Evaluation Study of a New Insurance Model for Extreme Weather

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Abstract. With the impact of climate change, extreme weather and natural disasters occur frequently around the world, which brings great challenges and pressure to the insurance industry. This paper focuses on how to establish a new insurance model adapted to different regions and types of disasters to assist insurance companies on the basis of catastrophe modeling and proposes to construct a value assessment model. This paper discusses how to assess catastrophe insurance risks in different regions to help insurance companies make decisions. In this study, disaster-related data of 146 countries and regions around the world were collected. The probability of occurrence of natural disasters is modeled using Poisson distribution, and the excellent rate of the loss ratio coefficient reaches above 0.9. The disaster insurance risk assessment (DIRA) model is established and risk factors are introduced to solve the problem. Taking storm disasters in the United States and earthquake disasters in China as examples, we found that under the critical value of 20%, insurance companies can provide insurance if the risk factor is greater than the critical value.

Keywords: Extreme Weather; Delphi Method; Poisson Distribution; Risk Assessment.

1. Introduction

As climate conditions continue to change, extreme weather and natural disasters are occurring more frequently around the world [1]. In the past few years, the rising number of claims for natural disasters has cot the insurance industry more than $1 trillion. These events make the development of the property insurance industry face extremely severe challenges, mainly including:

The huge financial pressure caused by the rapidly rising cost of insurance, which is expected to grow by 30-60% by 2040.

Re-evaluation of risk and pricing strategies to ensure business sustainability.

Because of the difference in the world's climate conditions, the global insurance protection gap has further expanded.

Owner's affordability crisis, it is difficult to find the suitable property insurance products.

Against this backdrop, the property-casualty insurance industry is concerned about sustainability and wants to find a more efficient property-casualty insurance model that will allow the system to flexibly cover future claims costs while ensuring the long-term health of insurers.

The Insurance Risk Indicator can effectively assess and manage risks and improve risk prediction, insurance pricing, financial soundness and customer service. The system integrates multi-dimensional information such as geography, weather, claims, construction and customers, enabling insurance companies to have a comprehensive understanding of the probability of occurrence and losses of various risks. This risk assessment helps companies diversify risks, select reinsurance partners, innovate insurance products, and respond to risk changes. At the same time, it is also in line with the company's social responsibility and sustainable development and gives it an advantage in market competition.

To this end, we need to establish an insurance risk indicator that is applicable to multiple countries and regions and covers several key indicators. First, we need to consider the frequency and severity of natural disasters, such as earthquakes, hurricanes and floods. Second, we need to assess risks to

buildings and infrastructure, such as structural strength and fire. At the same time, we need to consider adaptation to climate change and measure the ability to cope with extreme weather [2-3].

Ability to cope with extreme weather. Factors such as economic stability, government support and regulation, and the level of development of the insurance market also need to be considered. Combining these factors, we can establish a cross-country and cross-region insurance risk indicator to provide a more accurate risk assessment tool for the insurance industry [4].

2. The fundamental of data analysis

Different disaster scenarios require separate analysis of risk assessment models for policies, as they differ significantly in terms of incidence, impact and losses. Each disaster, such as earthquakes, hurricanes, floods, etc., has its own characteristics that affect damage to buildings and infrastructure, risk and economic losses. By comparing different catastrophe scenarios, we can better understand how risk factors change and enhance the predictive power of models. This also helps insurance companies design more effective risk management strategies, make targeted decisions for specific disaster types, protect customers, rationalize pricing, and ensure sustainable business development [5].

We use the Poisson distribution to model the probability of a natural disaster occurring. The Poisson distribution describes rare events in fixed time or space. Natural disasters, such as earthquakes and hurricanes, are relatively rare and infrequent over short periods of time. The Poisson distribution also assumes that events are independent, meaning that one event does not affect another. This usually applies to natural disasters in a particular region or time period. The Poisson distribution applies to discrete count situations, such as the number of occurrences per unit of time, which is how we count natural disasters. In some cases, the Poisson distribution is a simple and useful method for modeling the probability of natural disasters [6-7].

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Step1. Disaster frequency estimation

Using the characteristics of Poisson distribution, we need to construct a basic model for the frequency of natural disasters under extreme weather conditions:

$$P\left(X=k\right)=\frac{\lambda^{k}}{k!}e^{-\lambda} \tag{1}$$

Where k is the number of natural disasters that occur per unit time, λ is the average occurrence rate of disasters. The probability of k natural disasters is $P(X = k)$. So, we can calculate the probability of the number of natural disasters in a certain period when data from countries and related regions is provided [10].

Step2. Regional risk-taking model

We also need to establish a regional risk-taking model, considering whether local buildings and infrastructure have the ability to resist disasters and how fragile they are. Assuming that the losses of buildings, infrastructure, etc. are related to their structure and seismic resistance, the following simplified regional risk-taking model can be used:

$$L = \beta \cdot E \cdot n \cdot V_b + \beta_0 \tag{2}$$

Where L is the loss caused by the disaster, β is the coefficient of the loss ratio, E is the seismic grade, n is the number of buildings, V_b is the value of the building, and β_0 is the fixed loss. This model can be used to calculate the loss of buildings and infrastructure in a certain region when a disaster occurs.

Step3. Establishing a probabilistic risk assessment model

We can use the above two models to establish a probabilistic risk assessment model. The model can be used to calculate the probability of natural disasters and the loss of buildings and infrastructure in a certain region. This model can be used to assess the risk of natural disasters in a certain region and provide a basis for insurance companies to make decisions.

$$E(L) = \sum_{k=0}^{\infty} P(X = k) L_k \tag{3}$$

Where $E(L)$ is the expected loss, $P(X = k)$ is the probability of k natural disasters, and L_k is the loss of buildings and infrastructure when k natural disasters occur. This model can be used to calculate the expected loss of buildings and infrastructure in a certain region when a disaster occurs.

In order to enable insurance companies to decide whether to underwrite locally, it is neces- sary to introduce a standard for their judgment. So we introduced the insurance risk factor F for calculation, the formula is (4).

$$F = \frac{a * P - E(L)}{P} \tag{4}$$

Where F is the insurance risk factor, α is the underwriting capacity parameter of an insurance company is related to its own situation (such as company size, operating status, etc.). In the model, we will randomly generate data between 0 and 1 to simulate the underwriting capacity of the insurance company, P is the insurance premium, and $E(L)$ is the expected loss. This model can be used to calculate the insurance risk factor of a certain region and provide a basis for insurance companies to make decisions.

3. The establishment of data analysis

3.1. Results resource

This article is primarily from the following website: 'Our World' and forms a raw data file.This file contains natural disaster data for the United States, China, and Japan. These three countries have high economic and technological levels and enjoy a high international reputation. At the same time, they are also countries with frequent natural disasters, which can provide us with rich data. We have selected natural disasters that are more representative of the region, such as storms and wildfires in the United States, floods and droughts in China, and earthquakes and volcanoes in Japan. In this paper, we study the disaster data information and its trends from 1950 to 2022 in these three countries in terms of the number of deaths, economic losses, the scope of impacts, and insurance payouts. Based on these comprehensive data, better simulation results are obtained.

Of course, the lack of data is expected. In order to make the data more complete, we manually filled in the blank data. After running the corresponding code, this paper obtained a modified xlsx file of the data and visualized each column and selected country. Some of the results are shown in Figure 1 below. We chose China and the United States for analysis in disaster risk assessment and model

testing. These two countries have developed insurance markets and financial systems, which can provide a large amount of historical data for the model. In addition, China and the U.S. have complex geological and climatic conditions and a wide range of natural hazards, such as earthquakes, hurricanes, and floods, which makes the models more generalizable. Finally, the governments of the two countries have also given strong support to the field of insurance and risk management, including opening and sharing data, formulating relevant policies, and promoting technological innovation, which creates a favorable environment for the construction of disaster risk models. In conclusion, choosing China and the United States as the model analysis region is conducive to the establishment of a comprehensive and accurate disaster risk assessment model.

Before starting the simulation, we need to make additional model parameter assumptions based on the situation in the United States: The building value V_b follows a normal distribution of 200000 to 1000000.The disaster resistance level is a total of nine levels from 1 to 9, and the model is set to level 3. The number of buildings n follows a normal distribution of 50-100.

We first discretize the variables for the total economic losses caused by storm disasters in the processed data of the United States, and measure the economic losses caused by a storm disaster in the United States using the average of all years, which is about 1.6e+10. Then, we divide the total economic losses data by each economic loss to obtain the number of storms that occur in each year and draw a distribution histogram as shown in the following figure 2.

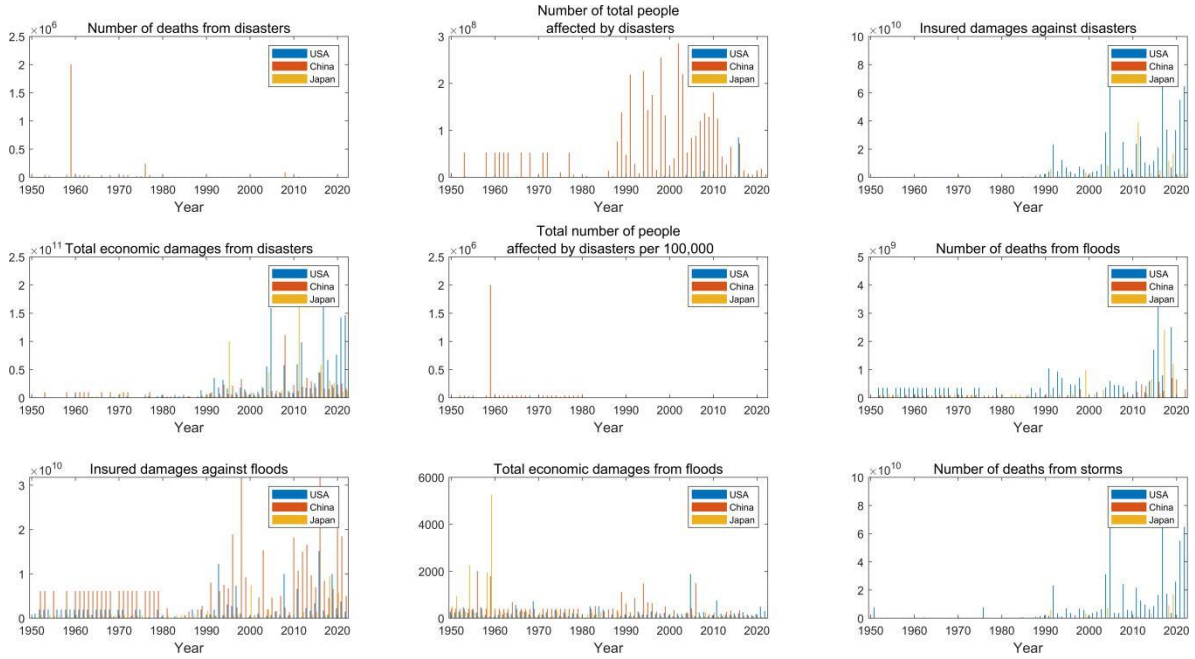


Figure 1: Data Processing Results

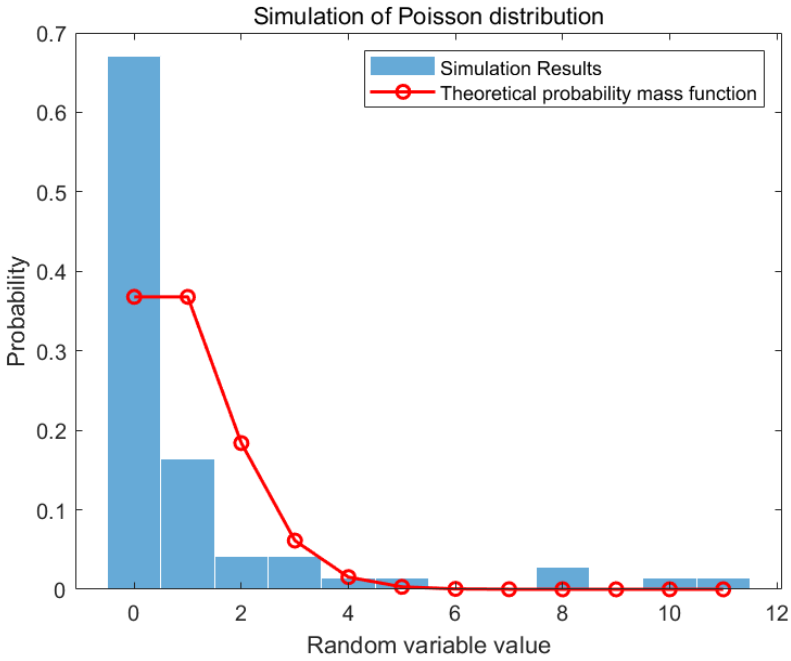
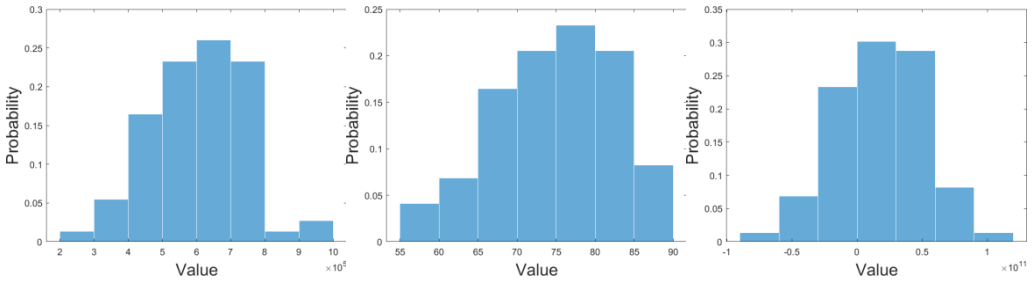


Figure 2: Simulation of Poisson distribution

After generating a normally distributed random number, we can also generate a histogram of the building value, number of lost houses, and total annual economic losses that follow a normal distribution, as shown in figure 3. According to Formula (2), obtain the loss proportion coefficient through fitting β, the fitting results are shown in the following Figure 4, with a goodness of fit of over 0.9. Finally, according to formula (3), the economic expected loss E (L) caused by storms in the United States each year from 1950 to 2022 is calculated as shown in the following Figure 5.

The annual risk coefficient caused by storm disasters in the United States is shown in the following figure by calculating the risk coefficient. The red line represents the dividing line of 20% profit for insurance companies, and the red line above indicates that the insurance company's profit has reached 20% and can be insured. In addition, we will continuously increase the premium P charged by the insurance company according to E (L) -2E (L). It can be seen that as the premium P increases, the profit of the insurance company also increases. Therefore, the higher the premium charged by the insurance company, the higher the corresponding underwriting profit obtained.



(a) Building value (b) Lost houses (c) Economic losses

Figure 3: Histogram of Normal Distribution Random Numbers for Parameters

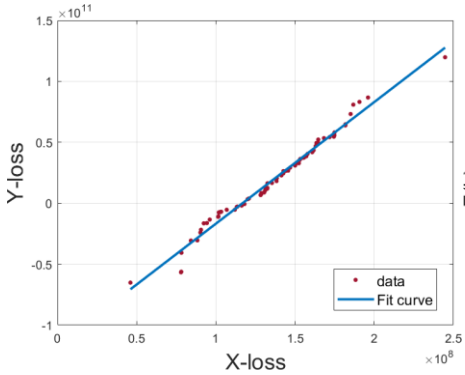


Figure 4: Fitting curve of losses

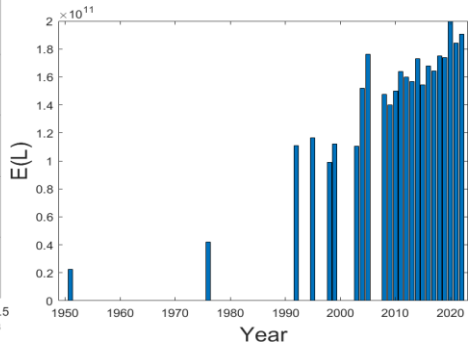


Figure 5: Economic expected loss

4. Conclusions

Under complex environmental conditions, insurance companies need to design new insurance models to determine whether they should underwrite. New assessment indicators are introduced based on relevant data from different regions and client groups to ensure that insurance companies can reasonably underwrite. With the impact of climate change, extreme weather and natural disasters occur frequently around the world, which brings great challenges and pressure to the insurance industry. Based on the research content of catastrophe model, this paper provides a reasonable modeling tool for premium setting of insurance salary for different countries and different types of disasters, which facilitates the research of corresponding price designation in its later stage. In this paper, the Delphi method (Delphi method) is used to analyze and propose a building value assessment model, which facilitates its work in the later stage of research using this policy.

References

[1] WU Zhongqun, ZHENG Ruijin, XU Feiyang, HUANG Ren, DONG Fugui, YANG Chan,FENG Xiaoying. Electricity price risk management based on weather derivatives under extreme weather scenarios[J]. Global Energy Internet,2024,7(01):66-78.

[2] Bie Zhaohong,Li Gengfeng. Risk assessment and resilience enhancement of new power systems under extreme weather conditions[J]. Global Energy Internet,2024,7(01):1-2.

[3] TIAN Yanfen, JIANG Zhidan,LIU Yang. Study on international commodity risk spillover under extreme conditions[J]. Financial Development Research,2023, (12):80-88.

[4] Liu Ling. Extreme risk contagion between international financial markets and RMB onshore and offshore exchange rates[J]. Economic Problems Exploration,2024, (01):67-75.

[5] ZHANG Shuai,Abduwali Aibai. The impact of extreme weather on regional financial risk[J]. Finance and Economy,2024, (01):30-40.

[6] ZHANG Yi, ZHENG Hao, SUN Fengxia, WEI Li, MO Xiaojiao, GE Ming,XIONG Lilin.A study on the impact of extreme temperatures on the volume of residential emergency medical consultations and attributed risks in Nanjing from 2020 to 2022[J]. Modern Preventive Medicine,2023,50(22):4077-4082+4129.

[7] Cui Yun Qi. Risk analysis and countermeasure research on urban flooding in extreme rainstorms[J]. Heilongjiang Environmental Bulletin,2023,36(08):24-26.

[8] ZHOU Bolun, WANG Yingzhong,WANG Yiming.ETF net worth tail risk, arbitrage behaviour and constituent stock correlation[J]. Shanghai Finance,2023, (11):15-32.

[9] ZHOU Yingying, REN Shuo,BU Lin. Tail risk spillovers and their drivers in Chinese commodity futures[J]. Financial Development Research,2023, (10):13-24.

[10] LI Li, WU Shimei, CHEN Zhenzhu. Extreme weather risk and macroeconomic volatility: A dual perspective based on network linkages and spatial spillovers[J]. Financial Research,2023, (09):58-75.