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Location Evaluation Based on AHP-TOPSIS Model

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ABSTRACT

Extreme-weather events bring a large scope of influence, cause a large degree of loss and a wide range, how to design a model that is both economical and effective in the evaluation and preservation of landmark buildings has aroused our attention. We firstly use AHP-TOPSIS-FCEM Model to establish comprehensive risk expression for four kinds of Extreme-weather events and weight them as comprehensive meteorological disaster risk assessment factors; we establish vulnerability analysis expression from the economic and social perspectives, and then combine the two to obtain comprehensive insurance risk index, which can be used as the trigger condition of index-based insurance. Then the insurance company's profit model is established: there is a functional relationship between the insurance company's premiums and claims among and the comprehensive insurance risk index. Our model has excellent evaluation decision-making functions, and the integrated disciplines as well as comprehensive factors make it highly practical, which can be extended to evaluation decision-making in investment, urban planning, and other fields in the future with the addition of variable rate adjustment and optimization of missing data values.

KEYWORDS

Evaluating Decisions; AHP-TOPSIS- FCEM Models; Insurance Models

1. INTRODUCTION

The occurrence of extreme weather events can lead to severe casualties and property damage, and Extreme-weather events account for a significantly higher proportion of insured losses than other insured events [9]. The low frequency and high loss characteristics of extreme weather events make them difficult to be mathematically predicted by the law of large numbers or the central limit theorem, so the catastrophe model adapted to it came into being, and some of the insurable catastrophe risks are derived from catastrophes. In recent years, the attention of the index-based insurance has been increasing, which shows that people are more and more concerned about compensating for the losses caused by catastrophes through insurance.

Weather index insurance products, which can be used to transfer various weather-related risks [2]. However, the huge losses caused by catastrophe risk make it difficult for many insurance companies to claim for the relevant coverage, so they raise premiums or refuse to underwrite, although index-based insurance can reduce moral hazard and adverse selection to a certain extent, but the existence of a large basis risk is still a major defect of index-based insurance. To date, the global insurance protection gap of more than half, which is not only detrimental to the innovation and healthy development of the insurance industry, but also unable to meet the needs of consumers. So the development of reasonable and economical underwriting solutions for insurance companies is an urgent problem. As a real estate developer, accurate prediction of the frequency and extent of disasters can provide good guidance for their choice of location or building materials, effective insurance products can help to reduce the risk of loss after the occurrence of a loss. As for real estate developers, accurate prediction of the frequency and extent of disasters can provide good guidance for the selection of sites and building materials, and effective insurance products can provide timely financial compensation after losses occur. As for community managers, reasonable prediction of disasters can provide better decision-making ideas for the preservation of historical sites.

As disasters are unpredictable, the prediction of risks and accidents, as well as the development of insurance and conservation models crucially, we need to try our best to contribute to the development of these model.

2. LITERATURE REVIEW

In foreign countries, the research on index-based insurance started earlier and developed rapidly. For example, Smith, R. C., & Watts, M. (2012). In The role of index insurance in agricultural risk management: A review. Journal of Risk and Insurance, the potential of index insurance in managing catastrophic risks in developing countries is explored, and they emphasize the role of this insurance product in improving the efficiency of resource allocation and promoting agricultural development. resource allocation efficiency and promote agricultural development; Marr, A., Winkel, etc. (2016). In Adoption and impact of index-insurance and credit for smallholder farmers in developing countries: a systematic review. agricultural finance review, the role of index-insurance in microfinance is analyzed, noting that it contributes to improving smallholder farmers' access to credit and promotes financial inclusion; in Africa, index-insurance research and practice is particularly active. For example, in Index-Based Insurance and Microfinance in Ethiopia, Dercon and Holmes (2009) show how index-based insurance can help farmers manage risk and improve their resilience to climate change through an empirical study in Ethiopia. These studies not only focus on the economic effects of index-based insurance, but also explore its potential impacts in terms of social welfare and sustainable development.

In China, the research on index-based insurance started late but developed strongly. In Review of Research Progress in Agricultural Index Insurance, Tingting Yang, Xinli Liu, Yuan Bai, and Tao Ye (2022) reviewed the research progress of agricultural index insurance at home and abroad during the period from 2000 to 2020. They pointed out that China's development in the field of index-based insurance has gone through a process from piloting to promotion, especially under the dual impetus of policy support and market demand. The study also highlights challenges in product design, risk assessment and market acceptance.

Overall, domestic and foreign studies on index-based insurance show a diversified trend. Foreign studies focus on the theoretical framework, product design and empirical analyses of index-based insurance, while domestic studies focus more on its application in the specific context of China.

3. ESTABLISH INSURANCE MODEL

3.1. Demand Analysis and Goal Setting

Extreme-weather events that may occur in a region are various, and they can cause loss of people's lives and property, which have a significant impact on agriculture, tourism, transport, energy supply and other industries, while extreme Extreme-weather events also pose a significant hazard to power, communication, transport and other infrastructure. Meanwhile the choice of whether to underwrite or not to underwrite the type of disaster, the amount of financial compensation for the post-disaster losses, and the conditions of payment are the urgent problems of the insurance industry nowadays. The insurance industry today is in urgent need of a solution. The first step to manage the risks of natural disasters is to identify the disasters [10], and we have selected four types of Extreme-weather events, namely, wildfire, drought, flood, and tropical cyclone, as the object of study.

3.2. Risk Assessment and Index Selection

Traditional weather index insurance uses meteorological observation indicators such as precipitation and temperature as well as a comprehensive weather index derived and calculated to determine the trigger and payout amount [5], which is prone to lead to a large basis risk. Due to the existence of basis risk, the rational demand for index insurance products is fundamentally different from that of indemnity insurance products [11]. In order to comprehensively consider the economic and social risks caused by weather risks, we take into account the insurable parts of the two risks separately. For the analysis of the economic vulnerability of insurance risk, the gross domestic product and totally regional consumption of judgement areas are chosen as the judgement indicators; since the more densely populated the area, the greater the loss of life caused by natural disasters, the population density of the risk area is chosen as the judgement indicator in the social vulnerability analysis. The next step is to build the model from the macro and micro perspectives.

3.3. Model Construction and Parameter Estimation

3.3.1. Using AHP-TOPSIS- FCEM Model to build comprehensive hazard expression

(1) The single disaster hazard is used as the judgement factor for the comprehensive natural disaster hazard. z_i indicates the risk of wildfire hazard. d_i indicates the risk of drought disaster. h_i indicates the degree of risk of flood hazards. t_i indicates the level of risk of tropical cyclone hazards. w_i indicates the danger degree of comprehensive Extreme-weather events, then the danger degree of comprehensive Extreme-weather events can be obtained according to the superposition formula as follows:

$$w_i = z_i + d_i + h_i + t_i \tag{1}$$

W_i indicates the composite meteorological disaster hazard indicator for each risk area, and its assignment function is as follows:

$$W_i = \begin{cases} \frac{w_i}{10}, w_i < 10 \\ 1, w_i \geq 10 \end{cases} \tag{2}$$

Where the hazard level of each disaster type hazard separately is calculated by the following AHP-TOPSIS- FCEM model.

(2) Establishment of AHP-TOPSIS Model

The evaluation result vector can be solved by multiplying the weight values of the comprehensive indicators derived from the hierarchical analysis method with the approximation matrix derived from TOPSIS, using the G which denotes the evaluation result vector, and the computational equation is shown below:

$$G = W_i N \tag{3}$$

(3) Establishment of Fuzzy Comprehensive Evaluation Model

The fuzzy comprehensive evaluation method can deal with the uncertainty and ambiguity in the evaluation process, and can consider multiple evaluation indexes at the same time. Using the affiliation function to describe the relationship between the evaluation index value and the evaluation grade makes the evaluation process more in line with human cognitive habits. At the same time, we use hierarchical analysis to determine the weight of each evaluation index, which makes the evaluation results more scientific and reasonable.

We firstly established 4 levels of evaluation levels and scoring criteria, which are "safe", "general", "dangerous" and "very dangerous", and used a hierarchical analysis method to determine the weight of each evaluation index to make the evaluation results more scientific and reasonable. With X_I denote X of the guidelines i, the actual values of the indicator factors x_{in} denotes i thresholds for indicators and factors at different risk levels. s_n is the scoring criteria for the different evaluation levels.

3.3.2. Calculation of economic vulnerability indicators

Gross domestic product (GDP) and total regional consumption by type of economy were selected as the two indicators to be judged in the economic vulnerability analysis. Using p_i donate j GDP for the year. $\overline{p_i}$ Denote the average GDP of each risk zone, using q_i donate i total regional consumption for the year. $\overline{q_i}$ Indicates the average gross regional consumption of the risk zones. k Indicates the interval of years used for the calculation. G_i donate i The values of the economic vulnerability indicators for the zones are expressed as follows for the average GDP, average gross regional consumption and economic vulnerability indicators for each risk zone:

$$\overline{p_i} = \frac{1}{k}\sum_{j=1}^{k} p_j \tag{4}$$

$$\overline{q_i} = \frac{1}{k}\sum_{j=1}^{k} q_j \tag{5}$$

$$G_I = \begin{cases} \dfrac{\ln(\overline{p_i} + \overline{q_i})}{k}, \overline{p_i} + \overline{q_i} < 10000 \\ 1, \overline{p_i} + \overline{q_i} > 10000 \end{cases} \tag{6}$$

3.3.3. Calculation of social vulnerability indicators

Population density was chosen as the indicator of social vulnerability in the social vulnerability analysis. r_i indicates the total population of the country's provinces, municipalities and autonomous regions. s_i denotes the area of the country's provinces, municipalities and autonomous regions, the expressions of the population density of each province, municipality and autonomous region, and for the indicator of social vulnerability, are as follows:

$$m_i = \frac{r_i}{s_i} \tag{7}$$

$$R_I = \begin{cases} \dfrac{m_i}{1000}, m_i < 1000 \\ 1, m_i \geq 1000 \end{cases} \tag{8}$$

3.3.4. Comprehensive judgement of meteorological disaster insurance windiness

On the one hand, economically developed and densely populated regions tend to face higher disaster vulnerability; however, on the other hand, these regions usually have stronger disaster tolerance, which to some extent can slow down the growth of disaster losses. As a result, the relationship between vulnerability and property and population shows a non-linear trend with an initial rapid increase followed by a gradual slowdown in the rate of increase. Based on this understanding, and also based on the possible trend distribution of the data, we chose to adopt the Using non-linear function to describe this relationship, the expression of which is as follows:

$$Y_I = \left[\frac{(P_j + R_i)}{2} \right]^{\frac{1}{2}} \tag{9}$$

The level of risks in natural disaster insurance should be assessed in an integrated manner by combining indicators of natural hazard, which reflects the natural characteristics of the disaster, and indicators of natural disaster vulnerability, which reflects the social characteristics of the disaster. In the absence of natural disasters, insurance risk naturally does not exist. Similarly, if a disaster occurs in an area that is sparsely populated and lacks economic value, the probability of causing loss of life and property is extremely low. Therefore, the perilousness and vulnerability of a natural disaster are the two necessary conditions for constituting a risk. Based on this concept, we adopt a comprehensive evaluation function to determine the risk area classification for natural disaster insurance. Y_i is an indicator of disaster risk. W_i is an indicator of social vulnerability. F_i is the insurance riskiness indicator with the following functional expression:

$$F_i = W_i Y_i \tag{10}$$

3.4. The Establishment of the Weather Disaster Comprehensive Index Insurance Model

Through the above analysis, we can get multiple insurance riskiness indexes between 0 and 1 as the index of the model, and we will take the insurance riskiness index of 0.5 as the claim trigger condition of the weather disaster comprehensive index insurance model, the insurance riskiness index of 0.8 as the upper limit of the claim, and the areas where the insurance riskiness index exceeds 0.8 will not be underwritten, which is described as follows:

$0 < F_t < 0.5$, Insurance companies cover but don't pay out

$0.5 \le F_t \le 0.8$, Insured by an insurance company and settle a claim

$F_t > 0.8$, Insurance companies don't cover

3.5. MDCIP Insurance Modelling:

According to our assumptions, it is known that the profit of the insurance company mainly consists of the premium. Using the amount of compensation and the investment income. Using S indicates a profit. μ_i donates i premiums for each region, and reviewing the relevant literature we obtained the formula for calculating the premiums, the X_p Indicates the amount of compensation. x_p Indicating the specific value of the amount of compensation. c denotes the return on the insurance company's investment, which is constant. β denotes the market changes and customer affordability, then the expression of the profit model is as follows:

$$S = \mu_i - x_p + c \tag{11}$$

$$\mu_i = P(F(t))(1+\beta)^2 \tag{12}$$

$$X_p = \begin{cases} 0, 0 < F_t < 0.5 \\ x_p, 0.5 \le F_t \le 0.8 \\ 0, F_t > 0.8 \end{cases} \tag{13}$$

4. MODEL-BASED EVIDENCE

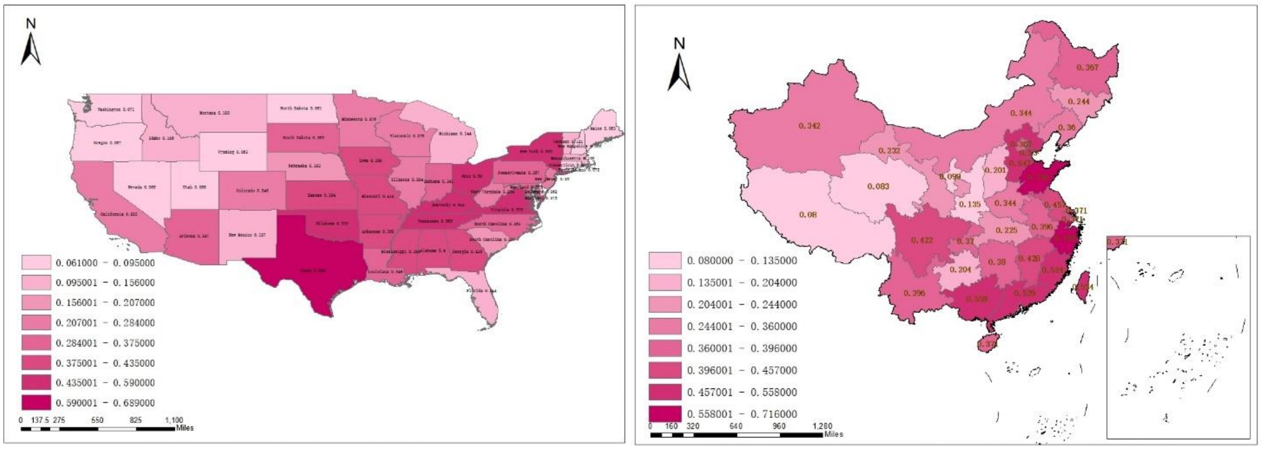

Figure 1. Distribution of Insurance Riskiness Indicators in the United States and in China

In the empirical demonstration of the Extreme-weather events comprehensive index insurance model, we only consider the bordering segments, and the non-bordering segments are not considered, so the maps of some countries have incomplete phenomena.

Through the measurement of the weather comprehensive insurance risk index in the south of the North American continent and the southeast of the Asian and European continents, it is easy to find that the closer to the southeast coast of the larger the value of the index, indicating that the more prone to Extreme-weather events, so as the insurance company will be more inclined to underwrite the central and northwestern part of the country, and for the insured, assuming that the risk of accidents, the central part of the country will get the highest probability of compensation.

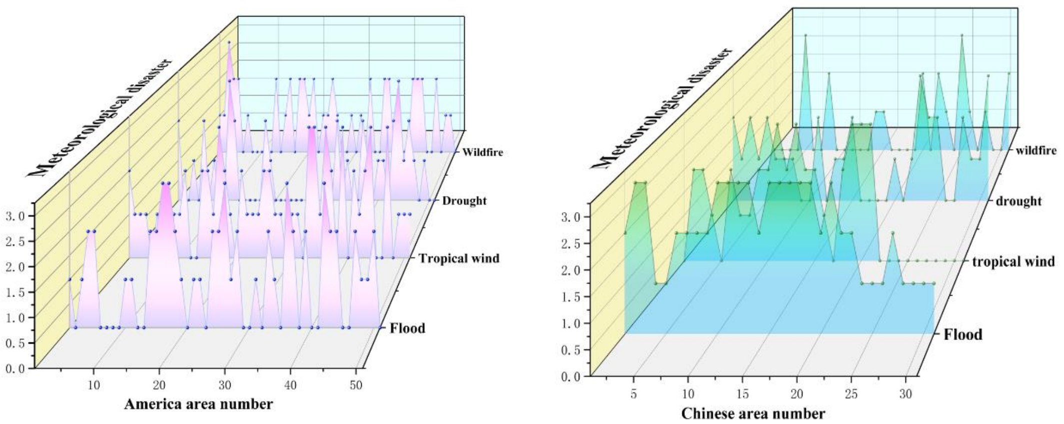

Figure 2. The Hazard Coefficients of Four Meteorological Hazards in the United States and China

Next, the combined graphs and figures as well as our established CDIP insurance model are selected for empirical evidence in specific regions on two continents respectively:

(1) The Midwest region of the United States

According to the insurance risk index, we can see that the region belongs to the low risk of Extreme-weather events, as the insurance company, the underwriting risk is small, and at the same time, due to the low risk probability of Extreme-weather events, the insurance risk index is generally low, so the likelihood of compensation is relatively low, and it is not recommended to insure the policyholder; for the insurance company, the possibility of profit is the largest, so for the insurance company Therefore, it is recommended for insurance companies to underwrite the policy.

(2) East Coast of China

According to the insurance risk index, we can see that this region is a high-risk area for Extreme-weather events, which is a higher risk for insurance companies. At the same time, due to the high risk probability of Extreme-weather events, the insurance risk index is generally high and most of them are in the scope of coverage, so the possibility of paying out is very high, and the profit is relatively small for insurance companies, therefore, it is recommended to insure for the policyholders; It is recommended for insurance companies, but they need to join hands with other insurance companies to spread the risk or take out reinsurance companies.

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