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Study on the Assessment of Insurance Rates in Response to Typhoon Disasters

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Abstract: In this study focused on Yinzhou District, Ningbo City, the determination of typhoon catastrophe insurance rates is explored using a discrete relational, matrixed catastrophe insurance actuarial model. The initial phase involved calculating the expected loss rate for residential typhoon insurance, utilizing historical data on insurance claims and tropical cyclone records. Further, the study integrated Yinzhou District yearbooks with typhoon insurance claim data to assess the vulnerability of individual streets and towns within the district. This assessment led to the creation of four gradient levels based on the vulnerability rankings and clustering. The research then involved calculating both the actual and adjusted risk gradient coefficients for each area within these gradient levels under varying scenarios. Findings indicated a significant disparity in the actual risk gradient coefficients across different areas, with the most vulnerable areas exhibiting coefficients that were 813 times greater than those of the least vulnerable. To address the high actual risk gradient coefficients, the study proposed adjustments that took into account factors such as residential risk, policyholders' payment capacity, and government support. The implementation of these three adjustment schemes significantly reduced the discrepancy in insurance rates among the different areas, more accurately reflecting the typhoon risk situation in Yinzhou District and aiding in the precise determination of catastrophic insurance rates.

1. Introduction

Typhoons exhibit characteristics of high frequency, an extensive impact range, and formidable destructiveness, often giving rise to secondary disasters such as strong winds and floods, which can result in the impairment or direct destruction of buildings [1–3]. A poignant illustration of this occurred during Typhoon Lekima (No. 9) in 2019, leading to the collapse of nearly 15,000 houses in provinces including Zhejiang and Fujian [4]. In recent years, with the advancement of science and technology and the improvement of disaster prevention awareness, the number of people affected by typhoon disasters has shown a downward trend, but the number of house collapses and economic losses are still on the rise [5]. As a pivotal component of catastrophe risk management, catastrophe insurance plays a crucial role in mitigating the economic burdens borne by residents due to disasters such as typhoons, while also furnishing the government with insights for disaster prevention and reduction [6]. However, the development of catastrophe insurance in the country commenced relatively late, with a relatively modest number of policies in force. This may be attributed to residents' limited perception of catastrophe risks and the perceived lack of fairness in insurance rates. Consequently, the judicious and scientific determination of catastrophe insurance rates holds paramount significance in advancing the adoption of catastrophe insurance and mitigating losses incurred by disasters.

Two international models for setting catastrophe insurance rates have been identified: the post-disaster loss data-based model and the post-disaster claim data-based model [7,8]. Since the onset of the 21st century, China's progress in catastrophe insurance has yielded initial outcomes, prompting scholars to explore the rate-setting models and pricing mechanisms. Notably, the post-disaster loss data-based model has been employed in this context, leading to the delineation of two primary categories in catastrophe insurance rate-setting and pricing research. Firstly, there is the catastrophe insurance pricing model grounded in the tandem risk-diversification framework. This model involves key stakeholders such as direct insurance companies, reinsurance companies, the capital market, and government catastrophe risk guarantee funds. It operates on the premise of allocating responsibility for claims based on the magnitude of the catastrophe risk, i.e., the extent of direct economic loss. However, this model facilitates only uniform rate setting for the entire affected area [9,10]. Secondly, the discrete relational, matrixed catastrophe insurance actuarial model emerges, with the insurance company serving as the primary claims entity. This model distinguishes itself by its capacity to calculate premium rates for different administrative divisions across the affected region in a precise and finely-grained manner [11,12].

In order to fulfill the United Nations' objective of mitigating the short-term or long-term adverse impact of disaster risks on society, this paper, adopting a disaster prevention and reduction perspective, employs the discrete relational, matrixed catastrophe Insurance actuarial model, integrated with the characteristics of typhoon-related natural disasters. The research area selected is the Yinzhou District of Ningbo City [13-14], a region frequently affected by typhoon disasters and characterized by a vague system for determining catastrophe insurance premiums. The study analyzes the vulnerability of residential buildings in different streets and towns in Yinzhou District, Ningbo City, ultimately determining typhoon catastrophe insurance rates. This article not only provides a methodological reference for establishing premium rates in other regions with similar catastrophe insurance needs but also offers decision-making support for the government in formulating disaster prevention and reduction policies.

2. Data & Research Area

2.1. Data

The data used in this study include (1) catastrophic typhoon insurance claims data of Yinzhou District in recent years from insurance companies; (2) List of landfalling tropical cyclones from 2000–2021 from the tropical cyclone information of China Meteorological Administration [15]; and (3) The number of households in each street and town of Yinzhou District and the price of residential houses from the 2021 Yinzhou District Statistical Yearbook [16]. The specific use of each data is shown in Table 1.

Table 1: Description of the study data.

Data	Source	Use
Insurance claims data	Insurance company	Calculation of the extent of damage to dwellings, average area of impact of typhoons
List of landfalling tropical cyclones	China Meteorological Administration Tropical Cyclone Data	Calculation of the probability of occurrence of typhoons of magnitude 12 and above, and the probability distribution of the number of occurrences of typhoons of magnitude 12 and above in a year
Number of households in each street/town in Yinzhou District, residential prices in Yinzhou District	Statistical Yearbook of Yinzhou District	Calculate the insurance amount of dwellings in Yinzhou District and the vulnerability of dwellings in each street/town, taking into account the insurance claim data

2.2. Research Area

As depicted in Figure 1, Yinzhou District of Ningbo is situated between longitude 121°08’~121°54’ E and latitude 29°37’~29°57’ N. Geographically, it borders Haishu District to the west, Jiangbei District, and Zhenhai District to the north, Beilun District to the northeast, Fenghua District to the south, and Xiangshan County to the southeast across the Xiangshan Harbor, residing in the south wing of the triangle on the eastern coast of Zhejiang [17]. This region falls within the subtropical monsoon climate zone, featuring a terrain that is generally higher in the south and lower in the north, higher in the east and lower in the west, with mountainous areas accounting for approximately 51% of the total land area. Positioned in the southern part of the Yangtze River Delta Economic Circle, Yinzhou District has witnessed rapid economic development and accelerated urbanization in recent years, resulting in a reduction in the urban surface groundwater infiltration area. This urban transformation has rendered the district highly susceptible to natural disasters such as floods and storm surges [18]. According to historical data, from 1953 to 2016, Ningbo experienced a total of 153 typhoons, primarily concentrated in the months of July to September. Approximately every 1–2 years, the region faced severe impacts from typhoons, and since the 1990s, there has been a noticeable upward trend in the number of typhoons affecting Ningbo [19].

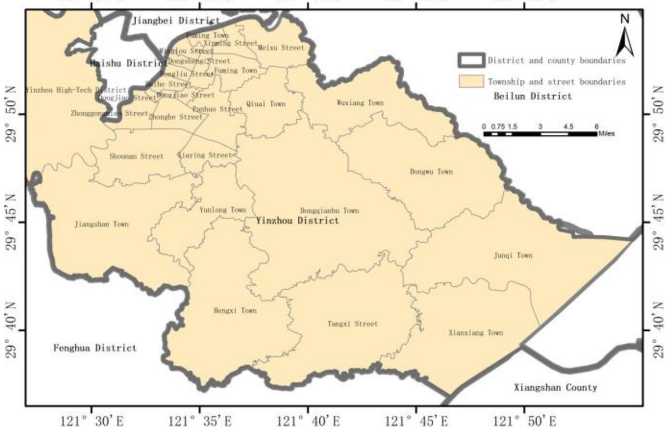

Figure 1: Geographic location of the research area.

3. Research Methodology and Technical Approach

3.1. Actuarial Modeling of Catastrophe Premium Rate

Catastrophe risk is characterized by a small probability of occurrence coupled with the potential for high losses [20], leading to devastating and destructive impacts. The methodology for determining rates in catastrophe insurance differs from the principles applied in general insurance rate calculations. It necessitates the consideration of factors such as the vulnerability of the disaster-bearing entity to catastrophe risk, the intrinsic characteristics of the catastrophe-causing factor, the valuation of the insured subject matter, and the potential evolution of compensation standards in tandem with societal development, among other factors [21]. Consequently, in light of these considerations, this paper opts for the discrete relational, matrixed catastrophe Insurance actuarial model. The specific calculation steps are outlined as follows:

(1) Measurement of insurance losses following a catastrophic event

The occurrence of catastrophic events is intricately linked to the environmental conditions fostering the catastrophe, the causative factor, and the entity bearing the disaster [22]. Assuming a certain level of stability in the building layout and natural environment of a region denoted as area R over a specific timeframe, and considering a degree of randomness in the occurrence of catastrophic events in the area, the degree of economic loss is contingent not only upon the intensity and type of the catastrophe but also on the socio-economic context, population density, and building layout within the affected area [23]. The computation of economic and insurance losses for residences in the affected area begins with the assessment of the extent of damage caused by the catastrophe. It is posited that the probability distribution for various levels of damage to dwellings in a given area due to a catastrophic event is represented as Y_1, Y_2, ……, Y_n, and the economic loss level for different damage levels is denoted as X_1, X_2, ……, X_n. The economic loss is influenced by the value and distribution pattern of dwellings, the effectiveness of disaster prevention and mitigation measures, and the structural characteristics of the dwellings.

Following a catastrophic event, insurers compensate the insured based on the principles of insurance loss compensation [24], where the insurance loss is primarily influenced by factors such as the insured's self-insurance ratio and deductible amount. Assuming the highest compensation ratio of the insurer, after accounting for the self-insurance ratio, deductible amount, and other factors, is denoted as I, the degree of insurance loss for various damage levels is represented as IY_1, IY_2, ……, IY_n. Subsequently, the degree of expected insurance loss (S) for residential houses in the region due to a single catastrophic event can be calculated using the following formula:

$$S = IX_1Y_1 + IX_2Y_2 \cdots + IX_nY_n \tag{1}$$

The extent of impact of a typhoon catastrophe event is primarily determined by factors such as the landfall location, intensity, development process, and duration of the disaster. Assuming that the average area of influence of a typhoon catastrophe event in the region is denoted as M, the probability of occurrence of a typhoon catastrophe event (specifically, a category 12 typhoon) is represented as D, and the expected number of typhoons per year is denoted as V, the total expected insurance loss rate ($LOSS$) caused by a typhoon catastrophe event in the region per year can be calculated using the following formula:

$$LOSS = S \times M \times V \times D \tag{2}$$

(2) Measurement of insurance base rates for catastrophic events

Assuming that region R is divided into N sub-administrative divisions, with actual risk gradient coefficients calculated from vulnerability denoted as Z_1, Z_2, ……, Z_N, and the insured amount of dwellings in each sub-administrative division represented as W_1, W_2……, W_L, the total expected insurance loss ($LOSS$) caused by the typhoon catastrophe risk faced by residences in the affected area over one year can be computed using Equation (3). The process of setting catastrophe insurance rates also necessitates the consideration of various additional factors, including the operating cost of the insurance company, the safety factor for disaster resistance, and the discount factor applied by policyholders when purchasing insurance. Assuming that the operating costs, safety, and discount adjustment factors are denoted as ω1, ω2, and ω3, respectively, the relationship between the base insurance rate ($Rate_0$), the total economic loss for residential properties, and the total expected insurance loss ($LOSS_{total}$) in the region is outlined in Equation (3), while the base catastrophe insurance rate ($Rate_0$) can be calculated using Equation (5).

$$LOSS_{total} = \sum_{L=1}^{N} W_L \times LOSS \tag{3}$$

$$Rate_0 \times (1+\omega_3) \times (1-\omega_1-\omega_2 \times \sum_{L=1}^{N}(Z_L \times W_L) = LOSS_{total} \tag{4}$$

$$Rate_0 = \frac{\sum_{L=1}^{N} W_L \times LOSS}{\sum_{L=1}^{N}(Z_L \times W_L) \times (1+\omega_3) \times (1-\omega_1-\omega_2)} \tag{5}$$

(3) Insurance Gradient Rate Measurement for Catastrophic Events

The gradient rate serves as an indicator of the risk intensity of a specific disaster experienced by various administrative divisions. Assuming that the actual risk gradient coefficients for each sub-administrative division are denoted as Z_1, Z_2, ……, and Z_N, the formula for calculating the catastrophe insurance gradient rate for the Nth sub-administrative division is:

$$Rate_N = Rate_0 \times Z_N \tag{6}$$

Equation (6) quantifies the insurance gradient rates for distinct sub-administrative districts within Region R, providing a reflection of the genuine variations in risk intensity when these districts face the same typhoon catastrophe. If the residential coverage and vulnerability significantly differ among sub-administrative zones, a notable contrast in the calculated risk gradient factors will emerge. In addition to ensuring fairness, catastrophe insurance must also consider its role as a "quasi-public product." Consequently, the risk gradient coefficients can be adjusted to formulate a final catastrophe insurance premium rate that is both reasonable and acceptable.

3.2. Technical Methodology

The technical methodology employed in this study is illustrated in Figure 2, encompassing three primary steps. Firstly, utilizing typhoon catastrophe insurance claims data from Yinzhou District to gauge the expected degree of loss in residential insurance and the average impact range of typhoons in the district. Subsequently, based on a list of landfalling tropical cyclones, the study calculates the probability distribution of the number of typhoons and their likelihood within a year, culminating in the computation of the annual expected rate of residential insurance loss in Yinzhou District. Secondly, relying on data from the Yinzhou District yearbook and the number of typhoon catastrophe insurance claims, the study computes the vulnerability of streets and towns in Yinzhou District, establishing the actual risk gradient coefficient for each street and town. Lastly, employing these actual risk gradient coefficients for each street and town, the study determines the basic rate for typhoon catastrophe insurance and the gradient rate for residential insurance in the event of a catastrophic typhoon in Yinzhou District.

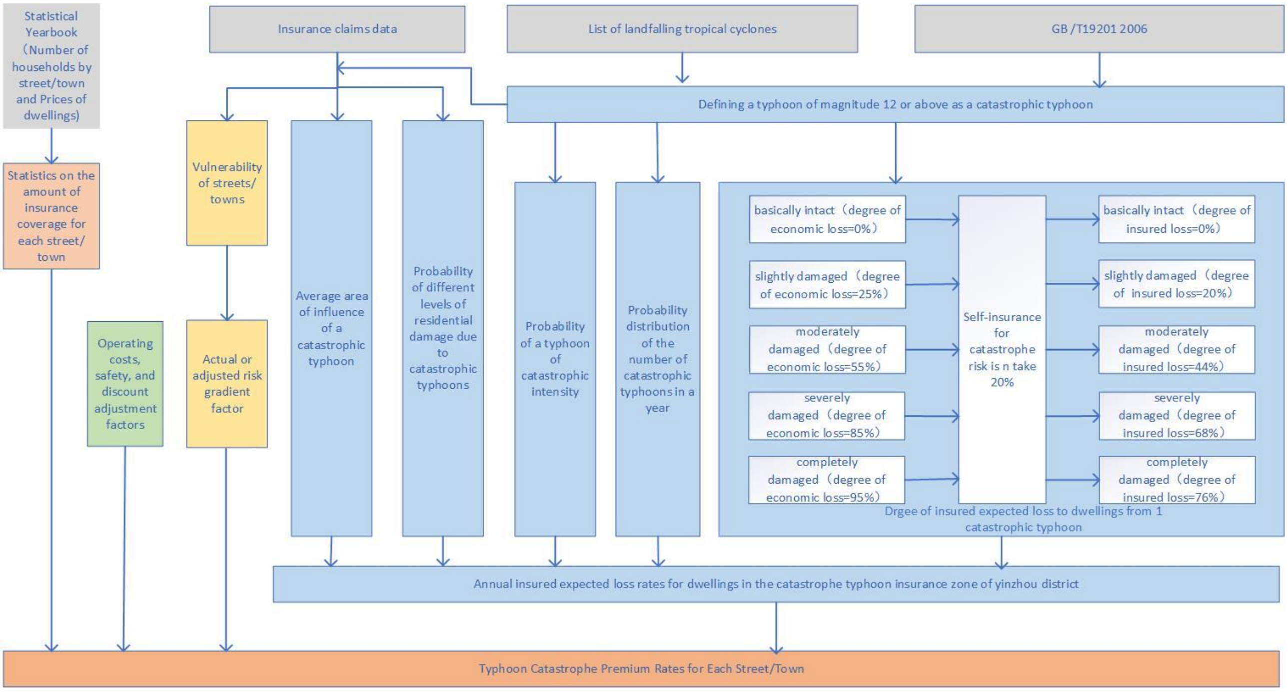

Figure 2: Technical Methodology.

3.2.1. Calculation of Expected Loss Ratio for Annual Insurance on Dwellings in Yinzhou District

Based on the 17-level wind scale [25] and historical typhoon records in Yinzhou District, this study focuses on catastrophic typhoons of level 12 and above. It assumes that residential economic losses caused by these catastrophic typhoons can be categorized into five levels: basically intact, slightly damaged, moderately damaged, severely damaged, and completely damaged, corresponding to 0%, 25%, 55%, 85%, and 95% of residential economic losses, respectively. Assuming an 80% participation rate in catastrophe insurance and a 20% self-insurance rate, the extent of insured losses for the five classes of catastrophic typhoon-damaged dwellings is 0%, 20%, 44%, 68%, and 76%, respectively. Subsequently, formulas 1 and 2 are applied to calculate the annual insurance expected loss rate for residential properties in Yinzhou District. The specific steps include: (1) Estimating the probability of five levels of residential economic losses in Yinzhou District when a level 12 typhoon occurs, based on insurance claim records, and calculating the insurance expected loss caused by level 12 and above catastrophic typhoons on residential properties in Yinzhou District using Equation (1). (2) Conducting statistical analysis on the 2000–2021 logged tropical cyclone list from the Tropical Cyclone Data Center of the China Meteorological Administration to determine the probability of occurrence and the probability distribution of the number of occurrences per year of typhoons of level 12 and above affecting Yinzhou District. (3) Obtaining the average impact range of catastrophic typhoons in Yinzhou District based on the claims data of Yinzhou District. (4) Utilizing the typhoon impact area, occurrence probability, expected number of occurrences, and expected loss degree of catastrophic typhoon insurance in Yinzhou District obtained from the above steps, Equation (2) is employed to calculate the annual expected loss rate of insurance for residences within the catastrophic typhoon insurance zone of Yinzhou District.

3.2.2. Calculation of Catastrophic Typhoon Risk Gradient Coefficients

Disaster vulnerability is primarily categorized into economic vulnerability and social vulnerability.

Economic vulnerability assessment involves indicators such as fixed assets, gross domestic product, and residents' income, while social vulnerability evaluation encompasses comprehensive social indicators like population density and education level [26]. Since this study focuses on residential catastrophe insurance, only economic vulnerability is considered. The risk gradient is determined by the actual loss ratio of residential insurance in different regions. The specific process is as follows: (1) Calculate the total value of residential houses in each street and town in Yinzhou District, i.e., the insured amount of residential houses, using the number of households and the average residential price of houses in each area. (2) Determine the average residential vulnerability to catastrophic typhoons for each street and town in Yinzhou District based on claim data and the insured amount of residential houses. Arrange these values in descending order. (3) Classify risk gradient levels considering the aggregation and disaggregation characteristics of the average residential vulnerability values in different streets and towns. Assume the lowest gradient level has an actual risk gradient coefficient of 1, corresponding to an average residential vulnerability of C. For the ith gradient level, if its average residential vulnerability is, then the actual risk gradient coefficient of the ith gradient level is C_i/C.

3.2.3. Measurement of Catastrophic Typhoon Residential Premium Rate

In this study, we assign the operating cost add-on factor (ω1), safety add-on factor (ω2), and discount factor (ω3) to 20%, 10%, and −5%, respectively. The base rate for catastrophic typhoon residential insurance is calculated using Equation (5), incorporating the actual risk gradient coefficients and insured amounts determined in Section 3.2.2. Additionally, the rates for different gradients are computed by applying the actual risk gradient coefficients in Equation (6). Recognizing the quasi-public product attributes of catastrophe insurance and aiming to mitigate discrepancies among the rates of various street and town gradients, we adjust the actual risk gradient coefficients. To equalize differences, the adjustments set the disparity between the risk gradient coefficients of two adjacent gradients to 0.5, 1, and 2 for three scenarios, respectively. This ensures that the values of the risk gradient coefficients for the four gradients under the adjusted scenarios fall within 1–2.5, 1–4, and 1–7, respectively. For instance, if the difference between the risk gradient factors of two adjacent gradients is set to 0.5, the risk gradient factors for the lowest to highest gradients will be 1, 1.5, 2, and 2.5, respectively. These adjusted gradient factors are then utilized to calculate the base rate and adjusted gradient rate for each gradient.

4. Results

4.1. Calculation of Annual Insurance Expected Loss Ratio for Dwellings in Yinzhou District

Utilizing the 2000–2021 logged tropical cyclone dataset from the China Meteorological Administration Tropical Cyclone Data Center, a statistical analysis reveals that the probability of typhoons with a level of 12 or above occurring in Yinzhou District is 43%, with the probability distribution of occurrences detailed in Table 2. Based on Yinzhou District claims data, the calculated average scope of influence of catastrophic typhoons in the district is 77%, and the extent of residential damage is outlined in Table 3. Notably, the majority of residences are categorized as "basically intact" (97.276%), while those considered "completely damaged" represent the smallest proportion (0.087%), aligning with post-typhoon loss patterns. Combining Table 3 and the information from Section 3.2.1 regarding the degree of residential loss for each economic loss level, the degree of insurance loss for each level can be computed and is presented in Table 4. Finally, leveraging the average impact range of typhoons in Yinzhou District (77%), the probability of occurrence (43%), the expected number of occurrences (1.47), and the expected degree of loss for catastrophic typhoon insurance (0.7562%), the annual expected loss rate for insurance covering residential dwellings in the Catastrophic Typhoon Insurance Zone in Yinzhou District is determined to be 0.00368.

Table 2: Probability distribution of the number of typhoons of magnitude 12 or above in Yinzhou District in a year.

Number of Times Per Year	**0**	**1**	**2**	**3**	**4**	**Total**
Probability	18%	36%	32%	9%	5%	100%
Number of expected losses	0	0.36	0.64	0.27	0.2	1.47

Table 3: Probability distribution of residential damage for typhoons of magnitude 12 and above in Yinzhou district.

Basically Intact	**Slightly Damaged**	**Moderately Damaged**	**Severely Damaged**	**Completely Damaged**	**Total**
97.276%	2.099%	0.399%	0.1392%	0.087%	100%

Table 4: Probability Distribution of Expected Loss Degree of Residential Insurance for Typhoons of Category 12 or Above in Yinzhou District.

Basically Intact	**Slightly Damaged**	**Moderately Damaged**	**Severely Damaged**	**Completely Damaged**	**Total**
0%	0.4198%	0.1756%	0.0947%	0.0661%	0.7562%

4.2. Catastrophic Typhoon Risk Gradient Coefficient Calculation Results

Table 5: Statistics on the amount of residential insurance for each area of catastrophic typhoon in Yinzhou district.

Town/Street	**Number of Households (Households)**	**Value (Ten Thousand Yuan)**	**Vulnerability**
Dongwu Town	7506	3,242,592	0.00004745
Wuxiang Town	12,424	5,367,168	0.00004702
Junqi Town	10,108	4,366,656	0.00003021
Qiuai Town	17,110	7,391,520	0.00001698
Yunlong Town	11,864	5,125,248	0.00001098
Dongqianhu Town	20,805	8,987,760	0.00000497
Tangxi Town	10,890	4,704,480	0.00000193
Shounan Street	13,728	5,930,496	0.00000178
Baizhang Street	15,015	6,486,480	0.00000121
Jiangshan Town	34,792	15,030,144	0.00000106
Dongsheng Town	11,797	5,096,304	0.00000102
Dongjiao Street	5010	2,164,320	0.00000044
Xiaying Street	9220	3,983,040	0.00000037
Hengxi Town	10,972	4,739,904	0.00000028
Baihe Street	21,427	9,256,464	0.00000025
Xianxiang Town	11,210	4,842,720	0.00000017
Minglou Street	15,120	6,531,840	0.00000017
Zhonggongmiao Street	20,831	8,998,992	0.00000014
Fuming Street	22,669	9,793,008	0.00000006
Dongliu Street	19,764	8,538,048	0.00000005
Panhuo Street	20,024	8,650,368	0.00000002
Zhonghe Street	36,695	15,852,240	0.00000001
Total	358,981	155,079,792	

Utilizing data on the number of households in each street and town within Yinzhou District, along with the average residential house price (4.32 million yuan/household) and claims data, we computed the total value of residential houses (i.e., insured amount of residential houses) and vulnerability indices for the respective streets and towns, as detailed in Table 5. The residential insurance coverage for the top five streets and towns, ranked by vulnerability, is observed to be lower than that for the bottom five in vulnerability ranking. Notably, Dongwu Town, Wuxiang Town, and Zhanqi Town exhibit the highest vulnerability, while Panhuo Street and Zhonghe Street display the lowest vulnerability. This discrepancy is attributed to the geographical positioning of Dongwu Town, Wuxiang Town, and Junqi Town along the southeast coast, where factors such as the presence of the Sanxi Pu Reservoir increase susceptibility to secondary disasters like flooding post-typhoons, rendering the region more sensitive to typhoon-induced disasters. In contrast, Panhuo Street and Zhonghe Street, located in the central part of Yinzhou District, experience minimal extremes in precipitation and wind speed during typhoons, resulting in a lower overall risk of typhoon disasters. The vulnerability ranking table is further employed to establish distinct gradients, with corresponding actual risk gradient coefficients delineated in Table 6. The actual risk gradient coefficient for streets and towns with the highest vulnerability ranking (i.e., vulnerability ranking of 4) is 813.21, exhibiting a substantial difference—approximately 13,130 and 813 times—compared to the risk gradient coefficients associated with vulnerability rankings of 3, 2, and 1. This significant variation in risk coefficients across different vulnerability gradients underscores the magnitude of the divergence in risk levels.

Table 6: Actual residential risk gradient coefficients for catastrophic typhoons in Yinzhou District.

Gradient Level	**Town/Street**	**Actual Risk Gradient Factort_j**	**Total Insurance Amount S_i (Ten Thousand Yuan)**
4	Dongwu Town, Wuxiang Town, Junqi Town, Qiuai Town, Yunlong Town	813.21	25,493,184
3	Dongqianhu Town, Tangxi Town, Shounan Street, Baizhang Street, Jiangshan Town, Dongsheng Town	53.12	46,235,664
2	Dongjiao Street, Xiaying Street, Hengxi Town, Baihe Street, Xianxiang Town, Minglou Street, Zhonggongmiao Street	6.91	40,517,280
1	Fuming Street, Dongliu Street, Panhuo Street, Zhonghe Street	1	42,833,664

4.3. Measurement Results of Catastrophic Typhoon Residential Premium Rate

Table 7 presents the premium rates calculated based on the actual risk gradient coefficients and the adjusted coefficients (modified to ensure a consistent difference of 0.5, 1, and 1.5 between the gradient coefficients of different grades) according to the four gradient levels. Analysis of Table 7 reveals that when determining catastrophe premium rates using the rates derived from the actual risk gradient, significant disparities exist among different classes, with variations exceeding a factor of seven. Notably, most streets in the northwest exhibit lower premium rates compared to those in southeastern towns.

Upon recalculating the premiums with adjusted coefficients, the results consistently fall within the range of 0.14% to 1.06%, signifying a noteworthy reduction in the gap between premium rates.

Moreover, the disparities in rates between different adjacency classes under all three scenarios were minimized to within 0.003. For instance, under scenarios with adjusted adjacent factor differences of 0.5, 1, and 2, the rates for a class gradient of 4 are nearly 3.59, 3.15, and 2.79 times lower compared to the pre-adjustment scenarios, leading to a reduction of premiums by more than 50,000 yuan in each case.

By utilizing the actual risk gradient factor, the rates for streets and towns with a grade gradient of 4 are 13, 130, and 813 times lower than the premium rates for streets and towns with grades of 3, 2, and 1, respectively. However, adjusting the risk gradient factor by a difference of 0.5 in the adjacency factor results in rates for streets and towns with a gradient of 4 that are 1.25, 1.67, and 2.49 times higher than the rates for streets and towns with grades of 3, 2, and 1, respectively. Similarly, adjusting the risk gradient factor by differences of 1 and 2 between neighboring factors leads to varying increases in rates for streets and towns with a gradient of 4, highlighting the sensitivity of the premium rates to adjustments in the risk gradient and adjacency factors.

Table 7: Typhoon Catastrophe premium rate for Yinzhou District.

Town/Street	**Premium Rate (before Adjustments)**	**Premium Rate (Adjusted Adjacent Risk Factors Differ by 0.5)**	**Premium Rate (Adjusted Adjacent Risk Factors Differ by 1)**	**Premium Rate (Adjusted Adjacent Risk Factors Differ by 2)**
Dongwu Town, Wuxiang Town, Junqi Town, Qiuai Town, Yunlong Town	0.03029957	0.00842876	0.00961151	0.01068219
Dongqianhu Town, Tangxi Town, Shounan Street, Baizhang Street, Jiangshan Town, Dongsheng Town	0.00197921	0.00674301	0.00720863	0.00763013
Dongjiao Street, Xiaying Street, Hengxi Town, Baihe Street, Xianxiang Town, Minglou Street, Zhonggongmiao Street	0.00025731	0.00505726	0.00480575	0.00457808
Fuming Street, Dongliu Street, Panhuo Street, Zhonghe Street	0.00003726	0.003371505	0.002402877	0.001526026

5. Discussion

5.1. The Need for Classification

This study categorizes the extent of residential loss, refines the statistical analysis of this loss, and furnishes foundational data for estimating insurance loss severity. The grading criteria can be adjusted to align with the claims standards of insurance companies and the varying degrees of damage to insured properties within a region. This adaptive approach ensures that the anticipated insurance loss aligns more closely with the actual housing losses incurred in the aftermath of local disasters, enhancing the accuracy and applicability of loss assessments in the insurance context.

5.2. The Need to Adjust Risk Gradient Factors

In this study, we delineate distinct risk gradients based on the quantity of streets and towns and their vulnerability rankings within Yinzhou District. The actual risk gradient coefficients are computed by amalgamating vulnerability values, with a specific focus on quantifying susceptibility to loss. To achieve this, we leverage recent claims data from typhoon catastrophe insurance, incorporating both the insured losses of residences and the corresponding insured amounts. This approach enables us to gauge the likelihood of loss in the insured amount for residences following a catastrophic event. Given the granularity of claims data, which extends down to the level of streets or towns, the actual risk gradient coefficients are calculated proportionately to the scale of these geographic units. Consequently, this methodology facilitates the precise and detailed determination of catastrophe insurance premium rates for residential properties.

In the premium rates determined based on the actual risk gradient coefficients, there exists a significant disparity among rates for different classes of streets and towns, necessitating an adjustment to the risk gradient coefficients. An examination of the adjusted insurance rates under various risk gradient coefficient scenarios (Figure 3) reveals that, alongside the insurance rates computed using the actual risk gradient coefficients, a decrease in the risk gradient coefficients between adjacent gradient levels correlates with an increase in the base premium rate. Simultaneously, the premium rate for the highest gradient level tends to decrease. This trend is attributed to the consistent total amount of insured losses across all scenarios, necessitating adjustments to the rates for specific gradient levels, whether to elevate or lower them, to maintain a constant total monetary value.

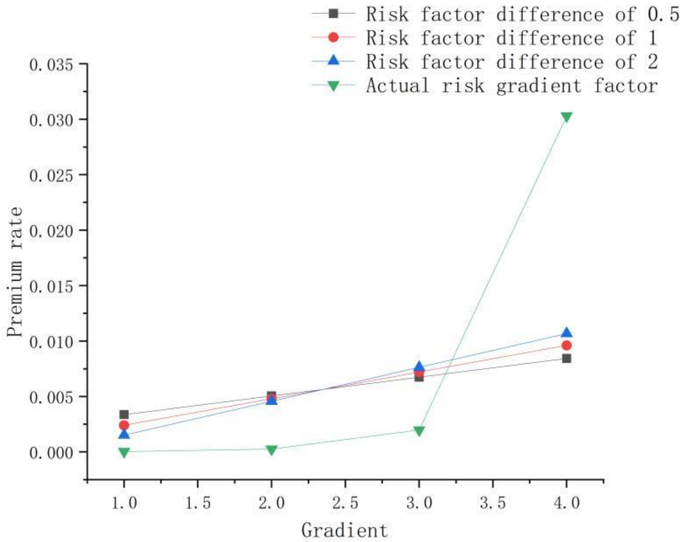

Figure 3: Chart of changes in premium rates.

5.3. Suggestions on Disaster Prevention and Mitigation and Catastrophe Insurance Promotion

The determination of whether to apply a uniform or differentiated catastrophe premium rate in an affected region is contingent upon the varying capacities of the insured populace in that region to withstand the specific type of disaster. In instances where the impact of a particular disaster spans the entire region, and the resultant losses suffered by insured entities are approximately uniform, or when the overall risk posed by the disaster to the region is relatively low with minimal damage to the insured entities, a uniform catastrophe premium rate is deemed appropriate. However, while this simplifies operational processes, it may evoke a sense of unfairness among residents experiencing lower degrees of damage, thereby potentially impeding the wider acceptance of catastrophe insurance.

Recognizing the diverse risk landscapes faced by residents in different disaster-prone areas, such as the significant vulnerability disparities among the streets and towns in Yinzhou District, warrants the adoption of distinct risk gradient coefficients. This approach aims to capture the nuanced impact of typhoons on various administrative divisions within Yinzhou District, facilitating residents' perceptions of the risk levels specific to their residential areas. Consequently, this enables individuals to make more reasoned and rational decisions regarding insurance coverage.

Although the rate differentials for adjacent grade gradients, as determined using the adjusted risk gradient coefficients, all remain within 0.003, a substantial disparity exceeding 10,000 yuan persists between the highest-risk gradient and the other gradients for streets and towns. In regions characterized by high catastrophe risk, proactive government intervention is imperative. This intervention should align with the regional promotion scope of catastrophe insurance, the refinement of the legal framework governing catastrophe insurance systems, and considerations of factors such as price levels, per capita income, and other constraints on the region's purchasing power. Implementing strategies such as subsidizing residents' premiums when purchasing catastrophe insurance and increasing financial allocations for disaster prevention and mitigation are essential. These measures aim to heighten residents' awareness of the importance of acquiring catastrophe insurance, guiding them to make informed decisions that mitigate risk and reduce potential losses [27]. Additionally, government and relevant departments can intensify pre-disaster hazard assessments, conduct disaster prevention and mitigation initiatives in high-risk areas, and provide robust safety assurances in advance of the complete widespread adoption of catastrophe insurance.

Utilizing the typhoon catastrophe insurance premium rates determined in this study, the calculated premiums for each gradient level surpass 40,000 yuan, potentially posing financial challenges for certain residents. Implementing premium subsidies exclusively for residents in high-risk gradient streets and towns could elicit dissatisfaction among those in low-risk gradients, complicating the promotion of catastrophe insurance. To address these challenges and the lack of awareness among some residents regarding how to leverage catastrophe insurance for natural disaster risk protection, the following recommendations are proposed: Firstly, irrespective of the risk level gradient, the government should incrementally establish a catastrophe insurance premium subsidy mechanism. This involves leveraging professional claims adjusters, streamlining complex claims settlement procedures, and enhancing residents' motivation to purchase insurance. Secondly, detailed risk maps for specific disasters should be generated for distinct administrative divisions within a given region. This includes an analysis of disaster vulnerability and intensity, enabling residents to interpret risk information more effectively, comprehend the importance of catastrophe insurance promotion, and undertake early preparations for prevention and mitigation. Thirdly, the government should guide insurance companies to actively engage in catastrophe risk management, motivate their participation in disaster prevention and mitigation, and reduce the loss severity of insured subjects during disasters. This can be achieved by collaborating with in-house professionals on risk early warning and providing incentives or tax benefits to insurance companies promoting their involvement in catastrophe insurance. Fourth, the establishment of a catastrophe insurance fund is recommended. The compensation needed after a catastrophe may exceed the capacity of insurance companies, and a catastrophe insurance fund can mitigate the financial impact of substantial claims on insurers post-disaster. The government can utilize this fund to provide post-disaster subsidies to affected residents. However, to prevent over-reliance on subsidies, measures such as linking subsidy amounts to the proportion of residents participating in catastrophe insurance should be adopted to judiciously control the scope and magnitude of subsidies.

5.4. Weaknesses of This Study

Despite its contributions, this study has inherent limitations stemming from data acquisition constraints. Firstly, the typhoon catastrophe insurance claims data employed spans only the period from 2016 to 2021, constituting a relatively short time series. This temporal constraint may introduce potential influences on the accurate calculation of the actual risk gradient coefficient. Secondly, the adoption of a uniform unit price of 4.32 million yuan for residential units across all streets and towns in Yinzhou District overlooks the inherent variations in actual residential unit prices. This discrepancy can impact the precision and granularity of rate determinations, compromising the accuracy of the findings.

6. Conclusions

This article leverages data from the Yinzhou District yearbook, typhoon catastrophe insurance claims, and the landfall tropical cyclone directory, employing a catastrophe insurance rate actuarial model to calculate the typhoon catastrophe insurance rates for streets and towns in Yinzhou District. The primary findings are as follows: (1) The catastrophe insurance rates in Yinzhou District exhibit a regional distribution pattern characterized by lower rates in the northwest and higher rates in the southeast. This trend is attributed to the predominantly plain topography in the northwest, reducing the likelihood of secondary disasters like floods and mudslides following typhoons. In contrast, the mountainous terrain in the southeast increases the vulnerability of structures, such as residences, due to factors like precipitation after typhoons. (2) The actual risk gradient coefficients calculated based on claims data for each street and town in Yinzhou District are notably large. Specifically, the actual risk gradient coefficient for the most vulnerable street or town is 813 times that of the least vulnerable. This stark contrast necessitates adjustments to the risk gradient coefficients. (3) The risk gradient coefficient significantly impacts the determined insurance premium rates. Following adjustments, the basic insurance premium rate experiences a substantial increase of approximately 100 times, resulting in a more than 8-fold reduction in the disparity of insurance premium rates between streets and towns. The risk gradient coefficient adjustments are carefully calibrated, taking into account the actual risk associated with dwellings, policyholders' ability to pay, and the level of government support.

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