Research Article
Pricing for Catastrophe Bonds Based on Expected-value Model

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Abstract: As the catastrophes cannot be avoided and result in huge economic losses, therefore the compensation issue for catastrophe losses become an important research topic. Catastrophe bonds can effectively disperse the catastrophe risks which mainly undertaken by the government and the insurance companies currently and focus on capital more effectively in broad capital market, therefore to be an ideal catastrophe securities product. This study adopts Expectancy Theory to supplement and improve the pricing of catastrophe bonds based on Value Theory. A model of expected utility is established to determine the conditions of the expected revenue R of catastrophe bonds. The pricing model of the value function is used to get the psychological value of R, U $(R-\bar{R})$, for catastrophe bonds. Finally, the psychological value is improved by the value according to expected utility and this can more accurately evaluate catastrophe bonds at a reasonable price. This research can provide decision-making for the pricing of catastrophe bonds.

Keywords: Catastrophe bonds, expected utility theory, pricing, value theory

INTRODUCTION

Catastrophic Events (Cats) have a low frequency of occurrence but generally huge losses. Different types of Cats have different characteristics of occurrence and impacts on human lives and properties (Wu and Chung, 2010). In recent years, with the intensification of global warming, natural disasters are increasing in frequency and intensity, while the rapid socio-economic development has made the destruction of the losses caused by disasters to further increase. Natural disasters are paid more attention. Earthquakes, hurricanes, tornadoes and hailstorms consist of the four most costly types of insured catastrophic perils in the United States. Of these, earthquakes and hurricanes pose the greatest catastrophic risk generating on average $9.7 billion in claims annually from 1989 through 2001(Gao, 2002). Correspondingly, the contradiction between the increasing demand for catastrophe insurances and the fact that insurance companies are reluctant to cover catastrophe insurances is caused by the old system of insurance policy. People concern the viability and stability of reinsurance as well as a bigger market. That is, capital market, which covers the insurance market. Therefore, a new type of catastrophe risk transfer mode is developed, that is, risk securitization. One form of solution is through catastrophe risk securitization by bringing catastrophe exposures directly to the capital market. Such mechanisms include Cat-linked bonds,

swaps, exchange-traded options and futures, etc (Zhu, 2011). Catastrophe bonds (or Cat bonds) are an important security for managing the risks of catastrophe event losses, e.g. hurricanes, European wind storms, or earth quakes (Jarrow, 2010). Since the 1990s, cat bonds have evolved as an alternative to standard reinsurance contracts. From 1997 to 2006, a total of 89 cat bonds were issued worldwide, 41 by insurers and 43 by reinsurers. And 2006 was a record year in the history of cat bonds, with 20 issuances (Guy, 2007).

Compared with the traditional reinsurance, the advantages of insurance securitization are: such pattern of financing exceeds the limitations of risk sharing among the original insurers, reinsurers and the insured while the risk was shared in the insurance contract with other parties who are in risk preference, transferring and sharing the risk in more extensive area; The prices and cash flows of risk securities are based on potential random variables, so investors can not totally control loss-sharing or exert significant impact. In addition, while catastrophe risk may affect the compensation capacity of the re-insurers for the original insurers, risk securities are almost to be not put in the problem. Meanwhile, capital market accesses to a huge development and have gradually become mature and motivated. Because capital market is always concerned about the new asset types and how these assets support the development of capital markets, as a new financial innovation, risk securities can provide more investment

choices, which were widely supported and encouraged (Wang *et al.*, 2006).

In this context, the international financial market comes about the new trend of securitization of catastrophe insurance in 1990s. As the innovation in capital market, catastrophe risk securitization which could enlarge underwriting capacity will have a major impact on the financial industry. The securitization of catastrophe risk is an important form of risk spread and capital accumulation, with the logical attribute of the insurance product, but in the form of investment products- securities. It can spread the catastrophic risk mainly taken by the government and insurance companies now and focus on the capital of broad capital markets more effectively. Therefore, the catastrophic securities are ideal catastrophe risk products. If a specified catastrophe does not occur (or if aggregate damages are less than a trigger level) before the maturity date of the bond, the investors get the full face value of the bond plus very generous coupon payments. If the specified catastrophe does occur (or if aggregate damages exceed the trigger level) before the maturity date, the bond defaults resulting in either a partial or no payment to investors. Fortunately, the capital markets are extremely large (approximately $31 trillion) relative to the scale of the property damage and can readily absorb this risk (Unger, 2010). Guy Carpenter and Company Inc. (2008) provides a 'year-end 2007 update' of all publicly disclosed transactions to date. They state that the CAT bond market has grown steadily when measured by the total outstanding risk capital of $13.8 billion at year-end 2007, compared to $8.48 billion at year-end 2006, $4.90 billion at year-end 2005 and $4.04 billion at year-end 2004. This total does not include private placements which are becoming more common. Cat bond risk principal now comprises 8% of the $169 billion property limits market globally and 12% of the $81 billion United States market.

Pricing models for catastrophe bonds have been studied several times. Cummins and Geman (1995) as well as Lee and Yu (2002),develop a no-arbitrage model for pricing CAT bonds ,the objective of the model depends on industry-wide hurricane losses along the Gulf and Atlantic coasts of the United States as reported quarterly by the PCS index. Poncet and Vaugirard (2002) derive a tractable formula within the more convincing arbitrage approach, in a framework of stochastic interest rates, but limit their analysis to non-catastrophic events. Lee and Yu (2007) introduced moral hazard and basis risk into the risk of catastrophe bonds pricing model, he thought catastrophe bonds can reduce the risk of the basis risk of reinsurance person effectively. Dieckmann (2008) proposes a dynamic equilibrium model for cat bonds with an external habit

process as in Campbell and Cochrane. Härdle and Cabrera (2010) priced a hybrid cat bond for earthquakes, assuming a doubly stochastic Poisson process for the flow of catastrophic events.

This study uses the pricing model of expected utility theory to determine the conditions of the expected revenue R; Then under the principle of the value function, using the most representative investment product-the stocks, as regression data to obtain a function to find the psychological value of R; Finally, the psychological value is improved by the value according to expected utility and can more accurately evaluate catastrophe bonds at a reasonable price and to provide decision-making for the pricing of catastrophe bonds.

PRICING MODEL

Expected utility theory: As a well-known theory of the uncertainty decision-making problem, Expected utility theory was first proposed in 1738 by Bernoulli (1954/1738) and wasn't given a complete system until (Von Neumann and Morgenstern, 1944) pointed out that EU theory is the gauge theory of the uncertainty decision-making problem in 1944 (Von Neumann,1944). EU theory is that if a decision maker makes risk decision-making process consistent with the effectiveness axiom, he must choose the largest value of the expected utility of the alternative programs. Expected utility is the function of the result of probability P and the utility of this result U. The probability used here is exogenous and objective. Savage (1954) made the Subjective Expected Utility (SEU) which considered that the subjective probabilities was used rather than objective probability when the choice of alternative programs was decided by following the principle of subjective utility maximization. By then, the expected utility theory has been widely applied to decision analysis. Schmeidler noted that, if non-additive beliefs were allowed in the SEU for decision-makers, the new model can describe the actual decision-making behavior of investors. Therefore, based on the Tolerance Theory, Schmeidler proposed Choquet Expected Utility (CEU) by Choquet integral (Yang, 2008) and established a complete axiom system. Yaari is most famous for amending the fifth theorem, introducing the dual theory and also putting forward insurance pricing theories on the dual principles. Barfod, AM&D. Lando measured of different risk-neutral probabilities through the use of numerical methods for solving differential equations and calculated the price of contingent claim (Frankfurter *et al.*, 2004).

Expected utility theory is the traditional idea of securities pricing which has occupied the mainstream position in the research and development for many years and has been constantly promoting forward, already possesses a relatively strict set of research ideas and theoretical framework.

Value theory in behavioral finance theory: Despite the catastrophe bond pricing technologies have developed to a certain height, the current pricing technologies of catastrophe bonds are established under the risk pricing framework of standard financial theory, because the assumptions of the standard financial theory are too "perfect", these catastrophe bond pricing techniques based on standard financial theory exist problems which need urgent amendment. Therefore, behavioral finance theory is increasingly developing.

In the 19th century, scholars have studied on the behavior of asset market-related groups, books of authority in the field are Mass written by Gustave lebon and Extraordinary Public Misconception and Groups Crazy written by Mackey. Kahneman and Tversky issued Prospect Theory: An Analysis of Decision Making Under Risk in 1979 (Daniel and Tversky, 1979). With a new theory to replace the expected utility theory, it's the first official appears of expectancy theory as theoretical system. In 1982, Kahneman, Slovic and Tversky further improve the expectancy theory system (Daniel *et al.*, 1982). Since the 1990s, the results of expected theoretical research are emerging: Tversky and Kahneman have witnessed the real birth of behavioral economics (BF) and declared to be contrary with the principle of CAPM/EMH (Kahneman *et al.*, 1982). In 1992, Tversky and Kahneman absorbed Quiggin's idea of RDEU, introduced of the concept of capacity and proposed cumulative prospect theory. In this theory, the probability weights are the judgment made by the policy-makers according to the probability p, it is neither a probability nor a linear function of probability but rather a weight corresponding to the cumulative probability (Tversky and Daniel, 1992). In 1998, Fama established people's choice theory under uncertainty situation based on the relevant results of psychological study (Fama, 1998). Campbell.Lo and Mackinlay published "Financial Market Econometrics"; Hersh Shefrin published "Beyond Greed and Fear: the Understand to Investment Psychology and Behavioral Finance "(Hersh, 2005); Andrei Shleifer published "No-effective Market-Behavioral Finance Introduction"; Hersh Shefrin published" Behavioral Finance II". Richard H. Thaler published" Progress in Behavioral Finance Episode II". Expectancy theory has been applied to all related areas, showing a flourishing situation.

In China, specialized publications of Behavioral Finance are: Dong has edited the "behavioral economics" and co-wrote "behavioral economics-Theory and Applications" with Xue. Zhang (2003) discussed the definition to psychology value: utility, value function, mental accounting and the different psychological laws, also gave simple evaluation of the Kahneman value function, this study only analyzed the theory of Kahneman involved in psychological laws ,not proposed a complete theory; Luo discussed Kahneman's theory of economics, held that the theory is from the psychological utility, constantly measuring personal effectiveness and exploring new ways of social welfare and also confirmed the influence brought by non-fully rational people to justice (Luo, 2009).

Since the standard finance theory is assumed too "perfectly", these standards-based pricing techniques exist to improve with the urgent amendment, in this context, theory behavioral finance theory in the core of prospect theory has been emerging. Behavioral finance theory is critical for financial theory and it's a better solution and supplemented for the insufficiency of standard financial theory.

For the Expected Utility Theory and the Value Theory, the former is a completely rational calculation under the rigorous assumption, the latter focuses on the impact of psychological evaluation on prices. This study explores a viable catastrophe pricing model under the guidance of their respective merits.

CATASTROPHE BOND PRICING BASED ON EXPECTED UTILITY THEORY

The basic assumption of utility function is that investors of catastrophe bonds are completely rational. That catastrophe bond investors are fully rational is dictated by the pursuit of their own economic interests-"utility maximization" and "profit maximization". In order to achieve the maximum of personal investment interests, people can make the most rational judgments and decisions without any factors.

Under this premise, this study aims at operating conditions and pricing issues of catastrophic risk bonds, discussing as follows: Suppose,

P = Profit
R = Return on investment
K = The amount of capital
r = The price of capital (interest rates)
C = The cost of other factors affecting the return on investment except the capital
U = The public benefit

Take short-term bonds of one-year for example, if the case of catastrophe occurs, the catastrophe bond

buyers recover principal K but lose interest, then lose the opportunity cost rK; If catastrophe does not occur, the catastrophe bond buyers receive bond interest as income and recover the principal of (1+R)K.

From the above parameters, we can see the investment return function relative to K as follows:

$$P(K)=RK-rK-C \qquad (1)$$

Then find the partial derivative of (1) to get the probability of profit on capital:

$$\frac{\partial P}{\partial K} = R - r$$

Therefore, the expected value of utility U can be obtained as follows:

$$E(U)= \frac{\partial P}{\partial K}(1+R)K - [1-\frac{\partial P}{\partial K}]rK = (R^2 + R - 2r - r^2)\ K \qquad (2)$$

On the conditions of E(U)≥0, K≥0, the function followed can be built as the condition of bond pricing:

$$T(R)=R^2 + R - 2r - r^2 \geq 0\ (R \geq 0)$$

By calculation, we can get the condition equation:

$$R \geq \sqrt{r^2 + 2r + \frac{1}{4}} - \frac{1}{2} \qquad (3)$$

Catastrophe bonds can be defined as bearer bonds, such bonds can be traded on the secondary market with the purchase price depends on the supply and demand condition of the market. When a factor in market changes, the price will has greater volatility, so it has opportunities for greater profits; in addition, the government can relieve the interest tax of catastrophe bonds so that the real rate of return would increases. Therefore, even if their pricing interest rates are not higher than the current bank interest rates, investors with strong sence of investment and the financial institutions would still buy them.

CATASTROPHE BOND PRICING BASED ON VALUE THEORY

The premise of the value theory: Based on the function of value theory, this study argues that when investors of catastrophe bonds are in the face of complex and uncertain problems, they cannot fully thought seriously for lack of time and adequate information, or the reason of overload of information and the limited processing capacity of information, etc. Gathering all the useful information for an objective analysis is impossible, therefore, catastrophe bond investors in market cannot make decision strictly in accordance with the Bayes rule. Firstly, according to value theory, in the reality are limited rational investors, mainly by virtue of intuition, experience and imagination to a sense of judging and evaluation directly; Secondly, based on value function theory, this study considers that the utility function is also a value criterion which does not meet the actual situation. Psychology research shows that investors of catastrophe bonds are making choices to one or more reference materials as a standard to compare to arrive at the perception relative to the reference. So this study holds that it depends more on the gains and losses which is relative to the reference point, rather than absolute loss and income calculated by the utility function theory of and standard when the catastrophe bond investors make decision; Finally, the value function theory is close to the actual investors' psychology feelings of "subjective value" and "subjective weight", it is a suitable decision-making tool.

Characteristics of value function: Substantial evidence shows that people generally do not consider the final status of wealth but the changing status of wealth. An enormous breakthrough of expectancy theory is the replacement of the value function for the traditional utility function, thus the carrier to the value implemented by the change in wealth rather than the final state of wealth.

Value function measures the value situation deviation from the reference point. On the right of reference point is for positive evaluation and the left of the reference point stands for negative evaluation. Value function breaks the hypothesis of rational man, overall, it has four important features:

- For individuals, the profit is always better than the loss under any circumstances and the greater profits, the higher the value. So the value function should be a monotonously increasing curve.
- The value function is defined as the profits and losses in relation to a reference point rather than the wealth in the end of traditional theory.
  Therefore, the value function is a monotonically increasing curve which through the origin point of reference point on the map whose abscissa is profit.
- According to the "reflection effect", the value function should be S-type on the origin as the center to the profit and loss directions. In the direction of profit function is concave, reflecting

Table 1: Statistics of basic situation

Stock type	Quantity	Proportion	Average rate of return	Average turnover
Stock of loss	58	64.44	-27.79	76.46
Stock of profit	32	35.56	46.11	85.3

risk-averse; In the direction of loss is convex, reflecting risk preference.

- The slope ratio in the loss-part of the value function of was larger than that in the profit-part, that means, when investors face the corresponding profit and loss, the marginal loss is to be more sensitive than marginal profit.

The value function for pricing of catastrophe bonds:
The data of 98 shares in 2009 are selected for the sample in Chinese securities market. Take IPO prices of the first day as the first-day returns, average about eight new shares were issued monthly during 2009. Therefore, it is appropriate to take the average yield of 8 lags as reference point to judge earnings. Subtracting the average yield of 8 lags from this return rate to get the difference between the income level and the reference, that is the independent variable x in the value function model: if the deviation is positive, indicating profit this time, if it is negative, indicating loss this time. Taking the difference between the return rates of present share and the last share as this psychological reference value, that is the dependent variable U(x) in the value function model. The psychological value of the level of return is directly relative with the return of the last new share, which is in keeping with the psychological feelings of investors. The statistics of basic situation is listed in Table 1.

What can be seen from preliminary results is that stocks of profit account for 35.56%, significantly less than the proportion of stocks of loss of 64.44%. It is caused by the overall downward trend in the stock market in the period selected, new shares in this phase have the overall low profitability. From the data of the average return rate of profit-stocks reached 46.11% and the average turnover rate was 85.3%; the average return rate of loss-stocks was -27.79% and the average turnover rate was 76.46%, we can see that the turnover rate of the profitable stocks is significantly higher than

that of loss-stocks, which shows that when investors get profit, they prefer to sold early to achieve profit, shown on the state of risk aversion; on the contrary, when investors meet loss, they prefer to hold stocks, shown on the state of risk appetite.

From the overall stock market, it is consistent with expectations theory and then verifying the applicability of expectancy theory from the units.
Construct the linear regression equation:

$$H_i = a + bX_i + \varepsilon_i \tag{4}$$

where,
H_i = The turnover of stock i of the first day
X_i = The return level of reference of stock i
a, b = Parameters to be estimated
ε_i = A random term of disturbance

Under the significance level of 1%, take the data of stocks into the regression, the results are shown in Table 2:

$$H_i = 79.785 + 0.119X_i \tag{5}$$
$$105.052 \quad 6.882$$

From the regression results, turnover and income levels of reference are positive correlation, the higher profits, the higher the turnover and this positive relationship has reached 11.9%, significant probability of t of coefficient of income level reference: p = 0<0.01, through the test at 1% significant level, indicating the reference level of return on the impact of turnover is significant and its coefficient is significantly positive. This shows the psychology of investors in China's stock market is in line with expectations theory.

Establishment of catastrophe-bond value function:
Regression method will be adopted to establish the value function in this study. The value function of a two-stage form of power function is proposed by Wakker and Zank (2002) as follows:

$$U(x_i) = \begin{cases} ax_i^\alpha, & x_i \geq 0, \ a>0, \alpha>0 \\ -b|x_i|^\beta, & x_i \leq 0, \ b>0, \beta>0 \end{cases} \tag{6}$$

Table 2: Coefficients (a)

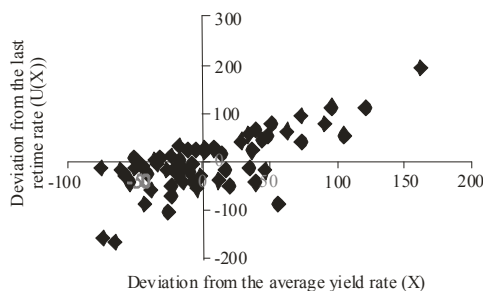| Model	Parameters	Unstandardized Coefficients		Standardized coefficients	t	Sig.	95% Confidence interval for B	
		B	S.E.	beta			Lower bound	Upper bound
1	(Constant)	79.785	0.759		105.052	.000	78.276	81.294
	Deviation from the average yield rate (X) (%)	0.119	0.017	0.592	6.882	0.000	0.084	0.153

Fig. 1: Data distribution of IPOs in 2009

Table 3: Parameter estimation of the value function on condition of loss

Variables in the equation

Variable	B	SE B	Beta	T	Sig T
X	0.681877	0.271224	0.318466	2.514	0.0148
(Constant)	-3.049695	8.966821	-	-0.340	0.7350

Table 4: Parameter estimation of the value function on condition of profit

Variables in the Equation

Variable	B	SE B	Beta	T	Sig T
X	0.972739	0.195154	0.673056	4.984	0.0000
(Constant)	-5.906126	11.485127	-	-0.514	0.6109

Firstly, the assumption form of the value function is sub-type, it can well describe the different risk preferences in the profit and loss range; Secondly, this value function form well describe the psychology changes of investors caused by the risks Changes; Thirdly, this form of value function uses power function, so it can be used to describe the marginal diminishing effect; Finally, the form of value function also has solved the issue of negative parameter, meet the concave requirements of the value function.

As the catastrophe bond has not officially released in China, it does not exist prices of catastrophe bonds in the secondary market, so the regression of this function adopts the data of stocks as samples. As the value function is mainly characterized the degree changes of psychological value when investors face the changes of risk, so choose the most representative risk investment product-stocks as the regression data can establish a better value function and simulate more accurately of mentality of investors' in China.

Data of from average yield rate serve as the independent variable x, deviation from the return of last stock stands for the dependent variable U(x). Excluding the abnormal data points from sample data, we get the following distribution graph shown in Fig. 1.

It can be found that U(x) increases along with x increases, but the rates of increase are different with the region, reflecting the aversion for risk of profit and appetite for risk of loss.

According to the formula (4), use SPSS software to estimate parameters respectively in region of profit and loss (Guo, 1999). The results are respectively shown in Table 3 and 4.

The constant term passes the t-test (X<0,P = 0.7350>0.05;X>0, P = 0.6109>0.05), the corresponding coefficient is not significantly different from 0. The independent variables X passes the t-test (X<0,P = 0.0148<0.05;X>0, P = 0.6109<0.05), the corresponding coefficient is significantly different from 0 and expectation function can be estimated by the regression results:

$$U(x_i) = \begin{cases} 0.973 x_i^{0.195}, & x_i \geq 0, \ \mathsf{a} > 0, \alpha > 0 \\ -0.682 |x_i|^{0.271}, & x_i \leq 0, \ b > 0, \beta > 0 \end{cases} \quad (7)$$

It can be seen: when profit, reference income level for each 1% change will cause investors to change with the psychological value of 0.195%; and when loss, the reference income level for each 1% change will cause investors to change with the psychological value of 0.271%. So equivalent changes of profits and losses bring people different psychological experience, painful sense of loss is greater than happiness brought by equal profits.

In most cases, the investment of products doesn't equal to the reference prices in investors' mind. When the actual prices are higher or lower than the reference prices, investment decisions of investors will be affected, thereby affecting the distributions and sales of investment products, especially on the condition that the actual prices are higher than the reference prices. If the deviation can be measured and adjusted to meet investor psychology, it will greatly boost the sales of catastrophe bonds. This is the basic guiding ideology which leads the value function into our Catastrophe Bond Pricing Model.

APPLICATION OF THE PRICING MODEL

This study selects the bonds issued from July 6 to July 23 of 2009 as a sample, if planed to issue new bonds at that time, based on this study of Catastrophe Bond Pricing Model, the process is as follows.

Make bank interest rate r in accordance with the 1-year rate of lump-sum deposit and withdrawal time deposits in July 2009 value for 2.25%, use the expected rates formula (3) to calculate the necessary condition of bond interest rate R:

$$R \geq \sqrt{r^2 + 2r + \frac{1}{4}} - \frac{1}{2} = 4.36\% \quad (8)$$

Next, amend the expectation function based on purely rational hypothesis through value model, the process is as follows: As shown in Table 5, 34 bonds

Table 5: Bond issuance in the primary market

Release date	Bond name	Bond type	Circulation(billion)	Period (year)	Interest rate (%)	Debt level	Main level
7-6	09 Bank 01	Financial bond	140	5+5	3.28%	AAA	AAA
7-6	09 Bank 02	Financial bond	240	10+5	4.00%	AAA	AAA
7-6	09 Liaoning debt 02	Local debt	26	3 years	1.79%	- -	- -
7-6	09 Ningbo debt 01	Local debt	15	3 years	1.79%	- -	- -
7-6	09 Shandong debt 02	Local debt	29	3 years	1.79%	- -	- -
7-6	09 Shenzhen debt 01	Local debt	24	3 years	1.79%	- -	- -
7-6	09 Xinjiang debt 02	Local debt	25	3 years	1.79%	- -	- -
7-6	09 Huaxin CP01	Short finance	6	365 days	2.75%	A-1	AA-
7-6	09 Shougang MTN1	Medium-term	60	5 years	3.85%	AAA	AAA
7-7	09 Jiugang CP01	Short finance	25	365 days	2.31%	A-1	AA
7-8	09Interest-bearing debt 14	National debt	275.2	1 year	1.06%	- -	- -
7-8	09 of Wuxi Traffic debt	Corporate bond	20	7 years	5.58%	AA	AA-
7-8	09 Hefei Construction Debt	Corporate bond	20	5 years	5.04%	AAA	AA +
7-8	09 Huayi CP01	Short finance	20	365 days	2.31%	A-1	AA
7-9	09 Bank Note 24	Central-vote	500	91 days	1.05%	- -	- -
7-9	09 Bank Note 25	Central-vote	500	1 year	1.50%	- -	- -
7-13	09 Changchun electric CP01	Short finance	10	1.00	1.85%	A-1	AAA
7-13	09 Yun Ye CP01	Short finance	10	1.00	2.50%	A-1	AA
7-14	09 South Electric MTN1	Medium-term	70	3.00	2.79%	AAA	AAA
7-14	09 Shen Resource CP01	Short finance	20	1.00	2.30%	A-1	AA +
7-14	09 South Electric MTN2	Medium-term	30	5.00	3.60%	AAA	AAA
7-14	09 Daihai CP01	Short finance	9	1.00	2.50%	A-1	AA
7-14	09 MCC MTN1	Medium-term	31	5.00	4.50%	AA +	AA +
7-15	09 Bengang MTN1	Medium-term	12	3.00	3.70%	AA +	AA+
7-15	09 Savings 03	National debt	400	3.00	3.73%	- -	- -
7-15	09Nuclear China 2	Corporate bond	25	7 + 3	4.50%	AAA	AAA
7-15	09 Nuclear China 1	Corporate bond	15	10.00	4.9%	AAA	AAA
7-17	09 Yuyuan debt	Corporate bond	5	5.00	5.9%	AAA	AA-
7-20	09 Discount bond 14	National debt	185.1	0.50	1.58%	- -	- -
7-21	09 Central vote 28	Central bank bill	150	1	1.65%	- -	- -
7-22	09 Shenjiang debt	Corporate bond	7	5	4.50%	AA +	AA +
7-23	09 Central vote 29	Central bank bill	50	0.25	1.21%	- -	- -
7-23	09 Interest-bearing debt 16	National debt	283	10	3.48%	- -	- -
7-23	09 Yang construction debt	Corporate bond	20	7	5.94%	AAA	AA-

were issued in China's bond market from July 6 to July 23, 2009, so choose the average yield as the reference point with which investors judged profits: $\bar{R}$ = 3.02%. We can get the deviation from the average yield rate is: $X = R-\bar{R} = R-3.02\%$, then take the value of X values into the model equation (7), according to R≥U (x_i), the following formula can be obtained:

$$\begin{cases} R-0.973(R-\bar{R})^{0.195} \geq 0, & R \geq 3.02\% \\ R+0.682|R-\bar{R}|^{0.271} \geq 0, & R \leq 3.02\% \end{cases} \quad (9)$$

From Eq. (9), the catastrophe bond pricing is the min R which meets the formula (8) and (9), by calculation, min R = 4.36%.

Making the interest rate as the pricing of catastrophe bonds, not only to meet the positive expected utility of investors, but also to ensure the psychological value is greater than the objective rate of the bonds, so as to ensure the sale of bonds, in addition, for the issuers such as governments, this issuance costs are the lowest. Substituting R = 4.36% into equation (7) as test: U (1.34%) = 41.97%. This result means that the

bond interest rates of 4.36% value to 41.97% in the investor's psychological, much higher than the objective yield 4.36%.

Therefore, we can say that the pricing of catastrophe bonds of 4.36%, is feasible, not only reaches an low cost in the issue, but also is given to the high price the investor's psychological evaluation, which is very beneficial to both the issue and sale.

After the calculation above, the interest rate of catastrophe security, through a common authentication of both expectations function and the value function, interest rate of 4.36% is entirely feasible. At the level of interest rate, the cost of the bond's issue is low and the investor is fully willing to accept the bonds, which is very favorable on the issuances and sales of catastrophe bonds.

CONCLUSION

Due to the no-avoidance of catastrophe and the inevitability of losses, the compensation for catastrophe will be an important and timeless proposition in the process of social development. In modern society, the

frequency and expandedness of disaster determine the disaster compensation of any single form cannot completely solve the problem, but rather a hybrid of the disaster compensation system, which in addition to the traditional ways such as governmental fund, insurance company and public donations, the introduction of the new sharing side of catastrophe risk is an urgent and important issue.

This study puts forward an idea of issuing catastrophe bonds, adopting the pricing model of expected utility theory to determine the conditions of the expected revenue R; then, under the principle of the value function, using the most representative investment product-the stocks, as regression data to obtain a function to find the psychological value of R; Finally, the psychological value is improved by the value according to expected utility, this can more accurately evaluate catastrophe bonds at a reasonable price and to provide decision-making for the pricing of catastrophe bonds. The study has important practical significance for the pricing behavior of the bond issuers and can provide decision-making support for bond investors in the capital market.

ACKNOWLEGMENT

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