Critical Illness Insurance Pricing and Markov Optimization Model: Based on the Analysis of Severe Malignancies in China

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Abstract: With the development of the insurance market and the growth of public demand, more and more people choose to buy critical illness insurance products to protect against related risks. With the introduction of many new critical illness insurance products by insurance companies, the study of the pricing of critical illness insurance-related products is of great significance. Based on the example of severe malignant tumors among critical illnesses, this paper calculates the pricing of critical illness insurance for severe malignant tumors in different age groups using traditional methods based on data from China. Subsequently, this paper explores the optimization of critical illness insurance pricing with the Markov model. Finally, it summarizes the conclusions and gives relevant suggestions on the pricing of critical illness insurance for severe malignant tumors in terms of data, comprehensive coverage, and government supervision and control, so as to provide a reference for the pricing and future development of standalone primary whole life critical illness insurance products.

1 INTRODUCTION

In recent years, with the continuous advancement of medical technology and increased attention to health, critical illness insurance has become one of the important risk management tools for people. Iranian scholar Seyed Morteza Adyani argues that the country's healthcare benefits are far from being insufficient not enough at all to fully solve the financial problems caused by high costs, and that the aid of commercial health insurance is essential (Adyani and Alizadeh 2018). CC Koay states in his article that critical illness insurance is a means of protection by which insurance companies provide payouts to insured people and that when an insured person suffers from a disease listed in the policy, such as cancer, the insurance company will make a claim accordingly (Koay 2003). Baione F and Levantesi did a study with an Italian subject, who flexibly applied the pricing model of medical insurance to critical illness insurance, but he argued that the model is very restricted and can only be applied under certain conditions (Baione and Levantesi 2014).

However, because of the large differences in the incidence and risk factors of critical illnesses, how to rationalize pricing has become an important issue for insurance companies. The traditional pricing method of major disease insurance is mainly based on statistical modeling and actuarial theory, but this method has certain limitations when facing complex risk factors. In order to predict the incidence and risk level of major diseases more accurately, this paper will consider introducing the method based on the Markov model for pricing. Most of the basic definitions of the Markov chain refer to BruceL. Jones's article "Modeling Multi-State Processesus inga MarkovAssumption" (Jone 1993). This article not only provides a detailed definition of Markov chains but also describes the use of pricing in long-term health insurance practices by insurance companies. Ermanno Pitacco's "Actuarial models for pricing disability benefits: Toward saunify in gapproach" builds on previous research by linking transfer probabilities and transfer intensities of discrete Markov chains, and initially constructs a three-state Markov model (Pitacco 1995). Christiansen illustrates a framework for actuarial modeling of Markov models as well as Semi-Markov models for health insurance and describes the need for randomization of transfer intensities (Christiansen 2012). the need for randomization. The multi-state Markov model was initially used to measure the pricing of disability income insurance, but has since been widely applied

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and extended to the pricing of other insurance products including health insurance. The main objective of this paper is to calculate the insurance pricing of severe malignant tumors for different age groups in China using the traditional pricing algorithm for critical illness insurance. Further, this paper also explores how to use the Markov chain for model optimization of insurance pricing.

2 PRICING PROCESS AND ACTUARIAL ASSUMPTIONS

2.1 The Basic Process of Pricing Critical Illness Insurance Maintaining the Integrity of the Specifications

According to existing research findings, the pricing process of critical illness insurance usually includes the following steps: first, the insurance company will build a Markov model based on information such as risk factors, claims history, customer's age, gender, occupation, etc., and use the model to predict the customer's future risk level. Then, the insurer will develop a pricing strategy based on the prediction results. Specifically, the insurer will determine premiums based on factors such as the customer's age, gender, and occupation, while taking into account the customer's historical risk factors and historical claims history. It is important to note that actuarial assumptions will vary as each insurance company is different. However, usually, the Markov model takes into account the influence of the customer's age, gender, occupation, historical risk factors, and historical claims record (Hailong 2023).

However, China's insurance industry has a limited time to develop, so in the early stage, it mainly refers to western empirical data, and can only be fit to China's specific situation as much as possible when the historical accumulated data is not complete. In this paper, this paper use specific data from the "China Life Insurance Industry Critical Illness Experience Incidence Table (2020)" published by the China Society of Actuaries to price critical illness insurance based on the traditional insurance pricing model.

2.2 Actuarial Assumptions

The establishment of appropriate actuarial assumptions is an important part of the pricing process of critical illness insurance. Actuarial assumptions are reasonable assumptions that are discussed and made in a certain actuarial model about the influencing factors of pricing (Yaling 2022). The purpose of actuarial assumptions is to enable insurance companies to estimate risks more accurately and thus develop more reasonable insurance rates. The significance of actuarial assumptions is that can help insurance companies to better manage risks and improve the profitability and competitiveness of the company.

2.2.1 Expected Incidence Assumptions

In insurance pricing, expected incidence is an important assumption that can be used to predict future levels of risk in order to set premiums accordingly. The meaning of the expected incidence assumption is that when insurance companies conduct a risk assessment, they will predict the probability of occurrence of a certain risk in the future based on factors such as historical data and statistical modeling. The purpose of expected incidence assumptions is to help insurance companies better manage risks, and it can also help consumers better choose insurance products that suit their needs.

In terms of experience incidence of major diseases, Table CI7 of the New Critical Illness Table, which is a table of experience incidence of malignant tumors - severe (2020 version definition), is selected. After data cleaning, column xi is the prevalence rate corresponding to each age under the New Critical Illness Table, and column ki is the probability of death of an individual with a critical illness at each age that is not due to an accident. Probability.The incidence rates of different age groups are shown in Table 1.

Table 1: Malignant Neoplasms - Severe (2020) Experience Incidence Table Unit (%).

Age	xi	ki
0-10	0.151727273	0.188513636
11-20	0.16105	0.177435
21-30	0.3451	0.17205
31-40	1.09575	0.299565
41-50	2.87155	0.38123
51-60	5.8071	0.4476
61-70	110.1685	4.4838
71-80	17.0727	0.312105
81-90	21.9204	0.146565
91-100	25.93215	0.07823

2.2.2 Interest Rate Assumption

Plus, the interest rate assumption is an important assumption that can be used to predict future changes in interest rates so that premiums can be set accordingly. The purpose of the interest rate assumption is to help insurance companies better manage their risks, and it can also help consumers better choose insurance products that suit their needs.

In this paper, with reference to the consistent conservative attitude of insurance companies, and comparing with the current insurance products circulating in the market, the interest rate is assumed to be $f = 2.5\%$.

2.2.3 Mortality Assumptions

Next, mortality assumptions in catastrophic insurance pricing refer to the level of mortality assumed by the insurer during the pricing process. The mortality (qx) assumption is an important assumption that can be used to predict future changes in mortality rates so that premiums can be set accordingly. The purpose of mortality assumptions is to help insurers better manage risk and also to help consumers better choose insurance products that are suitable for them.

Critical illness insurance belongs to a kind of health insurance, so this paper adopts the non-pension business one table in the experience life table of China's life insurance industry.The relevant data of different age groups and mortality in non-elderly care businesses are shown in Table 2.

Table 2: Mortality, Real-Time Survival and Real-Time Death Rates at Different Ages for Non-Pension Operations.

Age (i)	**Mortality assumptions(qx)**	**Real-time survival rate**	**Real-time mortality rate**
0-10	0.0308%	100.0000%	0.0308%
11-20	0.0314%	99.9692%	0.0314%
21-30	0.0472%	99.9378%	0.0472%
31-40	0.0842%	99.8906%	0.0842%
41-50	0.2061%	99.8065%	0.2061%
51-60	0.4862%	99.6004%	0.4862%
61-70	1.3277%	99.1142%	1.3277%
71-80	4.3794%	97.7865%	4.3794%
81-90	12.3894%	93.4072%	12.3894%
91-100	28.8295%	81.0177%	28.8295%

2.2.4 Internal Corporate Surcharge Rate Assumptions

In the pricing of critical illness insurance, the internal company surcharge rate assumption refers to the level of the internal company surcharge rate assumed by the insurance company in the pricing process. The China Banking and Insurance Regulatory Commission (CBIRC) issued the Circular on Actuarial Requirements for General Life Insurance in early 2020 in order to enable insurance companies to compete reasonably and fairly.According to the needs of the article, the average level of $t = 18\%$ surcharge rate of the insurance industry in the Circular is selected.

3 EMPIRICAL STUDY ON PRICING OF CRITICAL ILLNESS INSURANCE - AN EXAMPLE OF SEVERE MALIGNANT TUMOR

Because the Chinese insurance market is currently not well equipped with data on the conditions of critical illness patients of different ages, it is more difficult for this paper to calculate the intensity of entering a critical illness state without constant age, but this paper can make reasonable assumptions by using the critical illness table and the empirical mortality rate, and explore as one of the commonly used types of insurance in practice: the standalone primary type of whole life critical illness insurance product.

A stand-alone primary type whole life critical illness insurance policy is a type of critical illness insurance that consists of two parts, death, and critical illness liability, which are independent of each other, each with a single sum assured. If the insured suffers from a major illness, the insurance company pays the major illness benefit, then the death benefit will be zero, and if the insured does not suffer from a major illness, then the death benefit will be paid.

In the case of such insurance products, the expected incidence is affected and becomes M_i, $M_i = X_i - X_i * q_x$, $i = 1, i = 2, i = 3, \cdots, i = 10$. Corresponding to age groups of $0-10, 11-20, 21-30, \ldots, 91-100$ years old data values. Under the above assumptions, the average price for men and women for the different ages of annual term critical illness insurance was calculated for the critical illness experience incidence and normative mortality rates of the new critical illness table. Where the assumptions are that the unit sum assured is $Q = 100000$, $Y = 30$.

$$I_i = \frac{QM_i}{(1+f)^Y}(1+t), \quad (1)$$

here, $i = 1, i = 2, i = 3, \cdots, i = 10$ corresponding to age groups of $0-10, 11-20, 21-30, \ldots, 91-100$. The premiums for severe malignant tumor diseases in different age groups are shown in Table 3.

Table 3: Premiums corresponding to severe malignant neoplasm diseases at different ages.

Age（i）	Premiums（Ii）
0-10	85.32889296
11-20	90.5712186
21-30	194.0466084
31-40	615.9023608
41-50	1612.079383
51-60	3250.93911
61-70	61153.15774
71-80	9183.744862
81-90	10803.66356

4 IMPROVED ALGORITHM FOR PRICING CRITICAL ILLNESS INSURANCE BASED ON MARKOV MODELING

Markov model is a stochastic process model that can describe the probability transfer relationship of a system in different states. By building a Markov model for major disease insurance, this paper can obtain information such as correlation and transfer probability between various diseases. This information can help this paper to predict the occurrence and risk level of major diseases more accurately, thus providing a more scientific basis for pricing (Pasaribu et al 2019).

Taking severe malignant tumors as an example, the disease has high morbidity and mortality rates, which impose a huge economic burden on individuals and society. Therefore, research on pricing strategies for severe malignant tumors is of great practical importance. In this paper, this paper will take severe malignant tumors as an example, and analyze the degree of influence of different factors on the disease and the law of transfer by constructing its Markov model, so as to provide a reference for the development of reasonable pricing strategies.

The application of the Markov model in the field of insurance pricing is mainly to analyze the risk factors of customers and predict their risk level, so as to set reasonable premiums. The advantage of the Markov model is that it can take into account the historical risk factors of the customers, so as to more accurately predict the future risk level. Also, the Markov model can take into account a customer's historical claims history to set more reasonable premiums. However, Markov models also have some limitations. First, the Markov model assumes that a customer's risk factors are fixed, but in reality, a customer's risk factors may change over time. Second, the Markov model assumes that a customer's historical claims record has no effect on premiums, but in reality, the claims record may affect premiums (Hailong 2023).

When pricing critical illness insurance, discrete Markov chains are adopted for modeling, assuming that the state space is {1,2,3, ... ,k}, then in the stochastic process {x(t),x>0}, the state at moment t is denoted by x(t), if it satisfies for all $s,t>0$ and $i,j,x(u)\subset\{1,2,...,k\}$, both:

$$Pr\{X(s+t)=j\mid X(s)=i,X(u)=x(u),0<u<s\} \\ =Pr\{X(s+t)=j\mid X(s)=i\} \tag{2}$$

This paper then claims that this process satisfies a discrete Markov chain and can be used as a pricing model for critical illness insurance.

For the practical application of the Markov model, the following assumptions need to be made according to 2023 Zhao Hailong's study:

1) Taking every year as a minimum time interval unit, first fix the discrete time interval to one year, and the transfer intensity is uniformly distributed over the interval, that is, it is a constant, assuming that the transfer intensity from health to disease is the same as the transfer intensity from health to death.

2) Assuming that the strength of death at each age is constant, i.e., constant over an age interval, the strength of transfer from health to death is also constant (Chunjuan et al 2023).

3) Under the premise that the transfer intensity is constant, this paper can take the negative logarithm of the morbidity rate to derive the transfer intensity of the health state to the disease state.

Pricing of critical illness insurance, often that the insurance liability includes major diseases and death of two, so the pricing of critical illness insurance using the following formula:

$$\bar{A}^{AB}_{X:n}=\int_0^n {}_tP_x^{11}\mu_x^{12}(t)v^t dt+\int_0^n {}_tP_x^{11}\mu_x^{14}(t)v^t dt \tag{3}$$

P represents the transfer probability between states, the two numbers on its superscript represent the transfer from the initial state to another state, for example, P^{ij} represents the probability that the initial state is i, and at the next moment the state is j. μ as the transfer intensity, similar to our understanding of the deadweight force in the life insurance actuarial, then similarly μ^{ij} represents the intensity of the initial state of i, and at the next moment the state of j. The transfer probability between states is the probability that the initial state is i, and at the next moment the state is j. The first letter or number is generally a transferable state, and the second letter or number is generally a non-transferable state.

5 CONCLUSION

This paper uses traditional insurance pricing calculations to see that premiums gradually increase with age, peaking in the 61-70 age group. With age, the body's function declines, immunity weakens, and the risk of malignant tumors increases, so the premium calculation results are in line with common sense.

Through the case study in this paper, this paper found that this paper can develop and optimize in the following areas in the future. In terms of data-driven precision pricing, with the development of big data technology, actuarial research on insurance pricing will pay more attention to the in-depth analysis of the incidence rate, mortality rate, and treatment cost of patients with malignant tumors by using big data technology, so as to realize the precision of pricing malignant tumor insurance. By mining and analyzing a large amount of data, insurance companies can be provided with a more scientific and reasonable basis for pricing, reducing the risk exposure of insurance companies and improving the competitiveness of insurance products. In terms of comprehensive protection solutions, future actuarial research on insurance pricing will focus more on the development of comprehensive malignant tumor insurance products, covering a variety of treatment modalities, such as chemotherapy, radiotherapy and surgery, to provide customers with all-around protection. In addition, cooperation with related industries such as medical care and rehabilitation can also be considered to provide customers with a full range of services from prevention, and treatment to rehabilitation. Finally, in terms of policy support and regulation, government policy support and regulation in malignant tumor insurance pricing will have a positive impact on actuarial research. The government can encourage insurance companies to develop insurance products for malignant tumors by adjusting tax policies and providing financial subsidies. The theory of major disease insurance pricing based on the Markov model can be used as a basic model for practical application. Under the premise of data support, according to the algorithmic process of this paper, more states (e.g., healthy, mild, moderate, severe, and death) can be considered to be added, which has a positive reference significance to the industry's pricing of critical illness insurance.

In conclusion, future actuarial research on insurance pricing in China in terms of malignancy insurance pricing is expected to achieve precision, personalization, synthesis, innovation, and standardization to meet market demand, reduce patient burden, and promote the healthy development of the insurance market.

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