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Design and Pricing of Wenzhou Geological Disaster Risk Bond

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Abstract: In this paper, the direct economic losses of geological disasters in Wenzhou from 2007 to 2021 are taken as the sample data, and according to the distribution characteristics of geological disasters, considering the moral hazard, the yield and price of geological disaster bonds are calculated by using capital asset pricing model (CAPM) and bond pricing principle, so as to carry out the preliminary design of geological disaster risk bonds. Finally, based on China's market environment, this paper puts forward some suggestions on how to promote the securitization mechanism of catastrophe insurance and improve the catastrophe insurance market.

Keywords: Geological disaster bond, Risk securitization, Scheme design, Operational mechanism.

1. Introduction

Wenzhou city is located in the southeast coast of the Yangtze River delta south wing, geological structure is complicated. Every year from June to September, heavy rainfall brought by typhoons, easily lead to collapse, landslide, debris flow and other geological disasters. As for the management of geological disasters, in recent years, the Wenzhou Municipal government has carried out disaster prevention and control through the action of "eliminating risks and housing" for geological disasters. According to statistics, from 2010 to 2020, the Wenzhou Municipal government has invested 188 million yuan in geological disaster prevention and control annually, with 331 investment projects each year.At the same time, the Wenzhou Ouhai branch of PICC also launched the pilot project of comprehensive geological disaster control insurance project in Wenzhou urban area in December 2021.Although the disaster has been alleviated to a certain extent, due to the continuous acceleration of the process of industrialization, as well as the characteristics of sudden and joint disasters, the loss after the disaster is also quite serious.How to effectively prevent the risk of geological disasters is an important work to maintain social stability and promote the healthy and sustainable development of Wenzhou City.

As for disaster risk management, as early as the 1970s, some scholars proposed to fully disperse disaster risks with the help of the capital market. This idea was realized by taking disaster risks insured by insurance companies as the subject matter, so as to issue corresponding disaster risk bonds, so as to transfer the insurance risks to investors who buy bonds.For the risk management of geological disasters in Wenzhou, the risk management tool of catastrophe insurance risk securitization can also be used for reference, and corresponding geological disaster risk bonds can be developed and designed, so as to fully disperse the disaster risks by virtue of the power of the capital market.

2. The Design of Wenzhou Geological Disaster Risk Bond

Wenzhou geological disaster risk bond from design to application in the market involves the following five stages: geological disaster insurance stage, geological disaster reinsurance stage, bond design stage, issue stage, fund trust stage.

2.1. Bond scheme design

2.1.1. Geological disaster insurance stage

Firstly, in order to encourage insurance companies to actively underwrite geological disaster risks and include geological disasters into a wider range of insurance liability, the government can pool the financial funds planned for disaster compensation, establish its corresponding geological disaster risk fund, and provide certain premium subsidies for insurance companies to underwrite geological disasters. Or make appropriate compensation for the insurance companies that pay more serious losses.

2.1.2. Disaster reinsurance stage

Secondly, after underwriting geological disaster risks, insurance companies will transfer part of disaster risks out in the form of reinsurance in order to reduce business risks caused by excessive insurance payouts, and agree that during the term of the reinsurance contract, when the direct economic losses caused by disasters reach a certain extent, the insurance company needs to settle claims for the insurance holders. At the same time, the insurance company will get a part of the loss compensation.

2.1.3. Bond design phase

Thirdly, in order to effectively transfer the insured geological risks to the capital market, the reinsurance company will entrust the special purpose vehicle (SPV) (the company specially set up to issue geological disaster bonds) to design the corresponding sample bonds according to the characteristics of the disaster and the loss range.At the same time, in order to meet the risk preference and tolerance of different investors, the bonds can be designed into two grades: fully guaranteed principal type and partially guaranteed principal type.Then, the risk analysis model is used to determine the degree of risk premium of the bond price, and the credit rating of the bond will be evaluated by the third party credit rating agency.If the credit rating effect is not good, it may cause credit risk losses to investors, so the credit rating can be increased by means of the government's third-party guarantee.

2.1.4. Bond issuance stage

Finally, considering that disasters are often sudden and losses, it is difficult for investors to effectively assess risks. Bonds can be issued to institutional investors with good risk tolerance at the initial stage of bond issuance to avoid market panic.At the same time, SPV and investors agree that before the bond maturity, if no geological disaster occurs in the insured area or the disaster loss does not reach the trigger point, the investor can recover the principal and interest on time.On the contrary, during the term of validity of the bond, the direct economic loss caused by the bond reaches the trigger point, the investor will not be able to earn interest income in the current year, and sometimes even lose part of the principal. The extent of the loss of the principal depends on the guarantee type of the bond purchased by the investor (fully guaranteed principal and partially guaranteed principal). Meanwhile, The reinsurance company can use the exempted principal and interest to compensate the insurance company.

2.1.5. Fund trust stage

In order to effectively manage the principal funds collected from bond issuance and reinsurance premiums, the special purpose vehicle (SPV) will entrust trust institutions to allocate the funds effectively, mostly investing in low-risk and high-credit assets such as national bonds and local bonds, so as to obtain certain returns within a small risk range. The proceeds can be used for the repayment of principal and interest or reinsurance claims after the bond matures.

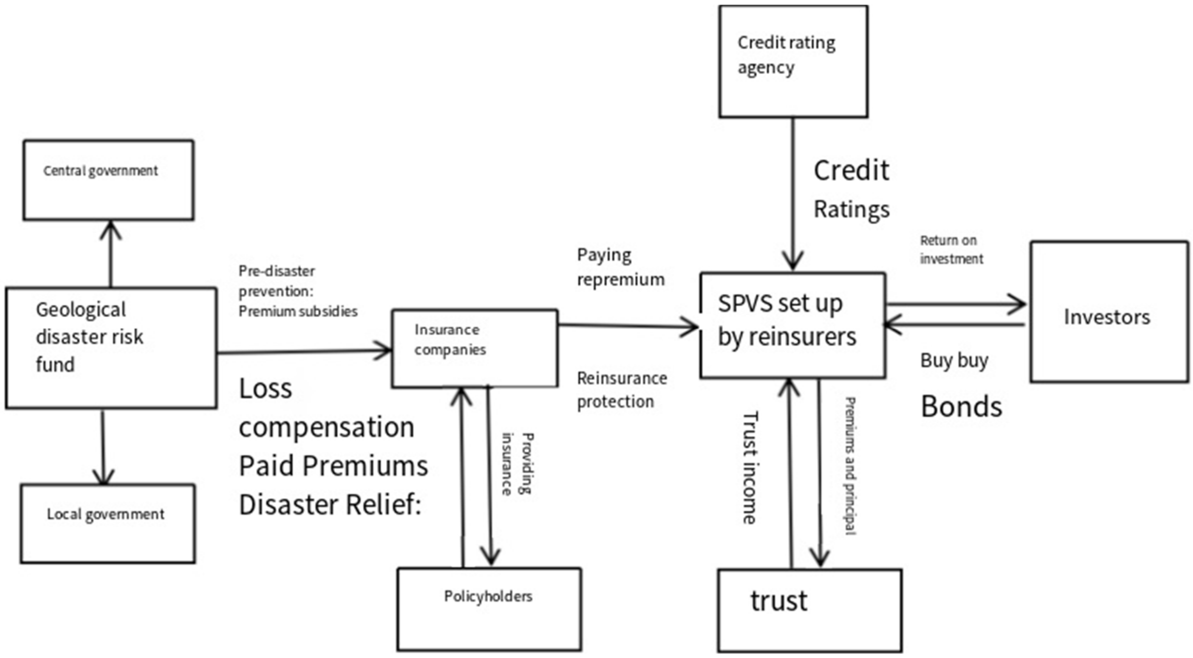

Figure 1. Operation mechanism of geological disaster risk bonds

2.2. Design of bond elements

2.2.1. Trigger mechanism of bonds

The trigger mechanism of bonds means that the issuer can avoid paying the interest or even part of the principal of the current bonds if the events agreed in the contract occur during the validity period of the bonds.According to the issuing experience of the current international catastrophe bond market, the trigger mechanism generally includes the actual loss trigger mechanism, the industry index trigger mechanism and the physical parameter trigger mechanism.

Table 1. Trigger mechanism of bonds

Types of trigger mechanisms	Concept	Representation	Advantage	Disadvantages
Actual loss trigger mechanism	Take the actual loss of the promoter as the execution threshold	Catastrophe bonds issued by USAA Corporation in 1997	Linked directly to insurance payouts, it has less basis risk	In order to avoid the repayment of principal and interest, insurance companies may exaggerate the loss of compensation and face certain moral hazard
Industry index trigger mechanism	Take the loss value of the whole industry caused by the disaster as a touch Originating node	Catastrophe bonds issued by SWISSRE in 1997 Catastrophe bonds	Issued as a third party institution Based on industry loss value, less moral hazard	Counting losses takes time, can not be paid in time, and there is a risk of basis
Physical parameters trigger mechanism	Take certain physical characteristics of the disaster as the basis for the payment of bonds	Earthquake catastrophe bond issued by Tokyo Marine Fire Insurance Company in Japan in 1997	Relatively simple operation, high transparency and low moral hazard	The disaster intensity is different in different ranges, and there is a certain basis Differential risk

In summary, although there is some moral hazard in the actual loss trigger mechanism, this risk can be weakened through continuous improvement of the subsequent system, strict supervision of relevant departments and continuous narrowing of the information gap, and the impact of moral hazard can be reduced by adjusting the triggered parameter values in the actual pricing of bonds. Therefore, the actual loss trigger mechanism is more in line with the claim settlement needs of insurance companies.

2.2.2. Risk term of bonds

It is generally believed that if the bond term is too long, the probability of catastrophe loss will be increased during the risk period, which increases the possibility of investors' principal and interest loss. On the other hand, because the issuance of bonds requires certain financial and material resources, if the maturity of bonds is too short, it will not be conducive to the allocation of issuance costs, and if the maturity is too short, it may not be able to cover the insurance period of insurance company, so the practical significance of this catastrophe transfer mechanism will be very low. At present, the maturity time of bonds in the international catastrophe bond market is mostly 3 years. On the one hand, it gives the issuer sufficient time to amortize the issuance cost. On the other hand, when the market environment changes or disaster indicators change greatly, it can provide a certain buffer time for the adjustment of related parameters of bonds. Therefore, it is more appropriate to set the risk maturity of bonds as 3 years.

3. Loss Distribution Fitting of Wenzhou Geological Disaster

3.1. Data Selection

Through consulting the Geological Disaster Bulletin of Wenzhou, the direct economic losses of geological disasters in the past years from 2007 to 2021 were obtained. Considering the effect of inflation, the sample data were adjusted with the price of 2021 as the base period and the price index of the past years as the GDP deflator. Next, descriptive statistical analysis of the data was carried out using SPSS.

Table 2. Descriptive statistics of the data

Research object	Minimum	Maximum	mean	Standard deviation	skewness	kurtosis
Direct economic loss	5.41	5454.77	860.9810	1518.5296	2.551	6.255

The skewness of this sample data is 2.551, which is greater than 0; The kurtosis is 6.255, greater than 3, showing a peak-to-tail distribution, and the sample data does not conform to the characteristics of normal distribution.

3.2. Fitting test

p-p diagram test is performed on the distribution function as follows:

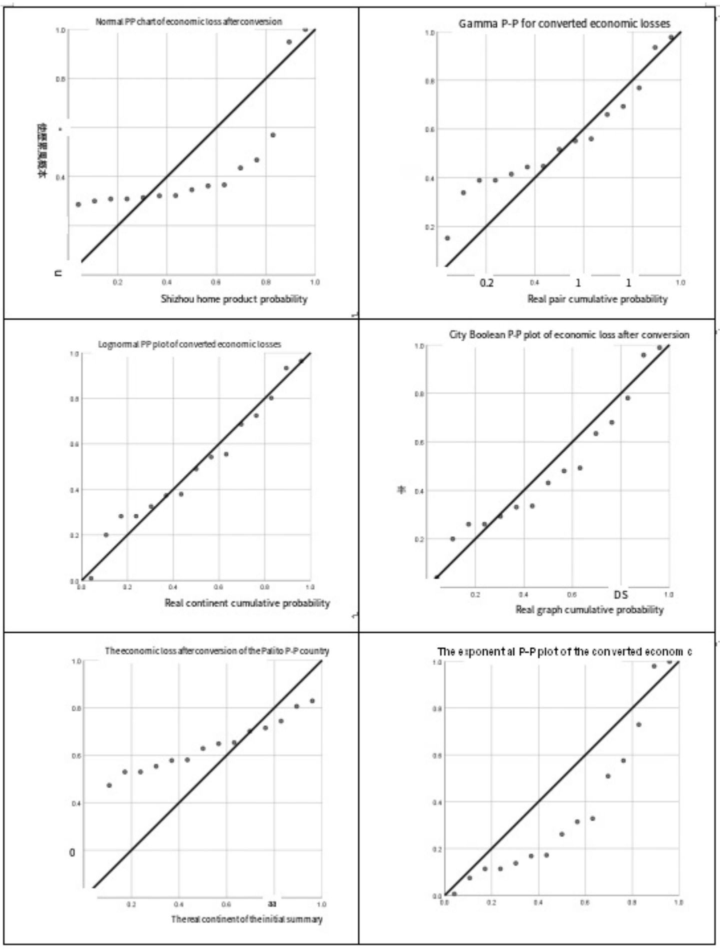

Figure 2. p-p test diagram of distribution function

It is found that the probability distribution of the data follows the lognormal distribution well by testing the results of the p-p graph.In order to verify whether the conjecture is correct, the K-S test is carried out.Firstly, the parameter values of the corresponding distribution were obtained by maximum likelihood estimation, and the K-S test results were analyzed at the significance level of 0.05.

Table 3. Fitting results of the distribution model

Probability distribution function	Parameter estimates	K-S test results (Z-values)	P value
Normal distribution	U = 860.981 The delta = 1467.039	0.33342	0.05473
Lognormal distribution	U = 5.607577 Lambda = 1.619847	0.14198	0.8823
Exponential distribution	Lambda = 0.1161466	0.93289	2.2 e-16
Pareto distribution	Alpha = 0.250 Lambda = 5.3844	0.9286	0.0580
Gamma distribution	Alpha = 0.54476 Beta = 0.06327	0.92895	2.2 e-16
Weibull distribution	Shape = 0.65591 Scale = 6.03481	0.92527	2.2 e-16

3.3. Model Estimation

As can be seen from the results in the table, P=0.8823 and Z=0.14198 of the lognormal distribution are the optimal results, so the fitting accuracy of the lognormal distribution is the highest. Therefore, the loss value of geological disasters follows the lognormal distribution.

The probability density function of the distribution model is as follows:

$$f(x,\mu,\delta)=\frac{1}{\sqrt{2\pi}\delta}\exp\left[-\frac{1}{2\delta^2}(\ln x-\mu)^2\right] \quad (1)$$

The estimated values of the parameters are:

$$\mu=5.6076,\quad \delta=1.6767$$

The probability distribution function is:

$$F(x)=\int_0^{+\infty}f(x)d(x)=\int_0^{+\infty}\frac{1}{\sqrt{2\pi}\delta}e^{\left[-\frac{1}{2\delta^2}(\ln x-\mu)^2\right]}d(x) \quad (2)$$

Then the probability of occurrence:

$$P(x)=1-F(x)$$

Corresponding return period:

$$a=\frac{1}{P(x)}=\frac{1}{1-F(x)}$$

Based on the probability distribution function, the probability of occurrence and the theoretical return period under different disaster losses are calculated. The results are as follows:

Table 4. Probability and recurrence period of direct economic losses caused by geological disasters

Direct economic loss of geological disasters (ten thousand Yuan)	Probability distribution function values	Probability of occurrence	Return period
16.61	0.0476	0.9524	1.0
103.63	0.2821	0.7179	1.4
103.80	0.2824	0.7176	1.4
127.18	0.3248	0.6752	1.5
158.34	0.3731	0.6269	1.6
162.44	0.3788	0.6212	1.6
260.73	0.4895	0.5105	2.0
272.50	0.5000	0.5000	2.0
325.16	0.5420	0.4580	2.2
342.45	0.5542	0.4458	2.2
737.96	0.7238	0.2762	3.6
1125.04	0.8011	0.1989	5.0
1117.60	0.8000	0.2000	5.0
2340.00	0.9002	0.0998	10.0
3328.21	0.9322	0.0678	14.8
5454.77	0.9630	0.0370	27.1
6000.00	0.9674	0.0326	30.7

As can be seen from the data in the table, geological disasters such as landslide, collapse and debris flow will occur in Wenzhou every year. On average, a geological disaster with a loss scale of more than 2.8 million yuan will occur every two years.The probability of annual losses exceeding 11.3 million yuan is about 0.2, that is, the direct economic losses brought by geological disasters to Wenzhou will reach 11.3 million yuan every 5 years on average.There will be a geological disaster with a loss scale of 23.4 million yuan every 10 years.

Since the parameter of disaster bonds with fully guaranteed principal and 70% guaranteed principal is economic loss, assume that the loss value X occurs once every 5 years1nullIs the trigger node of the fully guaranteed principal bond, and the loss value X occurs once every 10 years2nullIs the trigger node of 70% guaranteed bond, then:

$$P(X_1 \le X < X_2) = F_2 - F_1 = 0.2$$

$$P(X \ge X_2) = 1 - F(X_2) = 0.1$$

So $F_1 = 0.7$, $F_2 = 0.9$

From the above table of probability of loss, we know that X1null= 6.57 million yuan, X2null= 23.4 million yuan.That is, the direct economic loss of the bond with full principal protection and the bond with 70% principal protection is 6.57 million yuan and 23.4 million yuan respectively.

4. Pricing and Design of Wenzhou Geological Disaster Risk Bonds

This paper selects the capital asset pricing model (CAPM model) to calculate the yield of Zhejiang typhoon disaster risk bonds.The model formula is:. $E(r_i) = r_f + \beta_i \left[E(r_m) - r_f \right]$ Where, is the expected rate of return, is the systemic risk, is the risk-free rate of return and is the expected return of the market. $E(r_i)$ β_i r_f $E(R_m)$

First, the current market risk-free return =, with an average of 1.9596%, is taken as the average return of the national bond yield announced in 2022, and the arithmetic average of the beta value of the A-share stock portfolio in the last two years is taken as the systemic risk, and the weighted average return rate of the stock market in the last two years is taken as the market expected return rate.

In other words:

$$R_f = 1.9596\%, \quad \beta_i = 0.8499, \quad E(R_m) = 14\%$$

If the moral hazard factor is taken into account, in the case of information asymmetry, the issuer or insurance company may raise the disaster losses in disguised form in order to reduce the compensation for investors' interest.For example, the trigger loss node of the fake fixed coupon payment is 10 billion yuan, while the actual direct economic loss caused by the typhoon is 9.8 billion yuan. At this time, the issuer should pay the principal and interest to the investors on time, but in order to reduce the payment, it may take some measures to make the report finally show the loss value of 10 billion yuan, so the existence of moral hazard may harm the interests of investors.

In order to protect the interests of investors, the moral hazard factor is introduced into the bond pricing, so the trigger node of the bond will be reduced accordingly. β β If, after the introduction of moral factor, the trigger node of typhoon bonds will be reduced by 5%, that is, the corresponding loss values of bonds with fully guaranteed principal and 70% guaranteed principal are 6.241,500 yuan and 22.23 million yuan respectively, then the probability of occurrence is adjusted as follows: $\beta = 0.05$

$$P(169.1 \le X < 608) = 0.205$$

$$P\ (X \ge 608) = 0.105$$

The default probabilities of the two bonds become 0.205 and 0.105, respectively.Therefore, after the introduction of moral hazard factor, the trigger point of fully guaranteed principal bonds becomes (624.15,, 0.205), and the trigger node of 70% guaranteed principal bonds is adjusted to (2223,0.105).Next, the capital asset pricing model and discounted cash flow model are used to determine the coupon rate and issue price of bonds respectively.

4.1. Determination of bond coupon rate

4.1.1. Bond with full principal guarantee

$$E(R) = R_f + (R_m - R_f) \times \beta = (1 - P_1) \times R_1 + p_1 \times 0$$

$$R_1 = \frac{R_f + (R_m - R_f) \times \beta}{1 - p_1}$$

$$R_1 = \frac{1.9596\% + (14\% - 1.9596\%) \times 0.8499}{1 - 0.205} = 15.34\%$$

4.1.2. 70% principal guaranteed bonds

$$E(R) = R_f + (R_m - R_f) \times \beta = (1 - P_2) \times R_2 + p_2 \times (-0.3)$$

$$R_2 = \frac{R_f + (R_m - R_f) \times \beta + 0.3 \times p_2}{1 - p_2}$$

$$R_2 = \frac{1.9596\% + (14\% - 1.9596\%) \times 0.8499 + 0.3 \times 0.103}{1 - 0.105} = 17.08\%$$

As a result, the coupon rates for fully guaranteed principal and 70% guaranteed principal bonds are 15.34% and 17.08%, respectively. The latter yields a higher coupon than the former because a partially guaranteed bond would incur not only interest losses but also a 30% loss of principal if it defaulted. Based on the risk-return equilibrium principle, the higher the risk, the more return needs to be compensated, so the higher the coupon rate of the bond.

4.2. Determination of bond issue price

Next, discount cash flow model is used to price bonds with fully guaranteed principal and 70% guaranteed principal.

4.2.1. Fully guaranteed principal bonds

The coupon rate is 15.34% and the trigger point is (624.15, 0.205).

The present value of the expected earnings of the first phase is:

$$p_1 = \frac{15.34 \times (1 - 0.205)}{1 + 1.9596\%} = 11.96$$

The present value of the expected earnings of the second phase is:

$$p_2 = \frac{15.34 \times (1 - 0.205)}{(1 + 1.95965\%)^2} = 11.83$$

The present value of the expected earnings of the third phase is:

$$p_3 = \frac{115.34 \times (1 - 0.205) + 100 \times 0.205}{(1 + 1.9596\%)^3} = 105.85$$

The bond price is:

$$P = p_1 + p_2 + p_3 = 129.64$$

4.2.2. 70% Principal Guaranteed Bond

The coupon rate is 17.08% and the trigger point is (2,223, 0.105).

The present value of the expected earnings for the first instalment is:

$$p_1 = \frac{17.08 \times (1 - 0.105)}{1 + 1.9596\%} = 14.99$$

The present value of the expected earnings of the second phase is:

$$p_2 = \frac{17.08 \times (1 - 0.105)}{(1 + 1.9596\%)^2} = 14.70$$

The present value of the expected earnings of the third phase is:

$$p_3 = \frac{117.08\times(1-0.105)+70\times0.105}{(1+1.9596\%)^3} = 105.79$$

The bond price is:

$$P = p_1 + p_2 + p_3 = 135.48$$

According to the discounted cash flow model, the issuance prices of the bonds with a maturity of 3 years and 70% of the principal are 129.64 yuan and 135.48 yuan respectively.

4.3. Sample design of geological disaster risk bonds

In order to effectively manage the risk of geological disaster in Wenzhou area, an insurance company (such as Wenzhou Ouhai branch of PICC Property Insurance Company) is led under the organization of the local government to carry out the pilot project of comprehensive geological disaster insurance business in Yueqing, Yongjia, Cangnan and Taishun areas with high incidence of geological disaster. The insurance term is 3 years.Since the retention of a single risk of an insurance company can not exceed 10% of the capital and provident fund, 80% of the insured amount will be reinsurance; Subsequently, the reinsurance company entrusted the special purpose vehicle SPV to issue disaster risk bonds with 100% principal guarantee and 70% principal guarantee to institutional investors in the form of reserve price issuance, which raised about 10 million and 6 million bond principal respectively in the early stage. Among them, the trigger node of 100% guaranteed principal bond is 6.57 million yuan, and the trigger node of 70% guaranteed principal bond is 23.4 million yuan. It is agreed that during the issuance period, when the economic loss of disaster reaches the corresponding trigger node, investors who invest in fully guaranteed principal bond will lose interest income in the current period. While investors who invest in 70% guaranteed principal bonds will not only lose interest in the current period, but also lose 30% of the principal when the bond matures.

5. Countermeasures and Suggestions

Developing catastrophe bonds will help relieve the pressure of disaster relief and play the risk management function of capital market. Although the global catastrophe bond market continues to expand and is more and more recognized by investors, China's catastrophe bond market is still immature. The current development of catastrophe bonds can be started from both short-term and long-term aspects.

In the short term, public-private catastrophe bonds can be issued with the help of government credit, and the offshore issuance can be promoted. At present, the foundation of the catastrophe insurance market is relatively weak, and it is very difficult to take the path of complete marketization. At this stage, we can learn from the experience of other developing countries. The government can set up corresponding SPV institutions and jointly carry out catastrophe insurance business with general commercial insurance companies. Then, with the joint efforts of the government and the market, SPVS can transfer the risk to the capital market by issuing catastrophe bonds.

The long-term development of catastrophe bonds cannot be separated from the improvement of marketization degree, including the cultivation of investors, the construction of market infrastructure and the establishment of institutional framework. In terms of investor cultivation, priority should be given to institutional investors, the establishment of catastrophe investment funds should be explored, and the investment scope of pension funds and sovereign wealth funds should be expanded to include catastrophe bonds. In terms of market infrastructure construction, a risk modeling technology exchange platform should be set up jointly with universities, insurance institutions, modeling companies and other forces. Meanwhile, a catastrophe data sharing system should be established jointly by the government and the market to supplement the catastrophe data database. In the aspect of system construction; The first is to improve the institutional framework of insurance linked securities, to standardize the establishment conditions, business scope, information disclosure, capital supervision and other elements of SPV; Second, to give SPVS certain tax incentives to avoid double taxation in the circulation link; The third is to clarify the accounting treatment rules of insurance securitization and determine reasonable standards.

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References

[1] Liu Tingjie, Shi Neng, Gu Junqiang. Statistical analysis of typhoon disasters in Zhejiang Province [J]. Journal of Catastrophology,2002(04):65-72.]

[2] Yang Xiaoliang, Yang Min, Long Linxue, Yang Lv Yuci, Wang Haichuan, Yang Yue. Characteristics of northbound typhoons and their typical heavy rain processes affecting the Bohai Rim [J]. Marine Forecasting, 201,38(04):99-106.

[3] Shi Jian-xiang, Wu Yun-ling. Research on risk securitization of catastrophe insurance in China -- Design of typhoon disaster bonds [J]. Finance Research,2006(05):103-112.]

[4] Krzyszt of Burnecki and Grzegorz Kukla.Pricing of zero-coupon and coupon cat bonds[J].Applicationes Mathematicae, 2003, 30 (3) : 315-324.

[5] Ou H, Zhou Z Y. The innovation and pricing of flood catastrophe bonds [J]. Journal of Natural Science of Hunan Normal University,20,43(04):75-79. (in Chinese)

[6] J. David Cummins. CAT Bonds and Other Risk-Linked Securities: State of the Market and Recent Developments[J]. Risk Management and Insurance Review, 2008, 11(1) : 23-47.

[7] Shi Jianxiang, Wu Yunling. Research on risk securitization of catastrophe insurance in China -- Design of typhoon disaster bonds [J]. Finance Research,2006(05):103-112.]

[8] Tian L, Xiang F. Comparative study on catastrophe bond pricing model based on risk pricing framework [J]. Journal of Wuhan University (Philosophy and Social Sciences), 2006 (02): 168-174.]

[9] Kang Hanbin, Xing Tiancai. Considering multiple risk factors of catastrophe bond pricing research in China [J]. Journal of insurance research, 2013 (8) : 94-106. The DOI: 10.13497 / j.carol carroll nki is. 2013.08.008.