Optimal control strategy of rural medical insurance system based on elderly people's satisfaction

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Abstrac

As a key part of the modern social security system, medical insurance system is crucial for human health and medical insurance. Especially in rural areas, medical insurance system is an important way to guarantee the health of elderly people. Therefore, this paper concentrates on the problem of rural medical insurance system design to satisfy elderly people's requirements. In China, the medical insurance consists of "social medical insurance" and "commercial medical insurance". Particularly, the basic medical insurance is constructed by "Basic medical insurance for urban workers", "Basic medical insurance for urban residents", and "New rural cooperative medical insurance". Afterwards, we present an optimal control strategy of rural medical insurance system, and the elderly people's satisfaction is regarded as the restrictive condition. Particularly, the optimal control strategy aims to maximize the expected value using the dividend barrier and the control policy at a specific time point. Then, the optimal control strategy of rural medical insurance system is obtained via maximizing an optimal return function. Finally, performance of the proposed strategy is tested through insurance will investigation by randomly choosing 10 administrative villages in China's rural areas. Experimental results show that using the proposed optimal control strategy, insurance will investigation of elderly people is effectively promoted.

Keywords: rural medical insurance, optimal control strategy, stochastic differential equation, optimal return function

1 Introduction

As an important section of the social security system, medical insurance system is of great importance for human health and medical insurance. Several countries have started a pilot and exploration of the employee medical insurance system. Particularly, considering the intensification of the trend of old people, the pressure of old people provide a great difficulty for the construction of modern medical insurance system. Therefore, to construct the harmonious development of society, the medical problems of the old people need more attentions [1, 2].

Rural modernization is an important part in modern society, and it is a crucial component of modernization process. Particularly, In China, the living and health condition of peasants, perfect rural medical insurance system can effectively represent progress and standard of our country's modernizations. As is a kind of social welfare, good health care can enhance the capabilities of fulfilling human values [3]. However, with the market-oriented reforming of novel medical care method, peasants may become the underprivileged persons who pay the charges by themselves.

Hence, the issues of peasant health and living conditions are becoming more and more serious. Furthermore, problems of farmers' medical health should be guaranteed is quite important. Medical insurance refers to public goods, which determines that it should supply by the government [4, 5]. Rural areas, together with low economic conditions, should be paid more attentions by the national government. If this problem cannot be tackled well, development of China's modernization may be delayed. Traditional rural medical insurance is not satisfied, and then in this paper, we analyze the main obstacles of China reforming rural medical insurance system. Particularly, in this paper, we aim to establish the optimal control strategy for the government to obtain optimal value function and related policies.

2 Related works

In recent years, rural medical insurance system has attracted many attentions from governments and academic circles. The related works about rural medical insurance system are listed as follows.

Yan et al. underlines the importance of effective management capacity for New Cooperative Medical Scheme at the decentralized level and suggests pointers for the content and process of management capacity development. The results are grouped into three areas of management capacity: staff, organizational and contextual [6].

Long et al. aims to describe prenatal care use, content and costs of care in one county where prenatal care is included in the New Cooperative Medical Scheme and two different counties. Particularly, where this paper discoveries the perceptions of stakeholders of the prenatal care benefit package to understand the strengths and weaknesses of rural medical insurance system [7]. Afterwards, the authors studied factors influencing maternal health care utilization in western rural China and its relation to income before year 2002 and after year 2007 introducing a novel rural health insurance system [8].

Yi et al. concentrated on the problem of finding to assess some of the strengths and weaknesses of the program utilizing a panel of national-representative, household Survey data from 2005 to 2008. Furthermore, this paper concluded that the recent reports by the Ministry of Health that there have been substantial improvements to the NCMS

program according to coverage and participation [9].

Wagstaff et al. integrated differences-in-differences with matching approaches to get impact estimates, with data obtained from program administrators, health facilities and households. Particularly, the authors discover heterogeneity across income groups and implementing counties [10].

Different from the above studies, in this paper, we exploit the optimal control strategy to solve the problem of rural medical insurance system based on elderly people's satisfaction. In existing studies, optimal control has been used in insurance industry, and the related works are given as follows.

Wei et al. designed insurance surplus model with debt liability through solving the optimal control problem [11]. Liu et al. solved an optimal financing and dividend control problem of an insurance company. The management of the insurance company can manage the dividends payout, equity issuance and the excess-of-loss reinsurance policy [12]. Meng et al. maximized the expectation of discounted dividends and its terminal value which represents the company liquidation value upon the time of bankruptcy [13]. Liang et al. regarded the optimal control problem as a large insurance company under a fixed insolvency probability [14]. Baeuerle et al. aimed to optimize proportional reinsurance and investment policies in a multidimensional Levy-driven insurance model [15]. Jeong et al. obtained the long-run average cost per unit time and then propose an example to demonstrate how to seek an optimal investment policy minimizing the cost [16]. He et al. regarded the optimal control problem as the insurance company with proportional reinsurance policy under solvency constraints [17].

3 Problem description

As is illustrated in Wikipedia, medical insurance refers to an insurance against the risk of incurring medical expenses among humans. Through computing the overall risk of medical care and medical system expenses, the insurer can design a routine finance policy. Furthermore, the benefit is controlled by government department. In USA, medical insurance is defined as a system which can provide for the payments of benefits as a result of sickness or injury. Particularly, this kind of insurance covers the following aspects, such as losses from accident, medical expense, disability, or accidental death and so on. The basic structure of medical insurance system is shown in Figure 1.

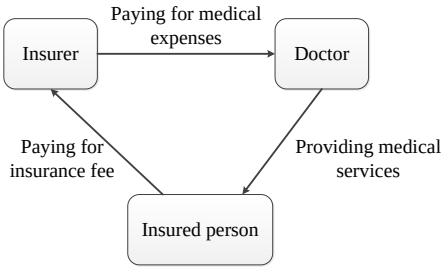

FIGURE 1 Basic structure of medical insurance system

In China, the medical insurance system has its own characteristics, and the whole medical insurance system in China is illustrated in Figure 2 as follows.

As is shown in Figure 2 the medical insurance in China is made up of social medical insurance and commercial medical insurance. Furthermore, social medical insurance include basic medical insurance and supplementary medical insurance, and the basic medical insurance is made up of three parts: 1) Basic medical insurance for urban workers, 2) Basic medical insurance for urban residents, 3) New rural cooperative medical insurance. In this paper, we concentrate on the rural medical insurance system under the constraint that we aim to propose a new medical insurance system in rural area which can satisfy elderly people's requirements.

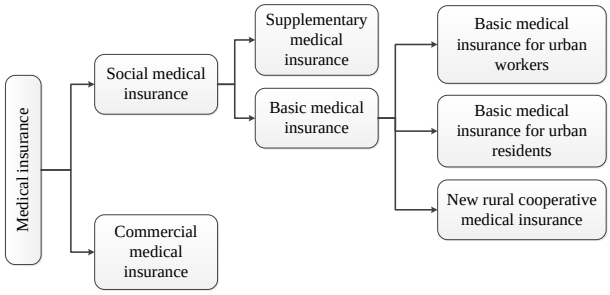

FIGURE 2 Structure of medical insurance system in China

4 Optimal control strategy of rural medical insurance system with constraints

As this paper consider the elderly people's satisfaction as the restrictive condition, therefore, in this section we focus on the optimal control strategy of rural medical insurance system with constraints.

If there is no dividend payout to low the risk, the stochastic differential equation should be defined as follows.

$$dR_t = \chi \cdot a(t) \cdot dt + \delta \cdot a(t) \cdot dw_t , \tag{1}$$

where w_t refers to a standard Brownian motion, and the range of $a(t)$ is belonged to $[0,1]$. Furthermore, a filtered probability space is represented as $(\Omega, F, \{F_t\}_{t\geq 0}, P)$, where $\{w_t, t \geq 0\}$ denotes a standard Brownian motion on this space. F_t means the information which is available at the time slot t. Furthermore, the optimal control strategy π is represented by the stochastic process $\{a_\pi, L^\pi\} \in \prod$, and parameter $\prod$ is the total set of the admissible strategy which is corresponding to the specific constraints. For the given strategy π, the rural medical insurance system is modelled as the equation as follows.

$$dR_t^\pi = \xi \cdot a_\pi(t) dt + \zeta \cdot a_\pi(t) \cdot dw_t - dU_t^\pi , \tag{2}$$

where the condition $R_0^\pi = x$ is satisfied, and it represents the initial liquid reserve x via the control strategy π.

If the existing rural medical insurance system fails when $T = \inf\{t \geq 0 : R_t^\pi < 0\}$, and T means the stopping time point. Based on the above analysis, the main task of the optimal control strategy is to maximize the expected value based on dividend barrier r_0 and the control policy π_{b0} on a specific time t_x^{b0}. This task can be represented as follows.

$$H(x,\pi)=E\left[\left(\int_0^{\pi} e^{-cs}\cdot dL_s^{\pi}\right)\right], \tag{3}$$

$$H(x,\pi_{b0})=\sup_{\pi\in\Pi_0} H(x,\pi), \tag{4}$$

where the parameter c means the discount rate.

Afterwards, we define the optimal return function of the rural medical insurance system with the following constraints:

$$V(x)=\sup_{b}\{V(x,b)\}. \tag{5}$$

Then, assuming that $\hat{b}$ refers to the optimal dividend payout barrier with no constraint condition. If the condition that $\hat{b}$ is larger than b, the optimal return $V(x)$ is equal to $V(x,b^*)$ with $b^*=\hat{b}$ is satisfied. Next, the optimal control strategy is given using the following Equation.

$$R_t^{\pi^*}=x+\int_0^t \xi\cdot a\left(R_s^{\pi^*}\right)\cdot ds+\int_0^t \zeta\cdot a\left(R_s^{\pi^*}\right)\cdot dw_s-U_t^{\pi^*}. \tag{6}$$

Subject to:

$$R_s^{\pi^*}\le\hat{b} \tag{7}$$

and

$$\int_0^{+\infty} I_{\left\{t:R_t^{\pi^*}<b\right\}}(t)\cdot dU_t^{\pi^*}=0. \tag{8}$$

To maximize the optimal return function, the optimal control strategy of rural medical insurance system can be obtained.

5 Experiment

In this section, the proposed rural medical insurance system based on elderly people's satisfaction is tested through insurance will investigation. In this work, we randomly select 10 administrative villages in China's rural areas and choose families in each village. The total number of questionnaire we provide is 500, and the number of valid ones is 487. As this work aims to design a medical insurance system satisfying elderly people's requirements, the respondents is limited to persons who are older than 50 years.

As the insurance will is a dichotomic variable, hence, in this experiment, when the farmer wants to insure the value of variable Y is set to one, otherwise Y is set to zero. Particularly, we select the binary choice model – Logistic, which is illustrated as follows.

$$P_i=F(Y_i)=\frac{e^{Y_i}}{1+e^{Y_i}}, \tag{9}$$

$$Y_i=\alpha+\sum_{j=1}^{k}\beta_j\cdot X_{ji}, \tag{10}$$

where i refers to id of the investigation sample, β_j denotes influence factors of regression coefficients, j is the id of influence factor, k is the number of influence factors, α means the regression intercept, and X_{ji} refers to the j^{th} influence factor of the i^{th} sample. Afterwards, the variables and their descriptions are shown in Table 1 as follows.

TABLE 1 Descriptions of the variables exploited in this experiment

Variable name	Value of variable	Mean	Variance
Age	1(50-55), 2(56-60), 3(61-65), 4(66-70), 5(>71)	3.28	0.54
Gender	1(Male), 2(Female)	0.57	0.47
Degree of culture	1(Illiteracy), 2(Primary school), 3(Junior middle school), 4(High school), 5(University or above)	2.48	1.28
Health	1(Healthy), 2(Good), 3(Occasionally sick), 4(Perennial sick)	3.13	0.74
Identity	1(masses), 2(Business owners), 3(Village cadres), 4(Cadre of villages and towns)	2.37	0.38
Number of children	1(None), 2(1), 3(2), 4(3), 5(4), 6(5 or above)	3.96	1.14
Annual per capita income	1(below 1500), 2(1501-3000), 3(3001-5000), 4(5001-7000), 5(7001-9000), 6(9001 or above)	4.76	0.75
Whether family members supporting	1(Approval), 2(Neutral), 3(Disapproval)	2.35	1.45
Location of the village	1(General village), 2(Township resident), 3(Suburb countryside), 4(Village in the city)	2.19	0.39
Pecuniary condition of the village	1(Poor), 2(General), 3(Better)	1.87	0.57
Mutual relationship between villages	1(Poor), 2(General), 3(Better)	1.57	0.29
Whether village collective providing subsidies	1(Yes), 0(No)	0.42	0.33
If can accept the rural medical insurance	1(Yes), 0(No)	0.57	0.97
Expected value of rural medical insurance	1(No expectations), 2(Low expectations), 3(High expectations), 4(High expectations)	3.07	0.83

Next, we use the SPSS 19.0 software to process the sample data using binary logistic regression model, and analyze the influencing factors of willingness of attending the insurance. Then, we use the proposed algorithm to estimate the degree of the willingness of attending the insurance for the given ten villages (denoted as V1, V2,…, V10). To testify the performance our optimal control strategy, we compare the willingness of insurance attending with and without the optimal control strategy.

As is shown in Figure 3, we can see that using the proposed optimal control strategy, willingness of the farmers with ages higher than 50 are obviously enhanced than the scheme without the optimal control strategy. Moreover, the average willingness is promoted 12.3%. Hence, the conclusions can be drawn that the proposed optimal control strategy can make the rural medical insurance system more suitable to older farmer.

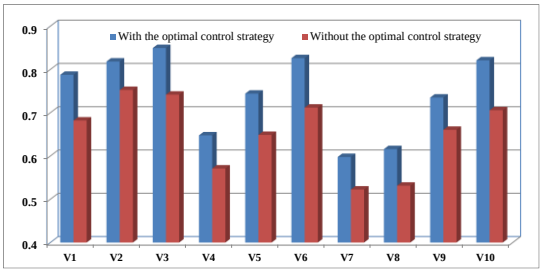

FIGURE 3 Comparison of the willingness of insurance attending with and without the optimal control strategy

6 Conclusions

In this paper, we propose a new optimal control strategy which is suitable to be used in rural medical insurance system design based on elderly people's requirements. The main innovations of this paper lie in that we propose an optimal control strategy of rural medical insurance system. Meanwhile, the elderly people's satisfaction is regarded as the constraint in insurance system design. Furthermore, the optimal control strategy may maximize the expected value utilizing the dividend barrier and the control policy at a specific time. Then, the optimal control strategy is gained through maximizing an optimal return function.

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