americas

## 1.2 Problems restatement

1. How to predict the probability of certain extreme weather risk?
2. How to predict property losses due to extreme weather and determine the appropriate insurance payout?
3. How to price appropriately to a certain extent? How to assess if current insurance premiums are appropriate for extreme weather risks?
4. How to price appropriately to a certain extent? How to assess if current insurance premiums are appropriate for extreme weather risks?
5. How to measure and quantify the negotiation dynamics between clients and insurance underwriters?
6. How to determine whether property insurance should cover an asset?
7. How property developers measure where, whether, and how to build and develop assets?
8. How to measure the specific level of protection for a given building?

## 1.3 Our work

To provide a systematic approach for insurance companies to innovate and manage risk, a comprehensive procedure is established to guide decision-making. The decision to underwrite catastrophe insurance hinges on the company's ability to accurately estimate potential future insured expenses and price its risk exposure accordingly. The negotiation process with potential customers is also crucial. If the premium is set too high, customer acquisition may be low. Conversely, if the premium is set lower than the expected expenses, the insurance company may choose not to underwrite, presenting a current dilemma in the industry. This procedure aims to balance these factors effectively based on calculating the disaster risk exposure and proper premium. Here is a basic graph representing the above decision steps:

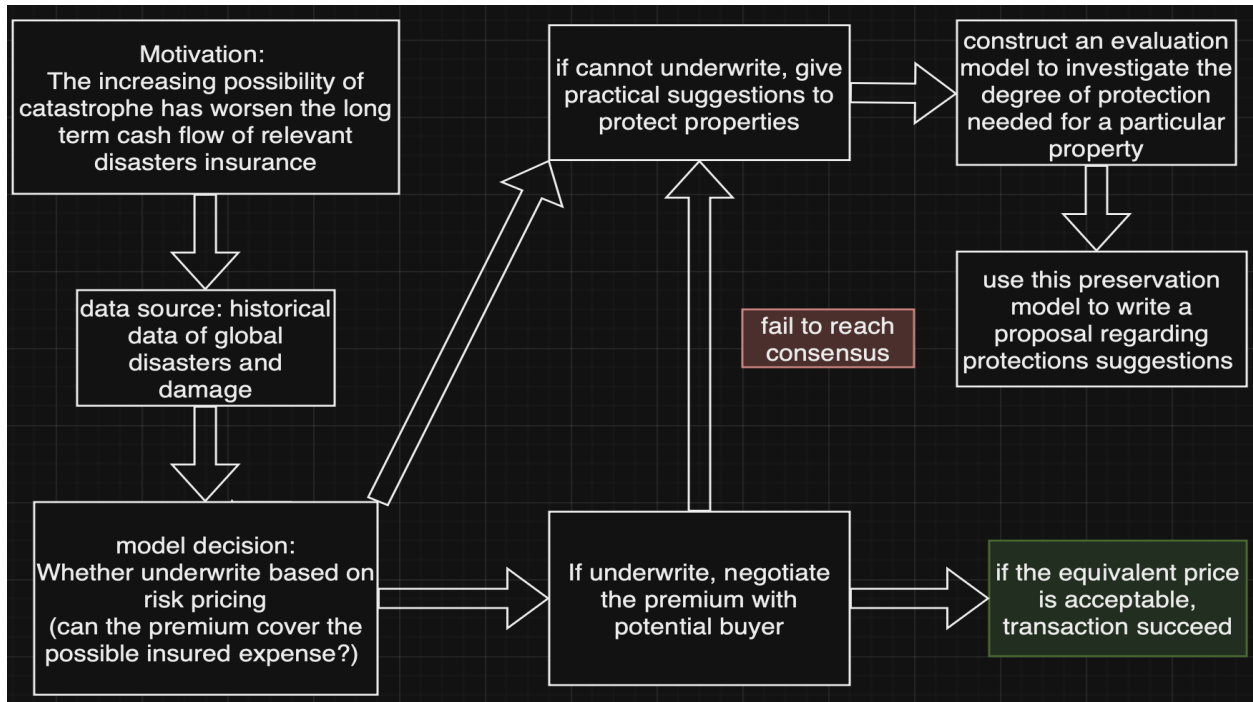


Figure 2: procedure of issuing catastrophe insurance

## 1.4 Notation

Abbreviation	Description	Unit
$n$	total number of insurance sold	/
$\omega$	decision profit generated from each share of insurance	dollar
$TFC$	total long term fixed cost	dollar
$IP_j$	intrinsic price of insurance premium	dollar
$IP_{ik}^{Ac}$	market fair price of p in year i, place k	dollar
$IP^*$	equilibrium insurance price after bargaining with clients	dollar
$TVC$	evaluation of total variable cost of catastrophe insurance	dollar
$PC_j$	price coverage of property j	dollar
$MV_j$	the market value of property j	dollar
$\alpha_i$	damage intensity index	$\alpha \in [0,10]$
$p_i$	year i predicted possibility of the happening of catastrophe	$p \in [0,1]$
$\kappa$	the auxiliary cost of insurance development	dollar
$r$	this pricing interest	percentage
$X_{ij}/x_i$	the total number of disasters in year i (place k)	/
$d_1 d_2$	patience factor regarding bargaining	$d \in (0,1)$
$\phi$	clients' initial ordering price of premium	dollar
$PR_j$	price-risk ratio	/
$EP_j$	expected profit of under-planning project j	dollar
$CF_{ij}$	estimated cash flow of the planned project j at time i	dollar
$VC$	estimated variable cost for planned project j at time i	dollar
$IC_j$	initial construction cost for planned project j	dollar
$\tau$	risk perception factor of property developer	$\tau \in (0, +\infty)$
$DM$	decision matrix of the protection AHP model	/

## 2 Assumption and Justification

Here is a formal elucidation of our property insurance offering and relevant assumption to simplify the model we defined.

1. **General Provisions:** The insurance policy herein is designed to provide protection for real property assets, including buildings, land, and land improvements, against the potential perils arising from severe weather conditions. These conditions include, but are not limited to, cyclonic events (hurricanes, tornadoes, typhoons), floods, heatwaves, wildfires, and extreme cold weather events. The policy aims to mitigate the financial risks our clients may face due to such extreme weather phenomena. This coverage is subject to the terms and conditions as stipulated in the policy document.
2. **Claims and Coverage Exclusions:** Under the terms of this policy, compensation will not be provided for damages or losses that do not directly result from specified meteorological events. This includes, but is not limited to, damages resulting from celestial aerolite impacts, fires attributable to human activities, and significant inherent structural defects within the insured property. These exclusions are fundamental components of the policy's terms and conditions and are non-negotiable.
3. **Premium:** The insurance premium for this policy is levied for once, with coverage commencing on the business day following payment and extending for a period of ten year. Exact premium will be determined and negotiated with policyholder and property owner.
4. **Compensation Provisions and indemnity:** In the event of property damage resulting from extreme weather events, a joint assessment of the degree of damage will be conducted by our team in conjunction with a third-party analyst. The insurance company is obligated to compensate the policyholder for the assessed loss with 1% deductible. The maximum compensation payable under this policy shall not exceed the market value of the insured property as determined within one month of contract inception. These provisions are binding and form an integral part of the policy terms and conditions.
5. **Insurance interest:** For the validity of this insurance contract, the party seeking insurance, herein referred to as the "Insured", must possess a legitimate insurable interest in the property or entity being insured. This insurable interest may be established by ownership, or by any financial interest in the continued existence and well-being of the subject matter of the insurance.
6. **Utmost good faith:** In accordance with the principle of utmost good faith, both the "Insurer" and the "Insured" are obligated to disclose all material facts honestly and completely. Any concealment, fraud, or misrepresentation of such facts may be grounds for the nullification of this insurance contract.
7. **Contribution and Loss Minimization:** If the same subject matter is insured with more than one insurer, the loss is shared proportionately.

### 3 Insurance Pricing Model

#### 3.1 Regional diversified insurance underwriting

*Motivation:* Extreme weather events are characterized by their low probability of occurrence but substantial impact on property. While it's rare for a single extreme weather event to affect the entire United States, it often wreaks havoc on specific regions prone to such conditions, resulting in significant economic losses. If a single insurance company were to cover all these risks, it would likely face bankruptcy due to the massive payouts involved. To avoid this, insurance companies set high premiums for property insurance, aiming to profit from their products. However, many property owners are unwilling to pay these exorbitant premiums. Consequently, insurers must advance premiums to mitigate their risk exposure. As climate change exacerbates weather-related property damage, premiums for property insurance continue to rise beyond expectations, a possible approach is needed to get out of this dilemma.

*Proposal:* Our proposed approach involves developing a standardized pricing rule for all insurance products and all insurance companies, considering the unique characteristics of extreme weather events.

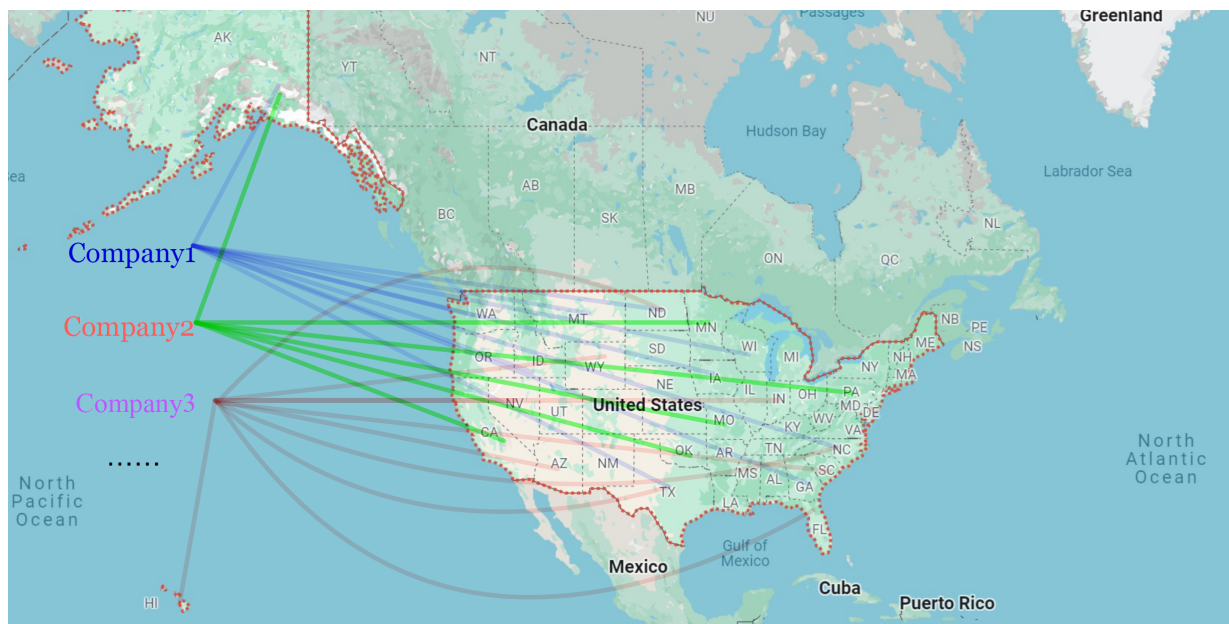


Figure 3: diversified model for insurance underwriting and responsible taking

To eliminate all idiosyncratic risk, a conference comprising all property insurance companies will be convened. Each company will be limited in the issuance of insurance products within a single state, with the requirement to extend their services to various parts of America. The pricing of insurance products for each company will be determined by our pricing model, ensuring that fierce competition is avoided.



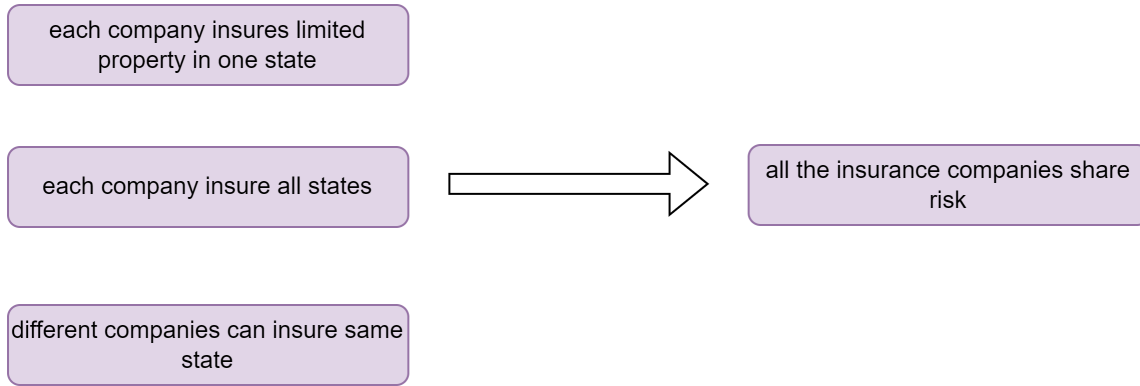


Figure 4: risk sharing model across insurance industry

To further prove this, let us assume an insurance company originally underwriting  $m$  shares of catastrophe insurance in an area with future expected expense  $\mu$  and variance  $\sigma^2$ . Then, in the advanced model, the company underwrite  $m/n$  shares separately in  $n$  areas, implying expected insured expense  $\mu/n$  and variance  $\sigma^2/n$  for each share of insurance. In summation, let the diversify factor  $n$  to be sufficiently large, the uncertainty regarding idiosyncratic risk can be fully diversified away. In particular,

$$\lim_{n \rightarrow \infty} \sum_{x=1}^n \frac{\sigma^2}{n} = 0$$

We want each company would not passively lower premium and raise loss risk for the sake of attracting customers. Due to the intrinsic feature of extreme weather, it is unlikely for a widespread event affects the entire large country especially like America and China, and the maximum extreme weather event coverage will be confined to a single state. By allowing each company to insure only a modest portion of state coverage, the risk of bankruptcy associated with issuing insurance products at relatively low prices is mitigated. This strategy enables more households to afford insurance, fostering a "small profits but quick turnover" model for insurance companies, promoting sustained economic growth.

### 3.2 Intrinsic Value Pricing model

As an insurance company thriving for long term development, the promise of generating stable cash flow is required. In general, the formulated premium price(IP) should be larger than the total variable cost (TVC, including the pricing of future insured expense), generating non-negative profit  $\omega$ .  $\omega$  here is the "planning" profit, which is the decision variable.

$$IP = TVC + \omega \quad (1)$$

By setting different target  $\omega$ , the number of shares  $n$  that buyers would like to purchase should also be influenced based on price perception, which will be discussion in

the following. Hence, our final goal is to optimize:

$$\text{Max } n \times (IP - TVC) - TFC = n \times \omega - TFC, \omega > 0 \quad (2)$$

In case of losing money by setting over low premium of insurance per share, a threshold ought to be determined to reflect the risk undertaken by the insurance company. Here, we use predicted risk exposure valuing model to decide the underwriting process. For the sake of simplicity, we posit that the maximum coverage price of this catastrophe insurance is equivalent to the actual market value of the insured property  $j$  ( $PC_j = MV_j$ ). Furthermore, we set the pricing interest to the risk-free rate  $r_f$ , given that the risk pricing has been incorporated into the risk factor  $\alpha_i$  and  $p_i$ . Moreover,  $\kappa$  is the auxiliary variable cost generated from the process of issuing insurance, including development fee, salary, administration fee and etc. For simplicity, we let it be proportional to the risk pricing kernel below, say,  $\kappa = k \times \text{risk\_pricing\_kernel}$ .

This is the fundamental formula for assessing the cost evaluation of potential catastrophes and their associated damage:

$$\begin{aligned} TVC &= \text{risk\_pricing\_kernel} + \text{auxiliary\_cost} = (PC_j \times \sum_{i=1}^n \frac{E(\alpha_i/10)p_i}{(1+r)^i}) + \kappa \\ &= (PC_j \times \sum_{i=1}^n \frac{E(\alpha_i/10)p_i}{(1+r)^i}) \times (1+k), i \in N^* \\ \text{s.t. } PC_j &= MV_j, i \in N^* \end{aligned} \quad (3)$$

This inherent premium pricing model is predicated on the frequency of historical catastrophes ( $p_i$ ) and the extent of damage intensity ( $\alpha_i \in [0, 10]$ ). The latter is quantified on a continuous scale from 0 to 10, derived from the cost of repairs (money loss), since we want to emphasize it is the possible monetary disaster damage that should be concentrated on rather than other details. The quantification function is defined by  $\alpha = 10 \times \frac{\ln(\text{damageloss}) - \min(\ln(\text{damageloss}))}{\max(\ln(\text{damageloss}))}$ , natural log function is used here to adjust the extreme value for simplicity. Known  $\alpha$  and  $p_i$ , TVC can be properly priced.

### 3.3 Evaluation of disaster occurrence based on data

According to the collected historical catastrophes of America from 1900 to 2023, the following figure shows the number of extreme weather events of each year and its responsive intensity  $\alpha_i$ .

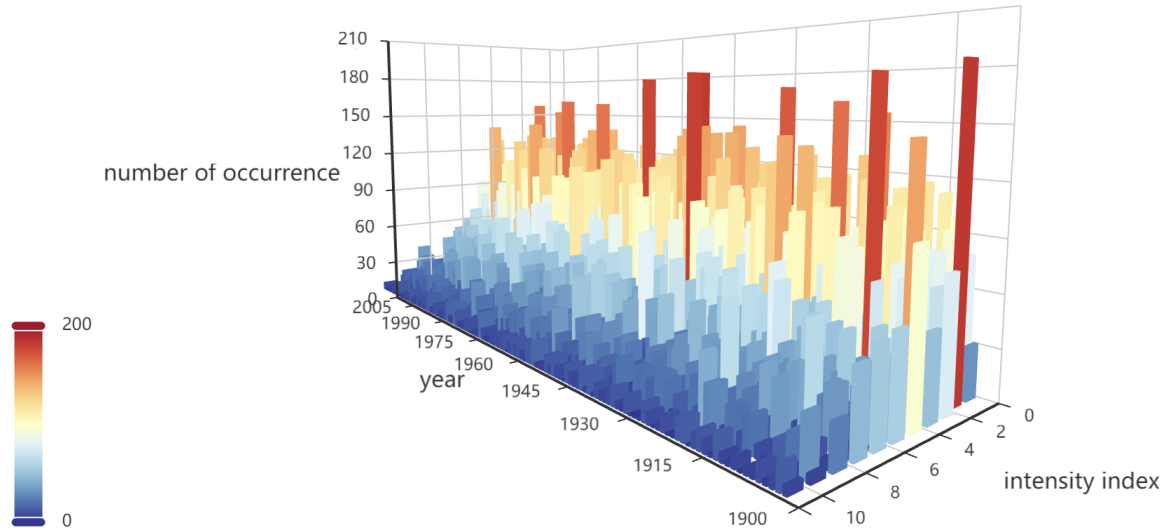


Figure 5: intensity index  $\alpha_i$  of catastrophes in the past centuries

In order to price property insurance, we need to figure out  $p_i$ .  $p_i$  is the adjusted probability that insurance company need to compensate policyholder. We have amassed a comprehensive disaster dataset spanning from 1900 to 2023, encompassing the intensity of various events and their corresponding frequencies. The compensation that an insurance company is required to provide to a policyholder is represented by  $X$ . An analysis of the data from 1900 to 2000 reveals that, on average, 3.2 out of every 500 extreme weather events necessitate compensation from the insurance company to the policyholder across the entire country. We postulate that climate change will incrementally increase  $X$  by 0.1 percent annually, starting from the year 2000. This assumption takes into account the potential impact of climate change on the frequency and severity of extreme weather events. Then,  $P_i = 1.01^i \times 0.0064$

### 3.4 Comparison model based on empirical regression

In 3.4, we have already got the model to evaluate the total future variable cost by using formula (3). From this formula, we can estimate the  $c$  (IP) of certain property insurance. This section uses a comparison model to evaluate  $\omega$ , which denotes profits generated from each share of insurance.

#### 3.4.1 General procedure

In this comparison model, we first derive a linear regression equation for property insurance prices from a global perspective using worldwide data. This is followed by a linear regression estimation of U.S. property insurance prices using local U.S. data, denoted by  $\hat{IP}_{ik}^{Ac}$ . After deriving this value, we compare  $\hat{IP}_{ik}^{Ac}$  with IP and use the difference to derive the  $\omega$ -value.

Given that our previous research models and insurance strategies are limited to the United States. We need to expand the applicability of our pricing model. We regressed the worldwide (including U.S.) data to formulate a pricing function for property insurance. Given that property insurance claims are primarily concerned with property damage, for the sake of simplicity, we focus only on the total property damage and the total number of catastrophes caused by extreme weathers suffered by an area each year rather than on specific types of catastrophes. The regression model is able to capture the potential damage to properties caused by extreme weather. This regression analysis is more comprehensive and robust than directly quoting existing U.S. insurance price data. The general regression model we adopted is established

$$IP_{ik}^{Ac} = \beta_0 + \beta_1 X_{ik} + \beta_2 \sum_{i=1}^i \alpha_i + \delta \quad (4)$$

Where,  $IP_{ik}^{Ac}$  is the value of insurance actual price in year  $i$ , place  $k$ .  $X_{ik}$  denotes the total number of overall disasters in year  $i$ , place  $k$ .  $\alpha_{ik}$  denotes the summation of disaster intensity index in year  $i$ , place  $k$ .

### 3.4.2 Data Acquisition and Processing

To obtain  $X_{ik}$ : We collected data on the total number of disasters for a given area per year worldwide. The data is cleaned and processed to ensure quality and usability. To get the damage intensity index: We used a mapping function to convert the property damage caused by each disaster to a value in a continuous closed interval from 0 to 10, which is the damage intensity index. The point of this procedure is to regularized and quantify the property damage. We utilize a large data set containing global data for model training. Through parameter optimization and model evaluation, we obtain relatively accurate models that capture the variation in insurance prices across regions and years.

### 3.4.3 Application of U.S. Data

We applied existing U.S. data about the total number of disasters and damage intensity index to formula P, generating  $\hat{IP}_{ik}^{Ac}$ . This is the value of a specific U.S. property insurance price in a global perspective under current global conditions. By arguing in the previous section, our insurance pricing model formula (3) calculates an insurance price that should be lower than  $\hat{IP}_{ik}^{Ac}$ .

### 3.4.4 Evaluation of $\omega$ range based on regression

We compare  $\hat{IP}_{ik}^{Ac}$  with our intrinsic premium (IP) formula (3). As we know From here, we derive the range of values of  $\omega$ . The practical significance of this range is the extent to which  $\omega$  (i.e. profit generated from each share of insurance) can be taken to reasonably reduce the cost of the U.S. property insurance market yet contribute to the sustainability of the insurance industry.

### 3.5 Bargaining Model and Underwriting decision making

Notice that although insurance company has the dominant power to price for their catastrophe insurance service, consumers also have the bargaining ability to bargain for the finding the proper price, which gives pressure to our decision profit  $\omega$ . Using Rubinstein bargaining model, we can find the final equivalent value  $IP^* = TVC + \omega^*$ , where  $IP^* \leq EIP$ . After bargaining, the company will decide to whether underwrite the insurance based on the bargain price under constraint  $\omega^* > 0$ .

The assumption of insurance price utility function for company and clients:

$$\begin{aligned} \text{for company, } U_1(IP) &= IP - p_i * \frac{\alpha_i}{10} * MV_j \\ \text{for client, } U_2(IP) &= E[\text{totalearning} - IP + p_i * \frac{\alpha_i}{10} * MV_j] \\ IP^* &= \arg \max_{IP} [U_1(IP) - U_1 d_2(IP) - U_2 d] \end{aligned} \quad (5)$$

, where  $U()$  denotes the corresponding utility function and  $d_1, d_2 \in (0, 1)$  are discount factor measuring the patience of bargaining for insurance company and its clients, usually,  $d_1 < d_2$ . Let us denote the initial ordering price clients is  $\phi$ , the initial price for insurance company is the regression fair value  $\hat{IP}_{ik}^{Ac}$  mentioned at 3.4. Then, according to Rubinstein balance model[7], the equilibrium price is:

$$IP^* = \frac{(1 - d_2) * (\hat{IP}_{ik}^{Ac} - \phi)}{1 - d_1 d_2} + \phi \quad (6)$$

Known the final ordering price, the insurance company then can decide whether underwrite with clients. If  $IP^* > TVC$ , implying  $\omega^* > 0$ , underwrite. Otherwise, do not underwrite.

### 3.6 Section Conclusion

In this section, we develop three distinct models to properly determine the appropriate pricing of catastrophe insurance premiums. These models are grounded in an analysis of historical disaster data and associated risk exposures. Furthermore, we introduce a mechanism that enables the property buyer to negotiate the premium price. This introduces a bilateral pricing process that mirrors real-world scenarios, thereby enhancing the robustness of our pricing model. This approach ensures that our model is not only theoretically sound but also practically applicable.

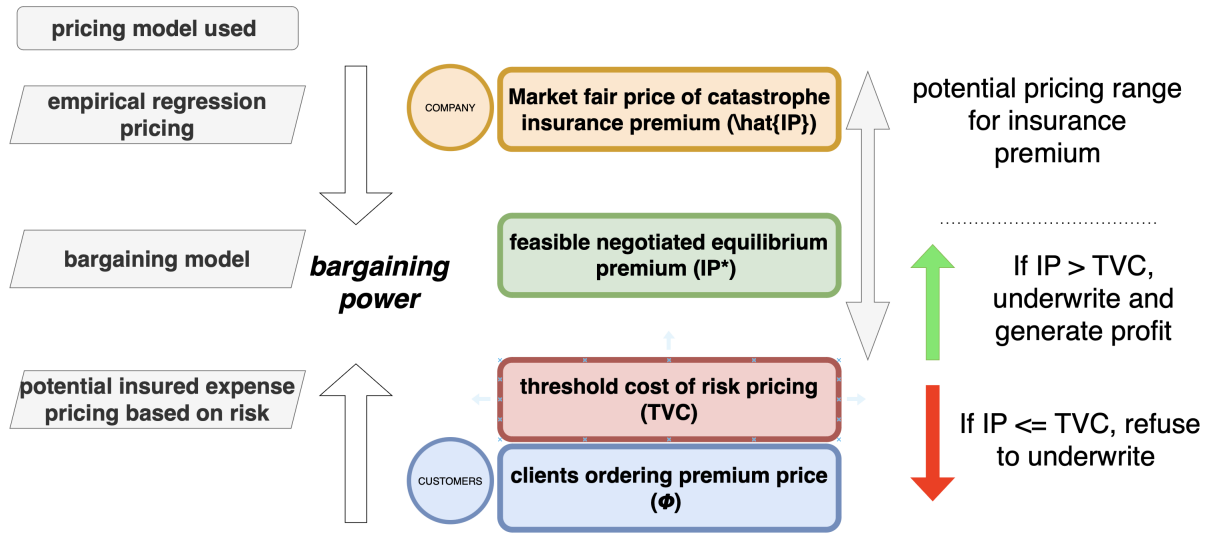


Figure 6: general procedure of premium pricing

## 4 Evaluation for Property Developer

In this section, we focus on how to quantify decisions regarding developer approval and denial of construction. We introduce the Profit per Risk (PR) ratio, designed to assess the feasibility of project development. The decision to approve or deny construction can be made by comparing the project's PR ratio to the distribution of similar projects in the U.S..

### 4.1 Introduction to PR ratio

We use Estimated Profit ( $EP$ ) to assess the potential profitability of a project in a given region if it is built at a given time. The calculation of  $EP$  involves the aggregation of discounted potential future cash flows, deduct the aggregation of discounted initial construction costs and discounted future variable costs, to obtain an overall view of potential profits. We use the risk free rate to denote the discount rate. Formula is established:

$$PR_j = \frac{ER_j}{IP_j * \tau_j} = \frac{\sum_{i=1}^m \frac{CF_{ij}}{(1+r)^{ij}} - \sum_{i=1}^m \frac{VC_{ij}}{(1+r)^n} - IC_j}{IP_j * \tau_j} \quad (7)$$

The PR ratio is calculated by dividing the  $EP$  by the product of the calculated value of the premium and the risk perception factor ( $\tau$ ) specified by the customer. Here,  $\tau$  measures the level of risk aversion of a client. A higher  $\tau$  means a lower risk tolerance, implying more profit is expected for penalizing the increase of risk premium ( $IP$ ). This factor can be customized according to the client's specific utility function and risk appetite, ensuring a personalized risk and profit assessment. A visualization of the level of risk perception is shown below:

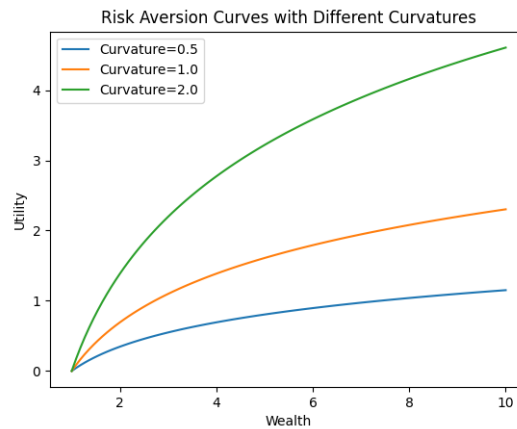


Figure 7: risk averse degree of property developer

## 4.2 Decision and Comparison model

A higher PR ratio indicates a more favorable balance between estimated profit and associated risk, making the property more suitable for development. The PR ratios of planing property are then compared to the distribution of PR ratios for similar projects in U.S.. This comparative analysis helps to assess the relative risk and profit potential of the project among similar projects. If the project's PR ratio exceeds the median for similar projects, it is considered worthy of construction; if it is below the median for similar projects, the asset is not recommended for construction.

**Provided suggestions for real estate developer:** If the projected  $PR_j$  for the target project exceeds the industry average, and the premium magnitude aligns with their financial constraints, it is advisable to initiate or expand the new project  $j$  in the specified area. The subsequent figure provides a comparative analysis of the estimated PR ratio for the proposed project against other analogous projects within the industry. Here, groups 1 to 5 represent the 0-25%, 25-50%, 50-75%, and 75-100% percentiles of projects, respectively, ranked according to their corresponding PR ratios. This comparison offers a comprehensive view of the project's potential return relative to industry standards. The following graph is a demonstration calculated through the formula[7], in this circumstance, we accept this potential project:

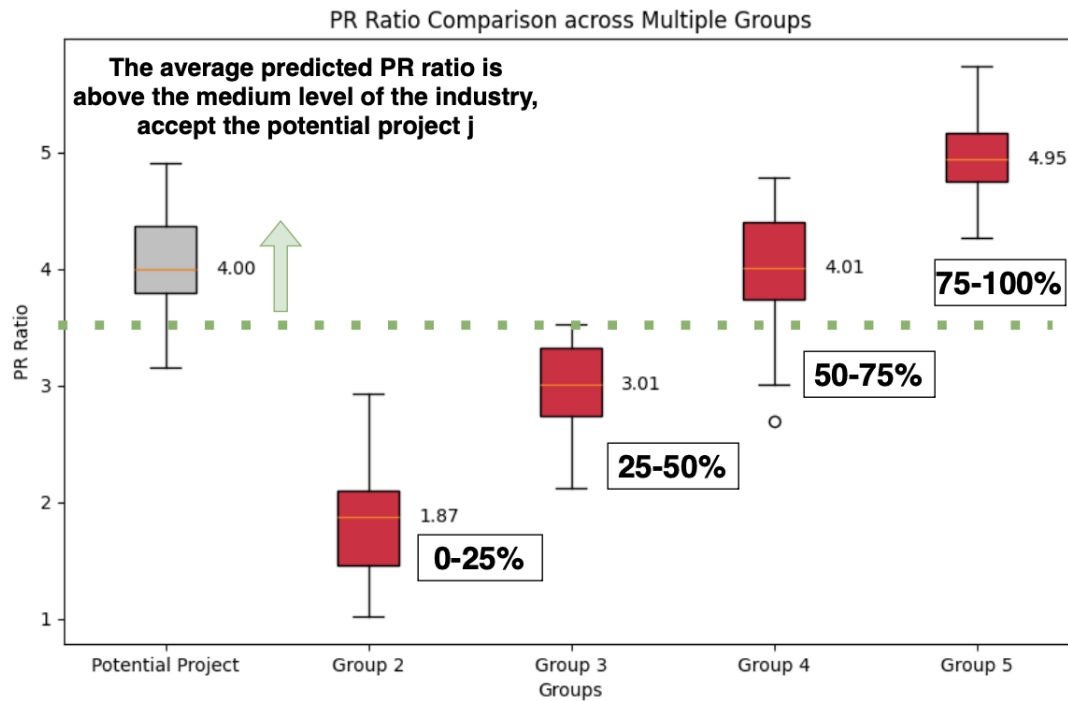


Figure 8: comparison of the PR ratio of the proposed project with similar industry projects.

## 5 Identification and Preservation model for Community Leader

Our initial step is to determine whether a property requires protection. If it does, we then apply human intervention and make necessary improvements based on the specific type and frequency of events.

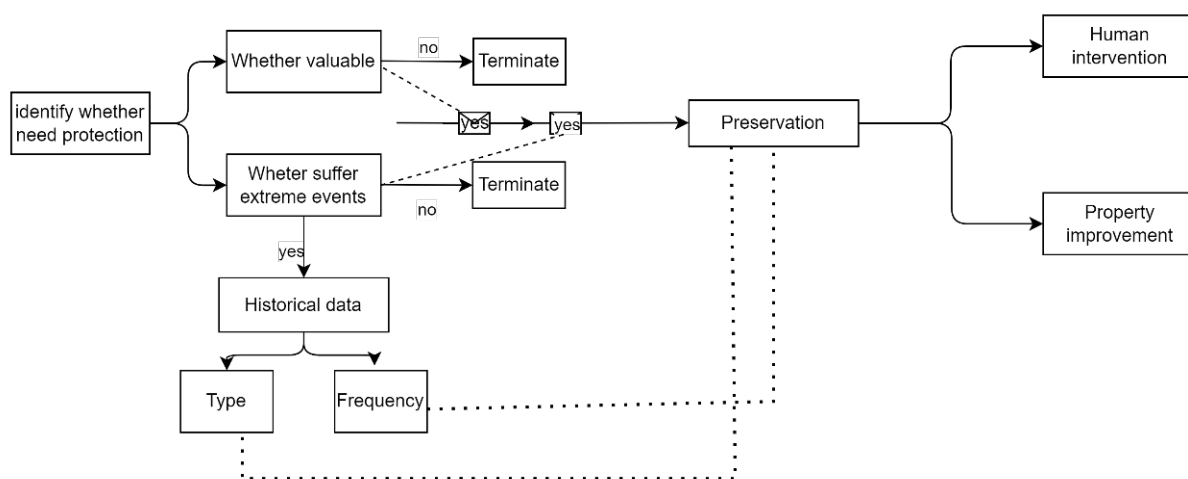


Figure 9: model procedure



## 5.1 Identification model

This section aims to identify buildings that require protection. We begin by assessing their value, considering factors such as historical, cultural, or economic significance. If a building holds substantial value, it warrants special attention. Next, we evaluate whether these buildings are vulnerable to extreme weather events. Factors such as location, structural integrity, and exposure play a crucial role in determining their susceptibility. By understanding both value and vulnerability, we can prioritize protective measures and ensure the preservation of these important structures.

- Cultural value: influence on tradition (a)
- Historical value: landmark age(b)
- Economic value: revenue from tourism(c)
- Community: use in community events and sense of belongings (d)

To identify their importance, we adopt The analytic hierarchy process (AHP). The comparison matrix and the corresponding weight we get is

$$DM = \begin{bmatrix} / & a & b & c & d \\ a & 1 & 4 & 3 & 7 \\ b & 1/4 & 1 & 1/3 & 3 \\ c & 1/3 & 3 & 1 & 5 \\ d & 1/7 & 1/3 & 1/5 & 1 \end{bmatrix}$$

with geometric mean  $\begin{bmatrix} \bar{a} \\ \bar{b} \\ \bar{c} \\ \bar{d} \end{bmatrix} = \begin{bmatrix} 3.03 \\ 0.71 \\ 1.50 \\ 0.31 \end{bmatrix}$  and Normalised weights =  $\begin{bmatrix} 0.55 \\ 0.13 \\ 0.27 \\ 0.06 \end{bmatrix}$ , where the  
geometric mean =  $(x_1 x_2 \dots x_n)^{1/n}$ .

In practice, we use an index analysis to analyze whether a building should be protected. **For each building, we evaluate and map four indices onto discrete closed intervals from 1 to 10. We then multiply these mapped indices by their corresponding weights. This gives us the total protectable value of the building.** We took Economic value = 2, Cultural Value = 2, Historical value = 2, and Community value = 3 as assessment thresholds. The total protectable value threshold based on these indices was calculated to be 2.08. In other words, any building with a total protectable value above 2.08 would be protected, otherwise it would not be protected. We use the Eiffel Tower to demonstrate this model. The Eiffel Tower has a value of 7 for all four items, which gives a total protectable value of 7.07. This value is greater than 2.08, so appropriate protection measures should be taken.

## 5.2 Protection of extreme weather events

The prediction of extreme weather events in a specific area relies on historical data. Typically, we observe recurring patterns and trends based on past occurrences. By analyzing historical records, we can infer potential future occurrences and prepare accordingly. Climate change further complicates this landscape. As our planet warms, the frequency and intensity of extreme weather events are expected to escalate. Heatwaves, intense storms, prolonged droughts, and rising sea levels are among the anticipated consequences. Therefore, proactive measures—such as improved infrastructure, early warning systems, and sustainable urban planning—are crucial to mitigate the impact of these events on communities and safeguard lives and property. Due to historical record of this area, we find major events are heat wave and sandstorm.

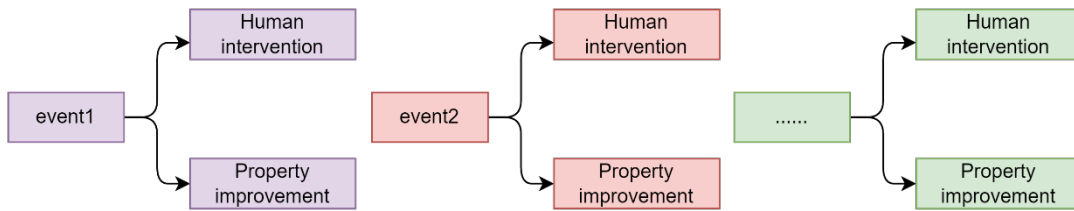


Figure 10: multi-thread event planning model

The preservation of a property is a multifaceted process that can be influenced by various events. This process can generally be categorized into two main strategies:

**Human Intervention:** This involves actions taken by individuals to protect and maintain the property. For instance, one could plant more trees around the property to create a natural barrier against environmental factors. Additionally, artificial cooling systems could be installed to regulate the property's temperature and create a more controlled environment.

**Property Improvement:** This strategy focuses on enhancing the physical aspects of the property itself. This could involve strengthening the structural integrity of the property, such as consolidating the walls to ensure they are robust and durable. Furthermore, it could also include upgrading the equipment within the building to improve its functionality and efficiency.

In essence, these strategies aim to preserve the property by mitigating potential threats and enhancing its overall condition. By implementing these measures, we can ensure the longevity and preservation of the property.

## 5.3 The application of evaluation model

### 5.3.1 A proposal letter

# PRESERVATION PROPOSAL

**To:** Forbidden City office

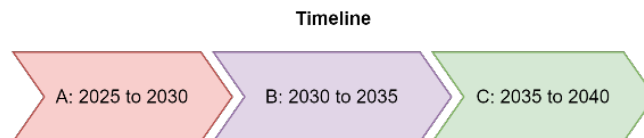
**From:** MCM Team 2411176

**Subject:** preservation suggestion

**Date:** February 5, 2024

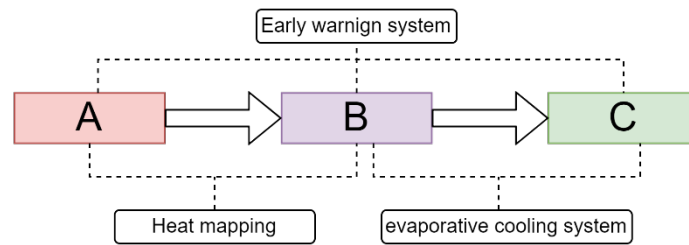
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Dear Secretary, We, at the I&P Institution, specialize in identifying extreme weather events that pose threats to landmarks and proposing solutions to mitigate their impact. Our data analysis reveals that Beijing has been experiencing severe heatwaves from May to October since 2010. The Forbidden City, with its immeasurable cultural and historical significance, is a crucial landmark in China. Our value model rates it at 9.5 out of 10. However, due to the acceleration of climate change and extreme weather events, there's a 20% probability that the Forbidden City could suffer 10% damage by 2050. Given its estimated economic value of over 150 trillion US dollars, insurance companies are hesitant to cover such a risk. Therefore, we strongly recommend taking action to protect this invaluable human treasure.



Our proposed plan, spanning from 2025 to 2040, is divided into three steps. Considering the Forbidden City's vast area of 720,000 square meters (with a construction area of 150,000 square meters), we suggest dividing it into three parts for effective management.

We aim to install an early warning system that can predict heatwaves in the Forbidden City and a heat mapping system to monitor any abnormal heat that could damage the palace. We plan to continue the installation of the heat mapping system and begin the installation of an evaporative cooling system. This system uses the high specific heat of water to lower the temperature without damaging the walls and roofs of the palace. We plan to complete the installation of the evaporative cooling system before 2040.



Cost		
Heat mapping system	Equipments	7 million
Early warning system	Equipments	15million
Evaporative cooling system	Equipments	30million
Humanity resources	500 engineers 1000 others	200million

The total investment for this project is estimated to be 252 million, with 52 million allocated for equipment and 200 million for human resources. We look forward to your support in preserving the Forbidden City for future generations. Best Regards, I&P Institution

## 6 Conclusion

### 6.1 Strength

This practical model reasonably calculates catastrophe premiums using various formulas that assess risk exposure from global historical data. It defines a clear threshold by linking the premium to potential future insured expenses. As climate change intensifies, a diversified insurance underwriting model is developed to mitigate the unsystematic risk of catastrophes, making it applicable to real-world scenarios.

The pricing model serves as a guide for real estate developers in decision-making, particularly when initiating or expanding projects with limited risk protection. The model simplifies complex decisions into manageable tests, streamlining the insurance underwriting process and providing a clear path to problem-solving and long-term profit optimization for insurance companies. Moreover, the preservation model's ease of implementation is based on the evaluation of multidimensional factors, further enhancing its utility in the insurance industry.

### 6.2 Weakness

The current model, while effective in certain assumption scenarios, does not account for specific data inputs such as nuanced weather changes and individual case analyses. In practice, catastrophe insurance pricing is heavily influenced by prior insured losses in a specific area. Our model, for the sake of simplicity, focuses on evaluating and predicting risk based on historical disaster data for each large location, rather than delving into detailed case studies. This approach may lead to an over-generalization issue, potentially diminishing the accuracy of our pricing. Furthermore, the data set used for testing does not sufficiently represent the complex global circumstances, which is another limitation of our model.

## 7 References

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## 8 AI report

### Report on Use of AI

OpenAI ChatGPT (Feb 4, 2024 version, ChatGPT-3.5)

Query1: <Polish these words: Given that our previous research models and insurance strategies were limited to the United States. We need to extend the applicability of the pricing model. We regress global (including U.S.) data to develop a pricing function for property insurance. Given that property insurance claims are primarily concerned with property damage, for simplicity we focus only on the total property damage suffered by a region and the total number of catastrophes caused by extreme weather each year, rather than specific types of catastrophes. The regression model captures the potential damage to property caused by extreme weather.> Output: <Given that our prior research models and insurance strategies were confined to the United States, it is imperative to broaden the applicability of the pricing model. We aim to expand the scope by incorporating global (including U.S.) data to formulate a comprehensive pricing function for property insurance. Considering that property insurance claims predominantly revolve around property damage, for the sake of simplicity, we concentrate solely on the overall property damage sustained by a region and the total number of catastrophes induced by extreme weather each year, instead of delving into specific types of catastrophes. The regression model adeptly captures the potential property damage resulting from extreme weather conditions.>

Query2: <Polish these words: In order to maximise the insurance company's profit, we take an upper bound on  $w$  (denoted by  $w_0$ ) to calculate equation (3). Note that  $w_0$  is not our final answer, and there will be further bargaining between the customer and the insurance company. With the assurance that the insurer's revenue is positive and the customer agrees to pay the price, the choice of  $w$  between the two parties decreases from  $w_0$  to the equilibrium value  $w^*$ . There are two possibilities for this.> Output: <To optimize the insurance company's profit, we impose an upper bound on  $w$ , denoted as  $w_0$ , for the computation of equation (3). It's crucial to emphasize that  $w_0$  does not represent our final solution, as subsequent negotiations will take place between the customer and the insurance company. With the assurance that the insurer's revenue remains positive and the customer consents to the proposed pricing, the selection of  $w$  undergoes a reduction from  $w_0$  to the equilibrium value  $w^*$ . This transition between the two parties can manifest in one of two possible scenarios.>

Query3: <Polish these words: We apply the total number of catastrophes and damage intensity index data available for the U.S. to Equation P to generate the  $IPikAC$  hat, denoted by  $EIP$ . This is the value of a given U.S. property insurance price on a global scale under current global conditions. As demonstrated in the previous section, our insurance pricing model, Equation X, calculates an insurance price that should be lower than the  $IPikAC$  hat.> Output: <Utilizing the available data on the total number of catastrophes and the damage intensity index in the U.S., we employ Equation P to compute  $IPikAC$  hat, symbolized as  $EIP$ . This represents the value of a specific U.S. property insurance price on a global scale within the current global conditions. As illustrated in the pre-

ceding section, our insurance pricing model, denoted as Equation X, yields an insurance price that is expected to be lower than the calculated  $\hat{IPikAC}$ .>

Query4: <polish these words:Climate has always been an important factor affecting human production and life. Over the past few decades, the frequency of extreme weather and natural disasters has increased significantly as a result of greenhouse gas emissions, changes in land-use patterns and many other factors. Extreme weather events have caused enormous property damage. Statistics show that from 1980 to 2023, economic losses caused by extreme weather accounted for 59.22Output: <Climate has consistently played a pivotal role in shaping human production and daily life. However, in recent decades, the incidence of extreme weather events and natural disasters has witnessed a substantial rise due to factors such as greenhouse gas emissions and alterations in land-use patterns. This surge in extreme weather occurrences has resulted in considerable property damage. According to statistics spanning from 1980 to 2023, economic losses attributed to extreme weather constituted 59.22

Query5: <Polish these words:On the other hand, insurance can be an economically effective response to a changing climate by estimating and pricing climate risks, encouraging risk sharing, and disbursing recovery funds in the face of disasters caused by extreme weather [3]. However, due to the frequent occurrence of extreme weather, the claims burden of property insurance has become heavier. According to statistics, insured losses due to natural disasters worldwide will increase by 25.23Output: <Conversely, insurance stands out as an economically efficient strategy in addressing the impacts of a changing climate. This is achieved through the assessment and pricing of climate risks, the promotion of risk-sharing mechanisms, and the efficient distribution of recovery funds in the aftermath of disasters triggered by extreme weather [3]. However, the escalating frequency of extreme weather events has substantially heightened the claims burden within the realm of property insurance. Statistics reveal a concerning trend, indicating that insured losses resulting from global natural disasters are projected to surge by 25.23