Research on Property Insurance Profit Forecasting Model and Response Strategy under Extreme Weather

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Abstract. In this paper, we propose and design an insurance profit prediction model that effectively handles complex coupled variables to address the issues related to the volatility of the property insurance industry due to the frequent occurrence of extreme weather worldwide and the strong demand of insurance companies for the prediction of insurance profits in the future. Considering the adaptability of the model as well as its relocatability, we comprehensively consider the impacts of various factors on the insurance industry, such as extreme weather, geographic location, insurance market, and national development, and use them as indicators to build an insurance profit prediction model. We quantified and averaged the multivariate influences in the insurance forecasting model and solved the complex coupling variables in the model. We conducted a sensitivity analysis of the model to determine that the model has good robustness, and used this analysis to obtain a strong correlation between the ideal profit margin of the regional insurance industry and the regional insurance profit return, i.e., the ideal insurance profit margin of the regional insurance industry is a key factor affecting the total profit. Meanwhile, the model prediction results obtained by adjusting the model parameters show that under certain conditions, the regional insurance industry can obtain lower or loss profits in the short term, but is profitable in the long term. This study provides a useful reference for the property insurance industry and helps insurers to better predict profits, formulate strategies, and provide effective safeguards for property owners to meet the challenges posed by extreme weather events.

Keywords: Frequent Extreme Weather, Regional Insurance Industry Profit Prediction Model, Big Data, MATLAB.

1. Introduction

Currently, globally, the frequency of extreme weather events has evolved into a looming challenge for global insurers: more than 1,000 extreme weather events have cost the global economy close to USYuan1 trillion. 2022 sees a 115% surge in natural disaster claims compared to the average of the last 30 years [1], with floods, hurricanes, cyclones, droughts and wildfires caused by weather-related hazards further driving up future insurance costs by 30-60% by 2040[1]. wildfires are pushing up future insurance costs even further, with a projected increase of 30-60% by 2040.

The property insurance industry is undergoing unprecedented change. Strategic adjustments by insurers have made property insurance not only expensive but difficult to obtain, while there is a global disparity in the cost of property insurance. The dual challenge facing the industry is that the insurance protection gap is averaging 57%, and this gap is gradually widening. This scenario clearly highlights the dilemma of the insurance industry the crisis of profitability and the problem of property owners' ability to pay. As shown in Fig 1.



Fig. 1: The property insurance industry in tough shape in the face of extreme weather conditions

2. Model building

2.1. Assumptions

Assumptions: The current global insurance protection gap in the insurance industry is 57 per cent on average globally and is increasing. Since it is difficult to quantify the insurance protection gap of insurance companies in each region due to a combination of factors, it is assumed that the insurance protection gap of insurance companies is the global average.

2.2. Description of symbols

All the symbols involved in the article and their corresponding explanations are shown in Table 1

Table 1: Explanation of symbols used in the text

Notation	Interpretations
P	Total profit earned by an area insurance company in a given year (Yuan)
I_{total}	Amount of total premiums paid by policyholders in an area in a given year (Yuan)
i	Annual premiums paid by insured persons to insurance companies in an area in a given year (Yuan)
C_{total}	Total amount of coverage paid out by an area insurance company in a given year (Yuan)
D	Ideal amount of insurance profit an area insurance company would like to make (Yuan)
n_c	Coefficient of exposure to extreme weather on GDP (%)
N	Total number of insured persons in a region in a given year (person)
G	Gross GDP of a region in a given year (Yuan)
k	Standardised base participation fee for the insurance industry in a region for a given year (Yuan)
M	Total population of a region (person)
a	Profit margins desired by the insurance industry in a given region

2.3. Data sources

We use real data as a reference and substitute the checks to ensure the reliability of the model, and the data sources involved are shown in Table 2.

Table 2: Sources of data in the text

Database Names	Database Websites Date
World Bank	https://data.worldbank.org.cn/indicator?tab=featured
Our natural data natural disasters	https://ourworldindata.org/natural-disasters
CEIC Global Market Economy Database	https://www.ceicdata.com/ja

2.4. Insurance Forecasting Model

We quantify the parameters of the paper and develop an insurance forecasting model.

The gross underwriting profit of an insurance company is the net income realised by the company in its annual operations and can be calculated in the following way[2]:

$$\mathrm{P} = I_{total} - C_{total} \tag{1}$$

The total amount of annual premiums paid by policyholders in their area is the total amount paid by all policyholders in the area for all types of insurance products during the year:

$$I_{total} = \mathrm{N} \cdot \mathrm{i} \tag{2}$$

We take into account that a policyholder may purchase a policy with any annual term in that year, but the calculation of the insurer's annual return can be done without considering the effect of the policyholder's one-time purchase of a policy term on I_{total}.

We have thus modelled premium setting (3), (4):

$$i = k + \frac{D}{M} + \frac{C_{total}}{M} \tag{3}$$

$$D = a \cdot I_{total} = a \cdot N \cdot i \tag{4}$$

$$C_{total} = 43\% \frac{\mathrm{n}_c \cdot G}{\mathrm{M}} \cdot N \tag{5}$$

Associate (2) (3) (4) (5) to solve the complex variable D, as shown in equation (6):

$$D = a \cdot I_{total} = \frac{a \cdot N \cdot (k\mathrm{M}^2 + 43\mathrm{n}_c \cdot G \cdot N \cdot \%)}{M(M - aN)} \tag{6}$$

Ultimately, an area insurer's total annual insurance profit can be derived by subtracting total claims and other costs from total premiums:

$$P == \frac{Nk\mathrm{M}^3 + 43\%\mathrm{n}_c GMN(N - \mathrm{M} + aN)}{\mathrm{M}^2(\mathrm{M} - aN)} \tag{7}$$

3. Result

3.1. Sensitivity analysis

We have analysed the sensitivity of the model parameters through a MATLAB code in order to study the impact of the input parameters on the output (total profit) of a given model[3]. The following is a description of the work of the code and the parameters used t-o build the model:

Parameter setting: initially, a set of basic parameters of the model are given, such as the number of insured persons (N), the base participation fee (K), and the desired amount of insurance profit (D). The detailed assumptions are shown in Table 3.

Table 3 Parameters for modelling

Parameters	Proposed value
N(person)	10000
k(Yuan)	500
a(%)	0.05
M(Yuan)	500000
C_{total}(Yuan)	200000
n_c(%)	0.02
G(Yuan)	1000000
D(Yuan)	100000

Parameter scaling factors: a set of parameter scaling factors are defined which vary over a range. These scaling factors are used to gradually adjust the input parameters of the model.

Main loop: for each parameter scaling factor, loop through the following steps:

a. Change the original parameter values one by one, multiplying each parameter using the parameter scaling factor to generate new parameter values.

b. Calculate the output of the model (in this case, total profit) using the new parameter values.

c. Calculate the sensitivity value for each parameter, which is obtained from the difference calculation and indicates the corresponding change in total profit for a relatively small change in the parameter.

d. Restore the original values of the parameters for the next loop iteration.

By looking at Figures 3 and 4, we understand how the model responds to changes in different parameters. The total profit in the model increases with the the parameter scaling factor increasing, and in sensitivity analysis,it indicates that the larger the absolute value of the slope is, the more sensitive to the change of the corresponding parameter is[4]. In our model, desired by the regional insurance company, the ideal insurance profit margin affects the factor most drastically. So from the above analysis, it can be seen that when P is greater than zero, which means the insurance company can obtain insurance profit, we believe that the insurance company should undertake the policy in order to make a profit, and from the image, there are situations where there is a low value of short-term profit or loss, but in the long run it is profitable, in this case, we believe that the insurance company should be bold and risky in order to seek an overall improvement of the company's efficiency.

Homeowners can conduct regular building inspections to ensure that their homes are structurally and foundationally sound and can withstand extreme weather conditions. Where possible, reinforcement measures are put in place, which can reduce the risk and therefore the premium.

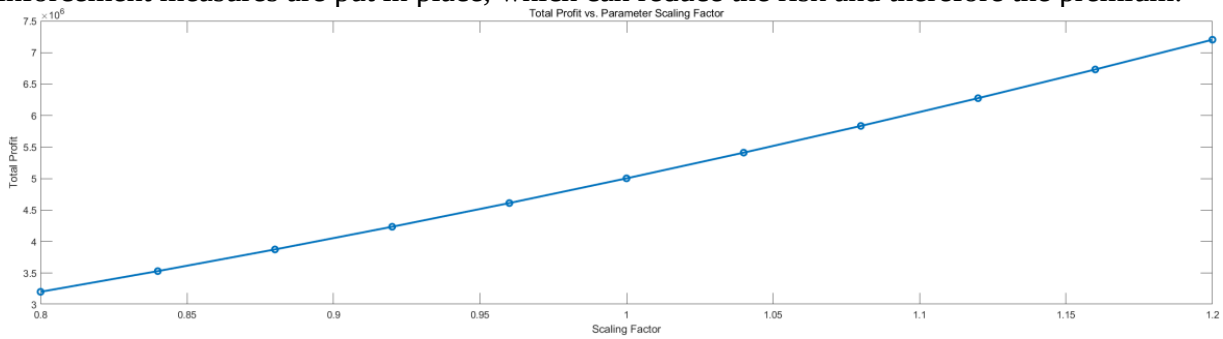


Fig. 3: Variation of total profit with parameter scaling factor

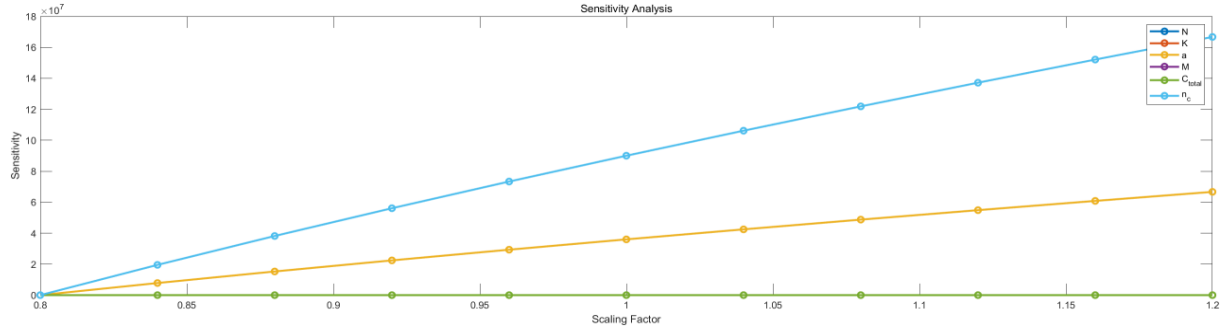


Fig 4: Variation of sensitivity values of parameters with parameter scaling factor

3.2. Analogue applications

In this section, we choose Asia and North America as the study object, and we select Japan as the reference object in Asia to bring the impact of extreme weather events on GDP into our model.[5] At the same time, we select the United States as a reference object in North America and perform the same operation[6], and The impacts of extreme weather on the two continents are detailed in Figures 5 and 6:

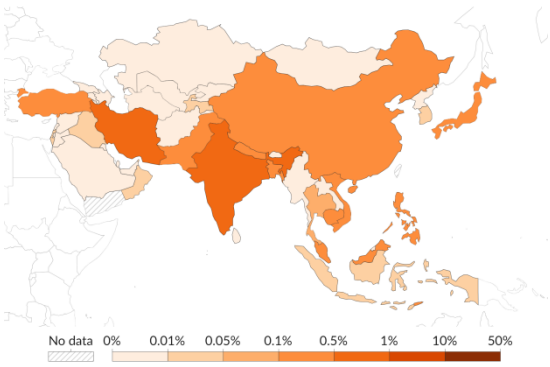


Fig. 5: Heat map of extreme weather impacts in Asia

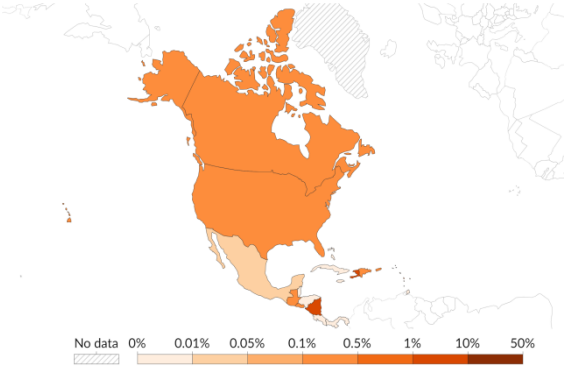


Fig. 6: Heat map of the impact of extreme weather on North America

We validated our proposed model by using actual data from historical disaster events in Japan and the United States[7]. Firstly, we obtained data from relevant data sources including GDP, at the time of the catastrophe, some of which were missing, and we complemented the fitted data by using various methods based on Newton's interpolation, and then we applied these actual data to our model and compared the model's predictions with the actual observations. We calculated that the insurance company is profitable in the region when $P>0$[8]. The results show that our model achieves satisfactory accuracy in predicting the impact of disasters in Japan and the United States. We note that the model may have limitations in some contexts, but overall it shows good applicability in practical applications[9]. This validation process strengthens the credibility of our model and provides a reliable predictive tool for future responses to similar problems. Figures 7 and 8 show the total profits of the insurance industry in the two regions over the next five years, as projected using the models we studied.

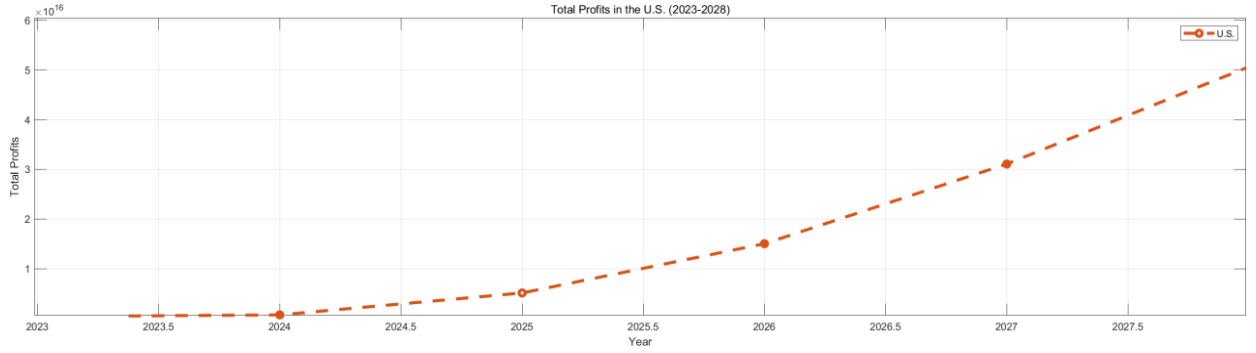


Fig. 7: Total profit forecast for the US insurance industry over the next five years

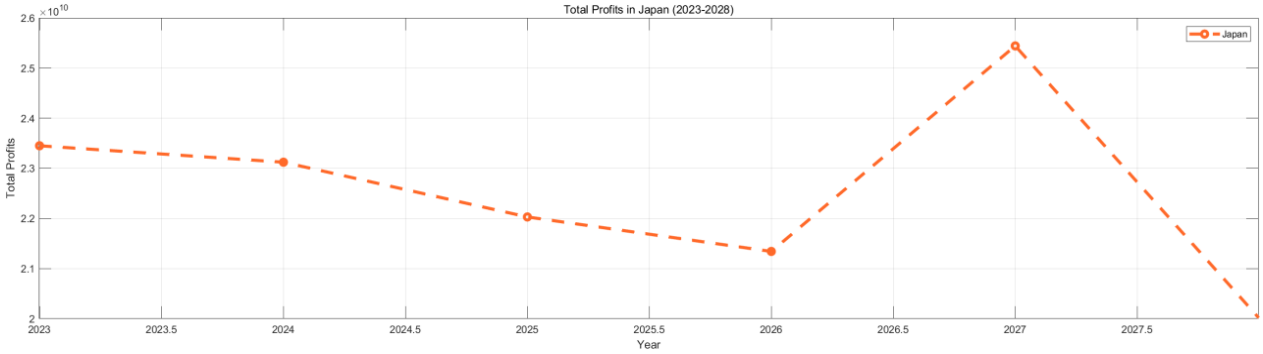


Fig. 8: Forecast of total profit of the Japanese insurance industry for the next five years

4. Modelling

4.1. Benefits of Insurance Forecasting Models

1. We have taken into account the influences of insurance markets, geographical locations, countries and other factors in our insurance prediction model[10], so that our model can adapt to the future insurance placement decisions of insurance companies in different regions and be flexible. Since the task of accurately quantifying multivariate influences is huge and very difficult, we quantify as well as average the multivariate influences in our insurance prediction model , and cleverly use the equalisation idea and the relationship between the whole and the part to deal with the complex coupled variables in the model, such as the premiums set by the insurance companies in different regions each year (i), the total amount of insurance coverage paid out each year, and so on.

2. We consider that the profit margins expected by insurance companies in different regions may vary according to the influence of the national and international insurance markets and the frequency of extreme weather, so we set the profit margins (a) separately, which not only takes into account the problem of the actual insurance companies' working capital, but also makes the insurance prediction model more elastic.

3. We use the ideal model idea , by predicting the economic loss (%GDP) that extreme weather may cause to a region can effectively bypass the probability that extreme weather may occur in a region.

4.2. Disadvantages of insurance forecasting models

We maximise the underwriting premiums (C_{total}) that insurers are likely to face in the insurance prediction model, and average the insurance protection gap of insurers, i.e., we assume that each extreme weather disaster affects the insured of this insurer and that the insurance protection gap is based on the global average of 57%, so that the economic losses caused by extreme weather in a certain region can be distributed equally to each resident of this region. By counting the total number of insured people, the maximum compensation value can be found. In the actual operation of the insurance company, the insurance company may need to pay premiums that are less than or equal to the underwriting premium model we set up. At the same time, the gap in protection promised by insurers in different regions may be slightly different from the world average benchmark, and will be adjusted by insurers as extreme weather events become more frequent and regional economies change.

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