Financial Engineering and Risk Management (2024) **DOI: 10.23977/ferm.2024.070421**
Clausius Scientific Press, Canada **ISSN 2523-2576 Vol. 7 Num. 4**

Research on insurance underwriting risk based on entropy weight method and break-even analysis

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Keywords: Entropy Weight, Break-Even, Underwriting Risk

Abstract: In order to help insurance companies decide whether to cover areas with increasing extreme weather events, this paper selects 5 primary indicators and 15 secondary indicators, and constructs a natural risk assessment model based on entropy weight method (EWM), and applies it to China's Yangtze River Delta region and Ecuador. Through literature research, five main aspects affecting insurance assessment were identified: risk exposure, vulnerability, emergency response and recovery ability, and disaster loss, and 15 most representative secondary indicators were selected from 81 related indicators to build a model. Based on the entropy weight method, the weight of each index is determined by standardizing the original data, calculating information entropy and information redundancy, and an evaluation vector and an impact vector are formed to quantify the impact of different factors on the overall result. The risk assessment standard adopts the ALARP principle, divides the risk into unacceptable risk area, reasonable acceptable risk area and widely acceptable risk area, and combines the risk factor ρ to build a risk matrix to evaluate the positive and negative impacts of natural disasters. Two regions experiencing extreme weather events are selected for case analysis: the Yangtze River Delta and Ecuador. The ρ value of the Yangtze River Delta is 0.57, which is a reasonably acceptable risk area and suitable for insurance companies to cover, but it needs to accurately assess the risk and determine the premium pricing. With a ρ value of 0.93, Ecuador is an unacceptable risk zone and is not suitable for insurance companies due to its frequent occurrence of high-risk natural disasters, which may require higher premiums or may not provide full coverage.

1. Introduction

Extreme weather events have a profound impact across the globe, causing trillions of dollars in property damage and placing enormous claims pressure on insurance companies. In recent years, the world has suffered more than $1 trillion in damage stemming from more than 1,000 extreme weather events.

In 2022, the insurance industry reported a 115% increase in natural disaster-related claims over the average of the past 30 years. As the effects of climate change continue, losses from extreme weather events such as floods, hurricanes, cyclones, droughts and wildfires are expected to increase further in the future [1].

At present, there are few studies on whether insurance companies take out insurance in areas with frequent natural disasters. This paper puts forward three innovations to improve insurance companies' insurance decisions in areas with frequent natural disasters. Firstly, a multi-dimensional risk assessment model is constructed to comprehensively consider natural disasters, social and economic factors. Secondly, determine the risk assessment criteria to accurately evaluate the risk level of the disaster. Finally, a personalized risk assessment strategy is developed to optimize the insurance plan according to different regions and customer needs.

2. Establishment of Insurance Model

2.1. Quantification of the risk of natural disasters

2.1.1. Indicators determination

When a natural disaster occurs in a certain region, the impact of insurance assessment can be mainly divided into five main aspects: risk exposure, vulnerability, emergency re-sponse and recovery ability, and disaster loss. Therefore, we took it as a first-level indicator and considered 81 official relevant indicators in combination with the literature, ultimately retaining the 15 most representative second-level indicators to build our model [2][3].Risk assessment indicator map is shown in Figure 1.

Figure 1: Risk assessment indicator map

For the convenience of subsequent articles, the following indicators are abbreviated, as shown in Table 1.

Table 1: Index reduction

Primary Index	Abbreviated Index	Primary Index	Abbreviated Index
Annual precipitation	AP	Percentage of sown area under crops	PSC
Plant cover	PC	Number of medical and health insititutions	MHI
River Network density	RND	GDP per caption	GPC
Urbanization rate	UR	Percentage of illiterates	PL
Population density	PD	General buget expenditure of local finance	GEF
Building density	BD	Direct economic loss	DEL
Economic density	ED	Crops affected area	CA
Number of young and old people per unit area	YOA		

2.1.2. Weight Calculation--EWM

Based on the entropy weighting method, it can objectively determine the weights of each indicator [4],

Step 1: Standardized raw data. The number of evaluation indicators is set to n and the number of evaluation units to m, where i=1, 2, 3, ..., n; j=1, 2, 3, ..., m. The formulas for positive and negative indicators, respectively, are as follows:

$$Z_{ij} = (x_{ij} - x_j^{\min})/(x_j^{\max} - x_j^{\min}) \tag{1}$$

$$Z_{ij} = (x_j^{\max} - x_{ij})/(x_j^{\max} - x_j^{\min}) \tag{2}$$

Step 2: Calculate the information entropy and information rms. The information entropy value of the j-th indicator is given by Eq:

$$E_j = -\frac{1}{\ln m}\sum_{i=1}^{m} z_{ij}\ln z_{ij} \tag{3}$$

Where m is the m th indicator m=1,2... 15.

Based on information entropy, it will further calculate the weights, defined for each evaluation indicator as follows:

$$W_j = \frac{1-E_j}{\sum_{j=1}^{n} E_j} \tag{4}$$

Step 3: The weights obtained form a vector and are called the "evaluation vector", which can be expressed as:

$$\overline{\Psi} = Evaluationvector_x = [weight1, weight2, weight3, ...] \tag{5}$$

Each weight represents the evaluation or importance of the corresponding factor. Such evaluation vectors can be used for a variety of purposes;

The influence degree of different aspects is formed into a vector, and it is called the "in-fluence vector", which can be expressed as:

$$f^T = Influencevector_x = [Influence1, Influence2, Influence3, ...] \tag{6}$$

Among them, the impact vector is a concept derived from related literature, and each impact represents the impact degree of the corresponding factor on the whole. The specific impact value should be defined and assigned according to the situation in order to better quantify the impact of different factors on the overall result.

Therefore, the final evaluation value is

$$Underwrite_x = \overline{\varphi} \cdot f^T = Evaluationvector_x \cdot Influencevector_x \tag{7}$$

Where x is risk, exposure, vulnerability, emergency response and recovery capacity and disaster loss.

2.1.3. Natural disasters quantitative outcome

As our first-level indicator system is divided into five dimensions: risk, exposure, vul-nerability, emergency response and recovery ability, and disaster loss, we apply EWM to each of these 5 dimensions and objectively obtain the weights of each indicator, which are shown in Figure 2 [5].

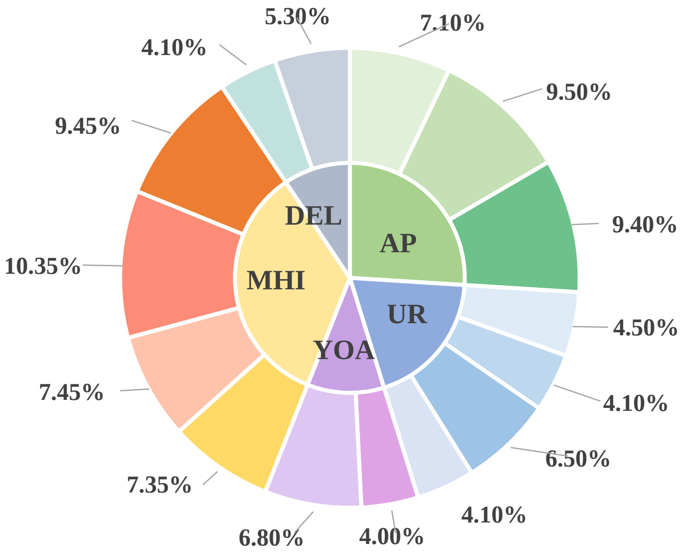

Figure 2: The weights of each indicator

2.2. Risk assessment

2.2.1. Risk Assessment Criterion--ALARP

Risk is the uncertainty between investments and benefits over a period of time in the fu-ture. The ALARP (as low as reasonably practicable) criterion is a common criterion for risk assessment and is still widely used for the selection of acceptable risks and the development of reasonable risk control plans [6][7].

The ALARP criterion divides risks into three zones: unacceptable, reasonably acceptable, and widely acceptable, as shown in Figure 3.

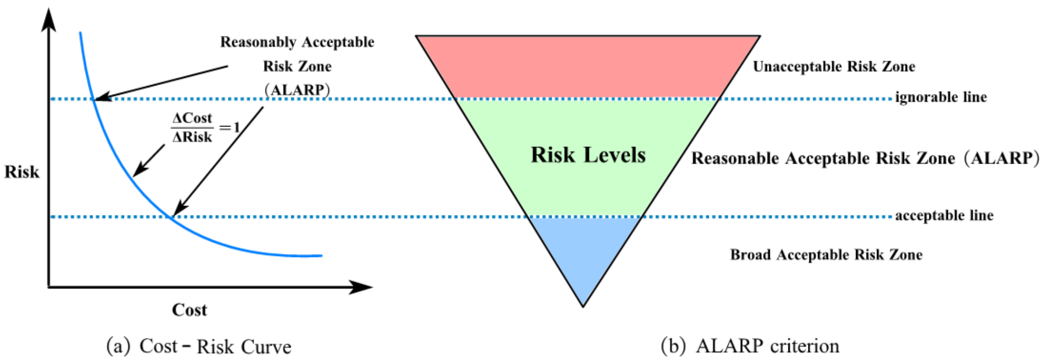

Figure 3: Diagram of risk assessment criterion

Top -- high risk, that is, intolerable risk area, because the risk is too high to be accepted or tolerated, the severity of the risk must be reduced to an acceptable area at all costs, otherwise, unless special circumstances, the opportunity should generally be abandoned to avoid the loss.

Middle -- Located between the top and bottom, it is called the acceptable risk zone, or ALARP zone, where the risk should be controlled to a level that is "(as) low and rea-sonably feasible", or "reasonably, realistically, and as low as possible".

Bottom -- low risk, that is, an acceptable area of risk. The risk of falling in the bottom area is quite tolerable due to its low level of risk. Therefore, where the risk falls into this area, there is no need to take special risk prevention and control measures.

2.2.2. Risk Factor ρ

In the above model, natural disasters have a negative impact on the socioeconomic level, while they may also have some positive effects. The paper believes that the risk of natural disasters arises from the interaction between positive and negative impacts [8].

The paper builds up a risk matrix:

$$Exposures_{(mn)} = \begin{bmatrix} ex_{11} & ex_{12} & \cdots & ex_{1n} \\ ex_{21} & ex_{22} & \cdots & ex_{2n} \\ \vdots & \vdots & & \vdots \\ ex_{m1} & ex_{m2} & \cdots & ex_{mn} \end{bmatrix}_{m \times n} \tag{8}$$

To make the model more reasonable, we define $Qpositive_i^{+}$, $Qnegative_i^{-}$:

$$Qpositive_i^{+} = \left| \sum_{j=1}^{n} (ex_{ij} - ex_j^{+}) \right| \tag{9}$$

$$Qnegative_i^{-} = \left| \sum_{j=1}^{n} (ex_{ij} - ex_j^{-}) \right| \tag{10}$$

In order to make $Sproximity_i^{+} = \dfrac{Qnegative_i^{-}}{Qnegative_i^{-} + Qpositive_i^{+}}$, Combined with the above content can be obtained:

$$\rho = \frac{n \sum_{i=1}^{m} Sproximity_i^{+}}{\ln n} \tag{11}$$

Combining risk assessment criteria ALARP and risk factors, we get the following risk assessment criteria:

$$\rho = \begin{cases} Broad\ Acceptable\ Risk\ Zone & , \quad 0 \sim 0.32 \\ Reasonable\ Acceptable\ Risk\ Zone & , \quad 0.32 \sim 0.87 \\ Unacceptable\ Risk\ Zone & , \quad else \end{cases} \tag{12}$$

3. Case Study

In this section, two regions experiencing extreme weather events on different continents were selected to demonstrate the model and determine whether an insurance company should cover them.

The data for the Yangtze River Delta are from the China Statistical Yearbook (2023), and the data for Ecuador are from the World Bank Open Data.

3.1. Relevant information about the two regions

The Yangtze River Delta: It is an important economic region in China, and its climate is subtropical monsoon climate. In summer, the Yangtze River Delta region is often affected by strong heat waves, the temperature may exceed 40 degrees Celsius, and the hot weather may last for a long time, bringing adverse effects on the human body and production activities. In addition, there is a lot of precipitation in the re-gion in a year, and in summer, the influence of monsoon humid air will lead to fre-quent heavy rain weather, which may lead to flood disasters [9].

Ecuador: It is a country located in the northwest of South America, consisting of the mainland on the equatorial line, the Galapagos Islands, and the Galapagos islands in the Pacific Ocean. Due to its geographical location and geomorphological features, Ecuador is often at risk of multiple natural disasters and extreme weather events.

The relevant data of the Yangtze River Delta and Ecuador are shown in Table 2.

Table 2: Relevant index data of the two regions

Secondary guidelines	Yangtze River Delta	Ecuador		Secondary guidelines	Yangtze River Delta	Ecuador
AP	1243	2685		PSC	32.83%	18.37%
VC	37%	50.32%		MHI	106005	20451
RND	1.82	0.79		GPC	170000	46470
UR	87%	64.60%		PI	1.74%	4.80%
PD	3000	72		GEF	10411.827	5628.6975
BD	22.70%	12.47%		DEL	2477	3750
ED	61.74%	3.36%		CA	5500	7975
YOA	58.7	26.8				

3.2. Analysis of results

The Yangtze River Delta: After calculation, the ρ value of the Yangtze River Delta is 0.57--a Reasonable Accepta-ble Risk Zone, indicating that insurance companies can underwrite policies in this region.

Because the Yangtze River Delta region faces extreme weather such as typhoons, heavy rains and floods, these weather phenomena can lead to huge property losses and claims. Therefore, insurance companies need to carry out accurate assessment of these risks to deter-mine the feasibility of insurance coverage and the pricing of premiums. But for residents and businesses in the Yangtze River Delta, understanding the risk to them from extreme weather means recognizing the need for insurance. So the underwriting risk in that region is in the ac-ceptable zone.

Ecuador: The ρ value of Ecuador is calculated to be 0.93 --unacceptable Risk Zone, indicating that insurance companies are not allowed to write policies in this region.

Because Ecuador is located in a high plateau region of the Andes Mountains, it is often at risk of earthquakes, volcanic eruptions and other natural disasters. These extreme weather events can lead to the destruction of homes, loss of property and threats to life. Given these risks, there may be difficulties in providing insurance in the region. Insurers may need higher premiums to cover potential risks, or may not even be able to provide comprehensive cover-age.

4. Conclusions

The insurance underwriting risk model established in this paper can effectively evaluate the underwriting risk in a region with frequent extreme weather. The main conclusions are as follows:

1). Validity verification:

The insurance underwriting risk model established in this paper has been effectively verified in areas with frequent extreme weather. By practical application, the model successfully evaluates the underwriting risk in two specific regions, and shows the reliability of its evaluation effect.

2). Risk assessment results:

The Yangtze River Delta region has a risk coefficient of 0.57, which is within the acceptable range, meaning that insurance companies can provide insurance services in the region.

In contrast, Ecuador has a risk factor of 0.93, which is outside the acceptable range and it is not recommended that insurance companies provide insurance services in the region.

3). Promotion significance:

The simplicity of the model makes it of great significance to popularize, and insurance practitioners can easily understand and apply the model.

This provides insurance companies with a convenient tool to better assess and manage risks under extreme weather conditions, thereby improving the accuracy and efficiency of business decisions.

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