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Research on the insured amount of disaster housing insurance based on particle swarm optimization algorithm

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Abstract. Due to the impact of global climate change, the frequent occurrence of extreme weather has had a huge impact on local economic development. Insurance can reduce risks and alleviate the burden on individuals or businesses. Based on the analysis of the profit model of insurance companies, it is found that profit is related to the company's revenue and expenses. Therefore, this article has defined the objective function, decision variables, and constraints for profit. This article conducted a detailed analysis of the relevant conditions between income and expenditure, analyzed the frequency of natural disasters worldwide, and predicted that there may still be many natural disasters in these two regions in the next five years using time series analysis. This article selected China and the United States as the two continents. Reuse particle swarm optimization algorithm to determine the highest and lowest insurance amounts for China and the United States, and develop detailed insurance strategies within the range of amount indicators to reduce losses.

Keywords: Insured amount; Insurance profit; Time series; Particle swarm algorithm.

1. Introduction

Mr. Zhang holds a positive attitude towards the promotion of weather insurance, setting different insured amounts based on different weather indicators to make it popular [1-2]. According to the laws of time and space, Jiayi Gao 's team selects multiple regions for latitude and longitude statistics to predict extreme weather and conduct risk assessments [3]. The Jian Qiu's team proposed to develop catastrophe insurance according to local conditions, and to introduce corresponding insurance for different terrains and situations, in order to provide a wide range of benefits for the public and reduce the pressure of government financial assistance [4]. This article uses time series analysis, combined with various factors such as GDP, disaster severity, and disaster situations in China and the United States in the past few years, to predict the number of major disasters in the two countries in the coming years. Corresponding functions are constructed, and particle swarm optimization algorithm is used to continuously optimize and update the optimal solution. Different insurance amounts obtained under different regions and GDP situations are listed, effectively helping insurance companies to launch reasonable policies.

2. Research on Insurance Models

2.1. Determination of objective function

In this paper, the revenue of a company is subtracted from the expenses, and the rest is profit. For this purpose, we can construct a function to ensure the long-term health of the insurance company and make the system resilient. As a catastrophe insurance modeler, we set up a functional model with the profit of the insurance company as the objective function and the amount of insurance as the decision variable.

The specific function is as follows (1):

$$S = A - T \tag{1}$$

S is profit, A is income, T is expenditure.

2.1.1. Income.

The income of the insurance company comes from the insurance of the people, and the income is related to the amount of individual insurance, and the proportion of insurance, and is proportional to the local population. It can be analyzed that the number of local insured is equal to the total number of local people multiplied by the insured proportion, then the income is equal to the local population (n) multiplied by the insured proportion of the program (m_i), multiplied by the insured amount of the program (p_i), i is the number of the program.

The specific formula is as follows (2):

$$A = \sum_{i=1}^{0} n m_i p_i \tag{2}$$

2.1.2. Expenditure.

To calculate the profit of an insurance company, we also need to calculate the company's payouts to policyholders, that is, a portion of the company's expenses. The company's payout should be equal to the local population multiplied by the proportion of the disaster scenario (k_i) and the amount paid out by that scenario (s_i).

The other part of the insurance company's expenditure is: the salary paid by the insurance company to its employees, the cost of posters, advertising, etc. There is a lot of uncertainty, so let's set it as a constant $(cost)$.

So we get the following formula (3):

$$T = \sum_{i=1}^{0} n \cdot k_i \cdot s_i + \mathrm{cos}t \tag{3}$$

2.1.3. Region selection.

On the official website of Our World in Data, this article has found a global natural disaster statistical chart, as shown below:

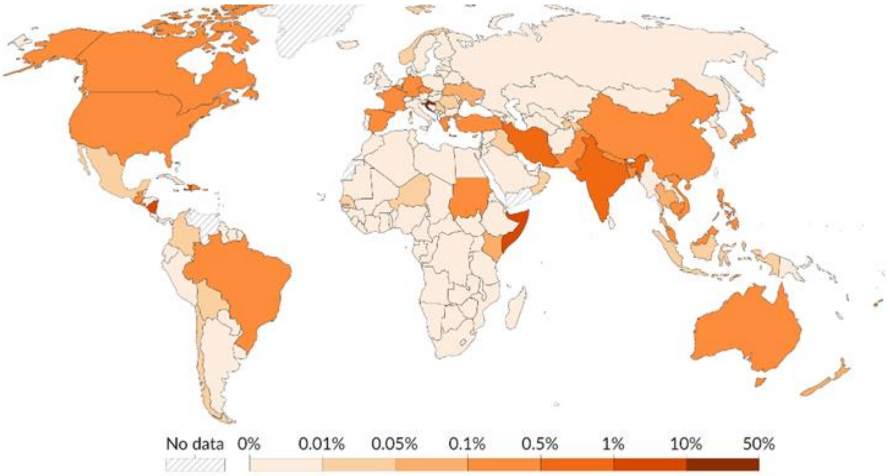

Figure 1. Disaster analysis graph

In figure 1, as the color deepens, the frequency of natural disasters increases.

Through observation, it is found that China and the United States belong to the regions with high frequency of natural disasters. Here we choose the United States mainland and Chinese mainland as the two representative regions.

2.2. Building the model

2.2.1. Determine the model.

The most important reason for insurance companies to choose a region for natural disaster insurance plans is that this region is a place with a high incidence of extreme weather events, and insurance companies need to participate in insurance in this region to alleviate the economic losses of enterprises and individuals. Therefore, we forecast whether natural disasters will occur in these two regions in the future. Both countries' disaster data are collected from our data world: https://ourworldindata.org/natural-disasters.

2.2.2. Data search.

We found the China and the United States in recent years, natural disasters impact on gross domestic product (GDP). As shown in Figure 2 and Figure 3.

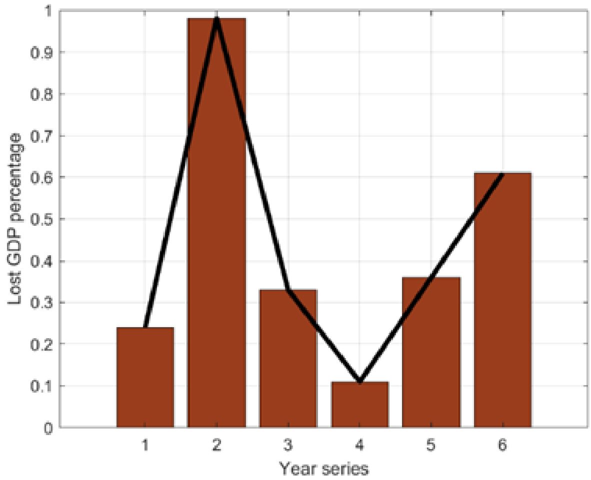

Figure 2. USA

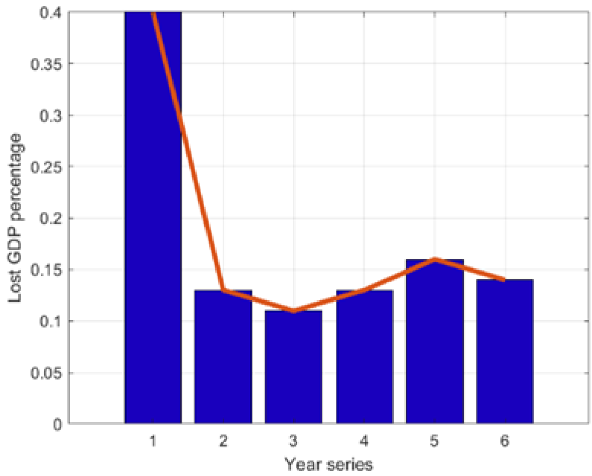

Figure 3. China

2.2.3. Establishment of the model.

As observed in the figure above, the data presents a certain periodicity, and the data is related to the year. From the perspective of a long time, the data follows a certain rule. In the short term, due to the impact of uncertain factors such as GDP growth, it is difficult to forecast. MA model has a high accuracy of short-term trends in the process, and is widely used as a method. Therefore, this paper uses time series to forecast [5-6].

(1) Take 2017 to 2021 as the original time series a_i (t=1, 2, …, 5), first test whether the series is stable, calculate q=1 from the significant level $\alpha = 0.05$, and the statistic $T = +\infty$, then calculate the a_i variables, difference order, $T = +\infty$, AIC value, etc., to test whether the time series is stable. The specific values are shown in the following Table.1.

Table 1. ADF inspection table

Variable	Difference order	t	p	AIC	Threshold		
					1%	5%	10%
Composite Score index	0	0.9	0.788	401.8	3.5	2.8	2.5
	1	6.4	0.000***	398.4	3.5	2.8	2.5
	2	7.3	0.000***	384.4	3.5	2.8	2.5

When the difference is 1 order, the significance P value is 0.000***, showing significance at the level, rejecting the null hypothesis, the series is a stationary time series. The AIC value is small, the model fits well, and the significance level is high at the observed critical value.

(2) Establish a stationary sequence, and compare the sequence $a_i(\mathrm{t} = 1,2,\ldots,23)$ perform the first-order difference operation $b_i = a_i + 1 - a_i$ to obtain the sequence $b_i(\mathrm{t} = 1,2,\ldots,22)$.

(3) Construct an autoregressive model for prediction (4):

$$y_i = \varepsilon_t + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} \tag{4}$$

Note: q=1 currently.

(4) Looking at the Figure 4, it is not difficult to see that the model (MA) residuals are white noise sequences.

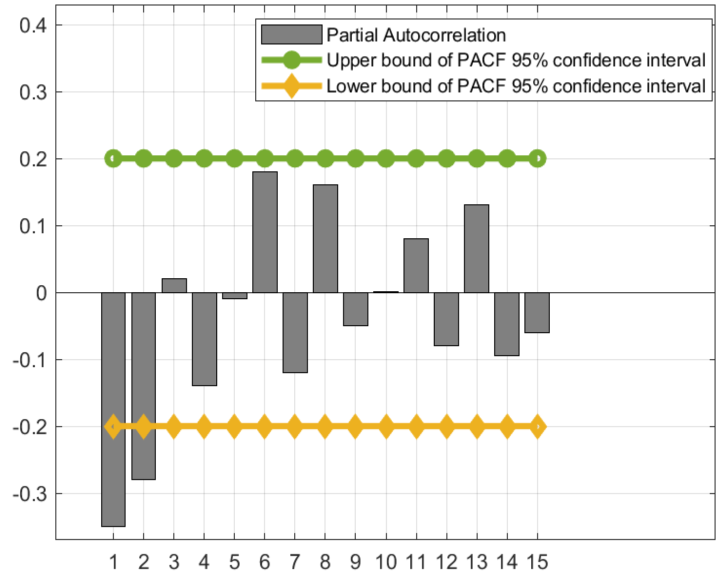

Figure 4. PACF result graph

Then the number of samples, degrees of freedom, Q statistics and goodness of fit of the information criterion model are calculated. The specific results are shown in the following Table.2.

Table 2. Test table

Model (0,1,1) Test table		
Item	Symbols	Value
Sample size	Df Residuals	97
	N	100
Q Statistics	Q6 (P-value)	0.04 (0.842)
	Q12 (P value)	5.663 (0.462)
	Q18 (P value)	14.267 (0.284)
	Q24 (P value)	22.131 (0.226)
	Q30 (P value)	26.676 (0.320)
Information Guidelines	AIC	458.903
	BIC	451.118
Goodness of Fit	R^2	0.897

Note: ***, ** and * represent significance levels of 1%, 5% and 10%, respectively

Based on the variable: comprehensive score index, it can be obtained from the analysis of Q statistic results that Q6 does not show significance at the level, and the hypothesis that the residual of the model is white noise series cannot be rejected. Meanwhile, the goodness of fit R^2 of the model is 0.897, which indicates that the model performs well and basically meets the requirements.

(5) The least squares B_i is obtained by substituting T = 17 into the prediction model to obtain the predicted value, and then substituting the predicted value of T = 21 into the original time series to obtain the predicted value of T = 26, do the following calculations using the 2017-2021.

2.2.4. Presentation of results.

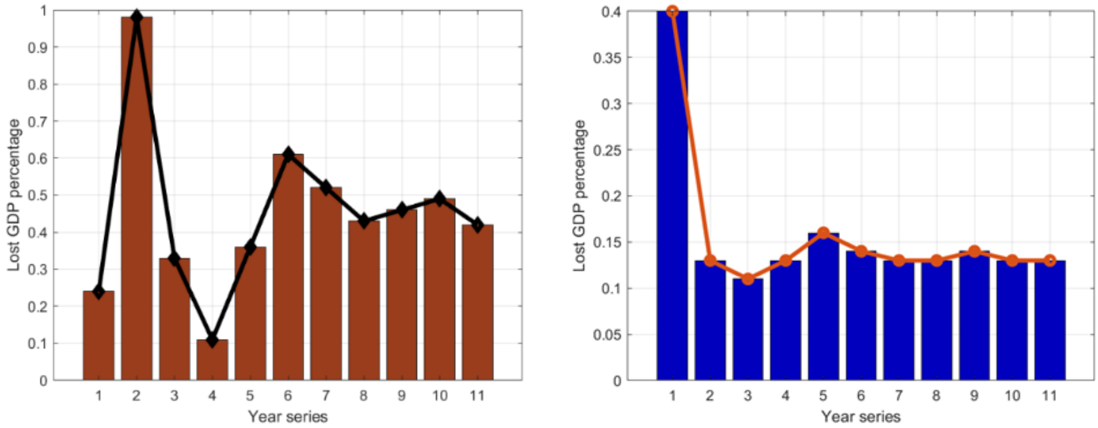

Figure 5. Forecasts for the United States and China

From Figure 5, we can see that both regions are still likely to have a lot of natural disasters in the future. Insurance companies need to offer more coverage in both regions.

2.2.5. Solution of the model.

In summary, this is a dynamic programming model. We defined the algorithm solution space and initialized the particle swarm algorithm population [7]. Then, update its position, speed and the historical optimal solution. As shown in Formula (6) and Formula (7) (8).

$$a_{ij}^{(k)} + v_{ij}^{(k+1)} = a_{ij}^{(k+1)} \tag{5}$$

$$\mathrm{v}_{ij}^{(k+1)} = w \cdot v_{ij}^{(k)} + c_1 \cdot s_1 \cdot (g_{ij} - b_{ij}^{(k)}) + c_2 \cdot s_2 \cdot (x_i - b_{ij}^{(k+1)}) \tag{6}$$

$$s(v_{ij}) = \frac{1}{[1 + \exp(-v_{ij})]} \tag{7}$$

$$x_{ij} = \begin{cases} 1, r < s(v_{ij}) \\ 0, else \end{cases} \tag{8}$$

At last, outputting the optimal solution. When the particle swarm algorithm satisfies the stop condition, we can get the optimal solution and invert the specific gravity and inertial weight, we can get the worst solution. The highest insured amount in China is 105.44 dollars and the lowest is 78.37 dollars. In the United States, the highest insured amount is 131.69 dollars and the lowest is 95.93 dollars. As shown in Figure 6, this algorithm has good convergence and high feasibility.

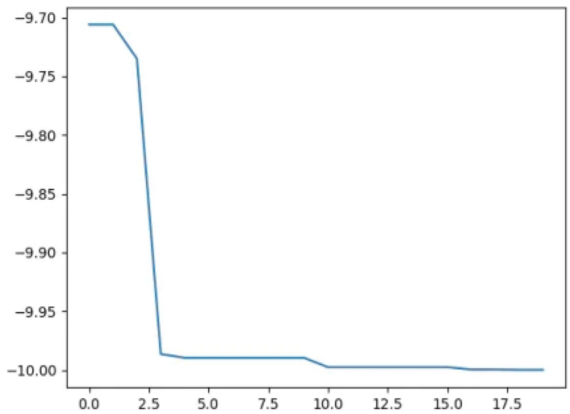

Figure 6. Convergence graph

2.2.6. Analyze the results.

Since the solution is the GDP development of the whole China and the United States mainland and the different regions on the mainland, we need to formulate the corresponding insurance amount for different regions according to the above calculated investment amount range [8-9]. The insured proportion of the masses is closely related to the insured amount, and the purpose of this paper is to reduce the economic loss of the disaster-stricken people or enterprises, so we should reduce the index as much as possible in high-risk areas, and in low-risk areas with relatively developed GDP, we can slightly increase the insured amount [10]. The specific indicators are established in the following Table 3.

Table 3. The insurance price list

Regional situation	China	United States
High-risk areas, or areas with low GDP	76.50 dollars	97.36 dollars
Low risk and good GDP	90.40 dollars	114.04 dollars
Medium risk and good GDP	104.31 dollars	130.74 ollars

3. Conclusion

Based on the above calculation, insurance companies should establish an insurance policy when the insured amount is greater than the minimum amount target but not higher than the maximum target amount. At this time, the insurance company should bear the policy. If it exceeds this range, the insurance company may face no insurance coverage or excessive compensation. This article focuses on the disaster situations in two major countries, the United States and China, and is divided into three standards. Different regions can refer to the standard of insured amount. However, due to the large size of the two regions, insurance companies should adjust their strategies in a timely manner based on local insurance situation, GDP development, residents' Engel coefficient and many other uncertain factors when making specific insurance plans to better adapt to the local situation, thereby reducing the losses of the people and the pressure of government assistance.

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