Critical Illness Insurance to Alleviate Catastrophic Health Expenditures: New Evidence from China

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Abstract

Currently, a high percentage of China's households face financial catastrophe as a direct result of having to pay for health care out-of-pocket (OOP). To design a health financing system for reducing catastrophic medical spending, this paper first constructs four financing models for critical illness in the context of China's New Urbanisation Plan. In addition, three key indicators, including the deductible, compensation ratio and cap amount, are developed for the models to maintain the ratio of OOP expenses to total expenditure at approximately 20%, while adjustment coefficients based on family net income per capita are applied to different income groups across three main regions in China to ensure the fairness of the payment. Moreover, differentiated pricing of critical illness insurance is conducted on the basis of the losses of medical insurance and the expected claim frequency. Using a funds balance calculation, analyses are conducted to test the sustainable performance of critical illness insurance. In addition, the models of critical illness prepayment are empirically simulated with the latest provincial data of China Family Panel Studies (CFPS). The results indicate that all four models can effectively alleviate the incidence and severity of catastrophic health expenditures and that the new mechanism can lead to a balanced fund.

Key Words: critical illness insurance, catastrophic health expenditures, insurance pricing, fund balance, Chinese data

JEL Classification: I18, I13, H51

1 Introduction

Prepayment for catastrophic health expenditures may be a crucial financial approach to prevent households from catastrophe and impoverishment and increase their level of financial protection (World Health Organization (WHO), 2005; Xu *et al.*, 2007; Sun *et al.*, 2009). China has undertaken a major health sector reform to provide a comprehensive package of new policies for improving residents' health care-related services. Among the policies, critical illness insurance, which covers the enrollees of the Urban Resident Basic Medical Insurance (URBMI) and the New Rural Cooperative Medical Scheme (NRCMS), compensates members for catastrophic medical spending due to critical illness that exceeds the limits of basic medical insurance (The State Council of China, 2012).

Universal coverage has three critical dimensions, as follows: who is covered from pooled funds, what services are covered, and how much of the cost is covered (World Health Report, 2010). Given the current situation in China, the first dimension, the extent of the population covered, has been successfully addressed. By the end of 2013, the URBMI plan provides coverage for 296.294 million urban residents and the coverage rate of the NRCMS plan reaches 98.7%. (China Statistical Yearbook, 2014); however, for both plans, the values of the second and third dimensions remain low compared with those of the Urban Employee Basic Medical Insurance (UEBMI) plan. Meanwhile, the average medical expense of discharged patients reached 6,980.4 CNY[1] in 2012 and has continued to rise in recent years. (As shown in Figure 1) The expenses in several large cities, such as Beijing, Shanghai and Tianjin, have even exceeded 10,000 CNY. The ratio of OOP expenses to total expenditures was approximately 34.4%, which remained much higher than the desired ratio of the WHO (WHO, 2010; China Health Statistical Yearbook, 2013). Heavy OOP expenses increase the risk of catastrophic medical expenditures and inhibit household consumption, which exert a long-term negative impact on economic growth. As a result, a mixed system of social and private health insurance (Kawabata *et al.*, 2002; Zhang, 2014) should be implied in the prepayment of catastrophic health expenditures.

In addition, the dualism of the urban-rural structure in China has not yet been overcome. Urban residents accounted for 53.73% of the total population in 2013; however, large gaps between urban and rural regions exist in many aspects, such as economic status and health care conditions. (As shown in Table 1) To improve the fairness of a catastrophic prepayment mechanism, an urban-rural integrated financing system with a high risk-pooling level is urgently needed, particularly in the context of China's New Urbanisation Plan.

Therefore, the current article attempts to construct mixed models of critical illness insurance with both public and private health insurance. Key indicators, including the deductible,

[1] The Chinese Yuan (CNY) to US Dollar (USD) exchange rate is approximately 1CNY=0.1603USD.

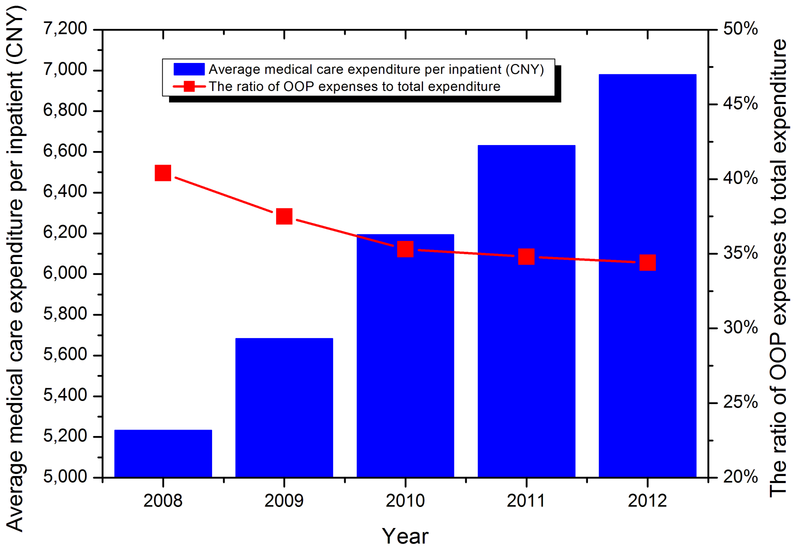

Figure 1: Comparison of average medical care expenditure per inpatient and the ratio of OOP expenses to total expenditure in China (2008-2012)

(Source: China Health Statistics Yearbook, 2013)

the compensation ratio and the cap amount, are designed. In addition, the insurance prices according to types of coverage are calculated to further investigate the fund balance. Thus, the remainder of this paper is organised as follows. In the next section, four cooperative mechanisms of critical illness insurance are developed. In section 3, we conduct the differentiation pricing and calculate the balance performance of the critical illness insurance fund. We then analyse the mechanisms using the latest provincial data from China Family Panel Studies (CFPS) in section 4. The final section concludes and summarises the main findings and their implications.

2 Design of the Critical Illness Insurance Mechanism

2.1 The Outline

According to the current situation of basic medical insurance for urban and rural residents in China, we attempt to design a mechanism that bridges basic social medical insurance and private health insurance under the condition of retaining the basic medical insurance premium rate. We posit three hypotheses concerning this mechanism.

(1) It covers the enrollees of both URBMI and NRCMS. The integrated critical illness insurance helps to eliminate the urban-rural dual structure, conforming to the national policy of

Table 1: Comparison of China's urban and rural residents' living standard

	Urban residents			Rural residents		
	2011	2012	2013	2011	2012	2013
The disposable income/The net income of urban/rural residents per capita (CNY)	21,810	24,565	26,955	6,977	7,917	8,896
Cash consumption expenditure of urban/rural residents per capita (CNY)	15,161	16,674	18,023	4,733	5,415	6,113
Households Engle's coefficient (%)	36.3	36.2	35.0	40.4	39.3	37.7
Inpatient beds per thousand population	6.24	6.88	7.36	2.80	3.11	3.35

Source: China Statistical Yearbook, 2014

the New Urbanisation Plan. Meanwhile, it may effectively diversify the risks by expanding the insurance base, thus increasing both the affordability and the sustainability of the critical illness insurance fund.

(2) It covers inpatient medical expenditures. Catastrophic medical expenditures are typically caused by urgent and serious diseases that require hospitalisation. According to China Health Statistical Yearbook (2013), the average outpatient expense was 192.5 CNY, whereas the average discharged patient expense was 6,980.4 CNY in 2012.

(3) It covers partial expenditures with the design of the deductible, compensation ratio and cap amount. Based on the Principal Agent Theory, the optimal insurance contract requires partial insurance due to the moral hazard caused by information asymmetry among the insurers, the insured and medical organisations (Rothschild and Stiglitz, 1976; Verlaak and Beirlant, 2003).

2.2 Further Assumptions

The mixed critical illness insurance was constructed based on the URBMI and NRCMS plans. When the individual cumulative annual medical expenditure is lower than the cost deductible of critical illness insurance, which is represented by CD, any inpatient medical expenditures that exceed the basic medical insurance deductible are compensated by the basic medical insurance. If the inpatient expenditure occurs more than once after the individual cumulative inpatient expenditure has reached the critical illness insurance deductible, the deductible is cancelled in the reimbursement.

Suppose the deductible of the basic medical insurance is De; the compensation ratio of social basic medical insurance is $(1-\alpha)$; the inpatient expenditure of the insured i at time j is x_{ij}; the individual cumulative annual medical expenditure is x_i; the OOP expense of the insured i at time j is OOP_{ij}; and the individual cumulative annual OOP expense of the insured i is OOP_i. N_i represents the accumulated number of inpatient visits. For the insured i with individual cumulative annual medical expenditure exceeding the cost deductible of critical illness insurance, there is an m_i satisfying $\sum_{j=1}^{m_i-1} x_{ij} < CD$ and $\sum_{j=1}^{m_i} x_{ij} \geq CD$. For m_i inpatient treatments, we introduce a two-valued variable n_{ij}, which shows whether the inpatient expenditure of the insured i at time $j(x_{ij})$ exceeds De; n_i is the total number of times that the inpatient expenditure exceeds the De of the insured i, $x_{ij}^{'}$ means that the OOP expense of the insured i at time j that x_{ij} is lower than De, and $\sum x_{ij}^{'}$ is the sum of $x_{ij}^{'}$. That is, if $x_{ij} > De$, then $n_{ij} = 1$, $n_i = \sum n_{ij}$; if $x_{ij} \leq De$, then $n_{ij} = 0$, $x_{ij}^{'} = x_{ij}$ and $\sum x_{ij}^{'} = \sum x_{ij}$.

Because the approaches of coinsurance and reinsurance are widely used in the insurance industry with specific insured persons or massive compensation amounts that effectively distract medical expenditure risks, we present four cooperative models, i.e., Model I–Coinsurance, Model II–Reinsurance, Model III–Coinsurance after Reinsurance and Model IV–Reinsurance after Coinsurance.

Model I and Model II are the basic forms of coinsurance and reinsurance application, respectively. The cost deductible is CD, the cap amount is TL, and the compensation ratio is $(1-\beta)$. When the individual cumulative annual OOP expenses exceed the defined standard of high medical expenditure HE, critical illness insurance issues a second reimbursement for the individual cumulative annual OOP expenses (the excess). Moreover, in Model I, basic medical insurance compensates $(1-\alpha)$ the qualifying medical expense greater than HE; but in Model II, basic medical insurance only compensates the qualifying medical expense less than HE.

Model III and Model IV are mixed forms of coinsurance and reinsurance. The deductible at the first level is CD, the compensation ratio is $(1-\beta_1)$, the cap amount is TL_1, which is also the deductible at the second level, the compensation ratio for the second level is $(1-\beta_2)$, and the cap amount is TL_2. When individual cumulative annual medical expenditures reach HE, critical illness insurance compensates the excess portion (the individual cumulative annual OOP expenses) with reinsurance (coinsurance); when the individual cumulative annual OOP expenses also reach HE, the critical illness insurance then compensates the OOP expenses (the excess) consistent with the coinsurance (reinsurance). Details of the four proposed models are shown in Table 2.

2.3 Design of the Indicators of the Mechanisms

We construct urban-rural integrated critical illness insurance models as mixed models of social basic medical insurance and private health insurance to relieve the problem of the relatively high ratio of Chinese residents' OOP expenses to their inpatient medical expenditures and

Table 2: OOP expenses according to the four proposed mechanisms

Mechanism	Individual annual cumulative medical expenses	Individual cumulative OOP expenses
Model I	$CD \leq x_i \leq TL$	$\beta \times \left[\alpha \left(x_i - n_i De - \sum x_{ij}^{'}\right) + n_i De + \sum x_{ij}^{'}\right]$
	$x_i > TL$	$\beta \times \left[\alpha \left(TL - n_i De - \sum x_{ij}^{'}\right) + n_i De + \sum x_{ij}^{'}\right] + (x_i - TL)$
Model II	$CD \leq x_i \leq TL$	$\alpha \times \theta_0 + n_i De + \sum x_{ij}^{'} + \beta \times (x_i - CD)$
	$x_i > TL$	$\alpha \times \theta_0 + n_i De + \sum x_{ij}^{'} + \beta \times (TL - CD) + (x_i - TL)$
Model III	$CD_1 \leq x_i < TL_1$	$\alpha \times \theta_1 + \beta_1 \times (x_i - CD) + n_i De + \sum x_{ij}^{'}$
	$TL_1 \leq x_i \leq TL_2$	$\beta_2 \times \left[\alpha \times \theta_1 + \beta_1 \times (x_i - CD) + n_i De + \sum x_{ij}^{'} + x_i - TL_1\right]$
	$x_i > TL_2$	$\beta_2 \times \left[\alpha \times \theta_1 + \beta_1 \times (x_i - CD) + n_i De + \sum x_{ij}^{'} + TL_2 - TL_1\right] + (x_i - TL_2)$
Model IV	$CD_1 \leq x_i < TL_1$	$\beta_1 \times \left[\alpha \times \left(x_i - n_i De - \sum x_{ij}^{'}\right) + n_i De + \sum x_{ij}^{'}\right]$
	$TL_1 \leq x_i \leq TL_2$	$\beta_1 \times \left[\alpha \times \theta_2 + n_i De + \sum x_{ij}^{'}\right] + \beta_2 \times (x_i - TL_1)$
	$x_i > TL_2$	$\beta_1 \times \left[\alpha \times \theta_2 + n_i De + \sum x_{ij}^{'} + \beta_2 \times (TL_2 - TL_1) + (x_i - TL_2)\right]$

Note: Here, we assume that $\theta_0 = CD - n_i De - \sum x_{ij}^{'}$, $\theta_1 = CD_1 - n_i De - \sum x_{ij}^{'}$ and $\theta_2 = TL_1 - n_i De - \sum x_{ij}^{'}$.

decrease the incidence of household catastrophic expenditures (CAT). Based on this objective, the following goals for the design of the critical illness insurance indicators are proposed:

(1) The goal for the models' design is to "keep the ratio of individual OOP expenses in total medical expenditures at approximately 20%" (WHO, 2010). An overly large OOP ratio increases residents' hospitalisation burden, causing a series of social problems that are damaging to sustainable economic development and societal stability, whereas an overly low OOP ratio leads to fund crisis for long-term sustainable operation.

(2) Both international and China's standards are used to calculate household catastrophic expenditure. The definitions of the international standards, and China's standards, can be shown as: $CAT_f = 40\% \times CTP$ (Xu *et al.*, 2003), $CAT_d = income$ (Minglai Zhu *et al.*, 2013), where *income* represents the urban-rural residents' average income, and CTP represents the household capacity to pay, which could be measured by a family's non-food expenditures.

(3) The cap amount of critical illness insurance is determined by the frequency distribution of inpatient medical expenditures, double the inpatient medical expenditures at the 99th percentile, which can be shown as follows: $TL = 2X = 2F^{-1}(X)$. $F(X)$ is the accumulative distribution function of the inpatient medical expenditures. Because China's critical illness insurance is in its initial phase, which means the pooling level of overall planning is relatively low, the

Table 3: Deductible according to the four proposed mechanisms

Mechanism	Deductible (CD)	
Model I	$(CAT - \varpi_1)/\alpha + \varpi_1$	
Model II	CAT	
	Deductible for the first level (CD_1)	Deductible for the second level (TL_1)
Model III	CAT	$[CAT - \alpha(CD_1 - \varpi_3) - \varpi_3]/\beta_1 + CD_1$
Model IV	CAT	$[CAT/\beta_1 - \varpi_3]/\alpha + \varpi_3$

Note: $\varpi_\lambda = \overline{n_i}(\lambda)De + \overline{\sum x'_{ij}}(\lambda)$, $\lambda = 1, 2, 3$. It is assumed that n_i and $\sum x'_{ij}$ are replaced by their means in the range of the corresponding x_i, $\overline{n_i}$ and $\sum x'_{ij}$. $\overline{n_i}(\lambda) = \frac{1}{Q_\lambda}\sum_{i=1}^{Q_\lambda} n_i$, $\overline{\sum x'_{ij}}(\lambda) = \frac{1}{Q_\lambda}\sum\sum x'_{ij}$; Q_1, Q_2, Q_3 are the numbers of people whose cumulative individual annual inpatient medical expenditures fulfil the requirement $x_{ij} \leq \frac{CAT}{\alpha}, \frac{CAT}{\alpha} \leq x_i \leq TL, CD \leq x_i \leq TL$. Similarly hereinafter.

establishment of a cap amount will benefit the funds' long-term operation. As the pooling level gradually improves, the cap can be cancelled.

2.3.1 Deductible

Based on the hypotheses above, we introduce the threshold of household catastrophic medical expenditure as the definition of high medical expenditure HE and then design the deductible for critical illness insurance. Details of the four proposed models are shown in Table 3.

2.3.2 Compensation Ratio

When the insured's individual cumulative annual medical expenditure is in the coverage scope of critical illness insurance, i.e., when $A \leq x_i \leq B$, we calculate the compensation ratio with the goal of maintaining the ratio of OOP expenses ($ROOP_i$) at approximately 20%. A, B, γ are the deductible, cap amount and OOP ratio, respectively.

$$ROOP_i = OOP_i/x_i \tag{2.1}$$

Inspired by the least squares criterion of the curve fit, we adopt the method of least square approximation, making the OOP ratio curve $y = ROOP_i(x_i)$ approximate to a straight line $y = 20\%$. That is, to minimise

$$J = \int_A^B [20\% - ROOP(x_i)]^2 \, dx_i \tag{2.2}$$

With the necessary requirements of the extremism, we find that,

Table 4: Compensation ratio according to the four proposed mechanisms

Mechanism	Compensation ratio
Model I	$\frac{20\%(TL-CD)}{\alpha(TL-CD)+\varpi_2(1-\alpha)(\ln TL-\ln CD)}$
Model II	$\frac{20\%(TL-CD)-(\ln TL-\ln CD)[\alpha(CD-\varpi_3)+\varpi_3]}{[(TL-CD)-CD(\ln TL-\ln CD)]}$
	Compensation ratio for the first level
Model III	$\frac{20\%(TL_1-CD_1)-[\alpha(CD_1-\varpi_3)+\varpi_3](\ln TL_1-\ln CD_1)}{[(TL_1-CD_1)-CD_1(\ln TL_1-\ln CD_1)]}$
Model IV	$\frac{20\%(TL_1-CD_1)}{\alpha(TL_1-CD_1)+\varpi_3(1-\alpha)(\ln TL_1-\ln CD_1)}$
	Compensation ratio for the second level
Model III	$\frac{20\%(TL_2-TL_1)}{[\alpha(CD_1-\varpi_3)+\varpi_3+\beta_1(TL_1-CD_1)-TL_1](\ln TL_2-\ln TL_1)+(TL_2-TL_1)}$
Model IV	$\frac{20\%(TL_2-TL_1)-\beta_1[\alpha(TL_1-\varpi_3)\varpi_3](\ln TL_2-\ln TL_1)}{[(TL_2-TL_1)-TL_1(\ln TL_2-\ln TL_1)]}$

Table 5: Adjustment coefficients of individual cumulative annual OOP Expenses

Adjustment coefficients γ_i		East	Middle	West
		$\mathrm{INC_E}$	$\mathrm{INC_M}$	$\mathrm{INC_W}$
Urban	$\mathrm{INC_U}$	$\frac{\mathrm{INC}_U}{\mathrm{INC}} \times \frac{\mathrm{INC}_E}{\mathrm{INC}}$	$\frac{\mathrm{INC}_U}{\mathrm{INC}} \times \frac{\mathrm{INC}_M}{\mathrm{INC}}$	$\frac{\mathrm{INC}_U}{\mathrm{INC}} \times \frac{\mathrm{INC}_W}{\mathrm{INC}}$
Rural	$\mathrm{INC_R}$	$\frac{\mathrm{INC}_R}{\mathrm{INC}} \times \frac{\mathrm{INC}_E}{\mathrm{INC}}$	$\frac{\mathrm{INC}_R}{\mathrm{INC}} \times \frac{\mathrm{INC}_M}{\mathrm{INC}}$	$\frac{\mathrm{INC}_R}{\mathrm{INC}} \times \frac{\mathrm{INC}_W}{\mathrm{INC}}$

Note: INC represents the national average diposable income.

$[(1,1)]\,[20\%] = [(ROOP\,(x_i)\,,1)]$

Here, $(g,h) = \int_A^B g\,(x)\,h\,(x)\,dx$. According to the expressions of individual cumulative annual OOP expenses in different models, the compensation ratios can be calculated. Details of the four proposed models are shown in Table 4.

2.4 Adjustment of Individual Cumulative Annual OOP Expenses

Based on the analysis in section 2.3, we obtain the forms of the deductible, compensation ratio and the cap amount of the four mechanisms. However, because regional and urban-rural differences exist in medical-expense affordability, we adjust the cumulative individual annual OOP expenses for urban and rural residents in different regions for the fairness of the financial system. The adjustment coefficients are based on the ratio of different family disposable income per capita to the average level. (As shown in Table 5)

The individual cumulative annual OOP expense after adjustment is:

$$OOP_{i-a} = OOP_i \times \gamma_i \tag{2.3}$$

The OOP_i represents the benchmark OOP expense calculated with the indicators when the cumulative individual annual medical expenditure reaches the critical illness insurance deductible. When the cumulative individual annual medical expenditure exceeds the cap amount of the critical illness insurance, the excess OOP expenses do not receive any adjustment. The adjustment coefficients are only for the individual OOP expenses within the scope of critical illness insurance. As expressed in Model I,

When $CD \leq x_i \leq TL$,

$$OOP_{i-a} = \gamma_i \times \beta \times \left[\alpha \left(x_i - n_i De - \sum x_{ij}^{'}\right) + n_i De + \sum x_{ij}^{'}\right] \tag{2.4}$$

When $x_i > TL$,

$$OOP_i = \gamma_i \times \beta \times \left[\alpha \left(TL - n_i De - \sum x_{ij}^{'}\right) + n_i De + \sum x_{ij}^{'}\right] + (x_i - TL) \tag{2.5}$$

2.5 The Incidence and Severity of Household Catastrophic Health Expenditures

Relatively excessive health care expenditures for the individuals will push the households into catastrophe or impoverishment (Berki, 1986; Bredenkamp *et al.*, 2011). Therefore, incidence and severity of houshold catastrophic health expenditures are two indicators that are important in designing the critical illness insurance. Incidence (I_{cat}) is the ratio of the insured whose OOP expenses equal or exceed the catastrophic medical expenditure; overall severity (S_{cat}) is the general average surplus of OOP expenses beyond the catastrophic medical expenditures of all insured individuals (Wagstaff and Doorslaer, 2003). To measure the severity of household catastrophic medical expenditures, we propose an additional indicator, the regional severity (S_{cat-a}), which is the regional average surplus of OOP expenses beyond the catastrophic medical expenditures of those insured individuals who incurred a catastrophic expense.

2.5.1 Incidence

We assume that the number of insured individuals whose OOP expenses reach the catastrophic medical expenditure is e, and the total number of insured individuals is E.

When $OOP_i \geq CAT$,

$$I_{cat} = P\left(OOP_i \geq CAT\right) = \frac{e}{E} \times 100\% \tag{2.6}$$

Because the calculations for total inpatient medical expenditures (x_T) when OOP expenses reach the catastrophic level are different in the four models, we present the following specific statements: in Models I and II, catastrophic medical expenditures are covered by critical illness insurance; in Model III, catastrophic medical expenditures are covered by the second level of critical illness insurance; and in Model IV, the first occurrence of catastrophic medical expenditures is in the first level of cap amount (and the second level of deductible) of the critical illness insurance.

2.5.2 Severity

When $OOP_i \geq CAT$,

$$S_{cat} = \frac{1}{E} \sum (OOP_i - CAT) \tag{2.7}$$

$$S_{cat-a} = \frac{1}{e} \sum (OOP_i - CAT) \tag{2.8}$$

Because the incidence and the severity of catastrophic health expenditures in the four models are different, they are represented by different calculation methods for the OOP expenses. Therefore, we calculate the severity of the catastrophic medical expenditure based on the interval of cumulative individual annual inpatient medical expenditures.

2.6 Summary

This section establishes a framework for critical illness insurance for urban and rural residents. The conclusions are as follows. First, with the approaches of coinsurance, reinsurance and a combination of coinsurance/reinsurance, four models of critical illness insurance are constructed. Second, with the goal of "keep the ratio of individual OOP expenses in total medical expenditures approximately 20%" (WHO, 2010), the deductible, compensation ratio and cap amount of critical illness insurance are designed. Third, based on differences in the residents' per capita income, coefficient adjustments are applied to the OOP expenses. Finally, the performance of critical illness insurance is evaluated using the incidence and severity of household catastrophic medical expenditure.

3 Differential Pricing and Sustainable Performance of the Critical Illness Insurance

3.1 The Outline

Because the critical illness insurance is short-term health insurance, the premium is paid once per year, and mortality and long-term care are not taken into account. The pure premium is equal to the expectations of future compensation, and it can be simplified to include medical insurance losses and the expected claim frequency. In addition, catastrophic health expenditures often display the characteristics of a small probability but a large loss, and the distribution function is typically right-skewed and fat-tailed. Therefore, we use the lognormal distribution to fit high medical expenses. The probability density function and cumulative distribution function of annual cumulative medical expenses(x) are as follows:

$$f(x,\mu,\sigma)=\frac{1}{\sqrt{2\pi}\sigma x}e^{-\frac{1}{2\sigma^2}(\ln x-\mu)^2} \tag{3.1}$$

$$F(x,\mu,\sigma)=P(X\le x)=P\left(Z\le\frac{\ln x-\mu}{\sigma}\right)=\Phi\left(\frac{\ln x-\mu}{\sigma}\right) \tag{3.2}$$

Combined with the interactive mechanisms that were built in section 2, we discuss differential insurance pricing according to different levels of coverage. In addition, in the determination of pricing, we assume that all the residents are forced to purchase critical illness insurance.

The critical illness insurance pricing process involves the following: (1) Calculate the expression of critical illness insurance loss (Y) on the basis of the compensation models, and then calculate the cumulative distribution function ($F_Y(y)$) and probability density function ($f_Y(y)$). (2) Calculate the risk premium based on the expected insurance loss and claim frequency. (3) Consider safety factors and the rising coefficient of medical expenses on the basis of the risk premium to determine the pure premium. (4) Calculate the gross premium in consideration of all additional costs. In the following section, we select Model III to discuss pricing analysis; the pricing principle and calculation method of the other three models are consistent with those of Model III.

3.1.1 Critical Illness Insurance-Pricing I

Pricing I is the pricing for the lower coverage at the first level of critical illness insurance, which only covers the annual cumulative medical expenses (X) between CD_1 and TL_1. If only the first level of critical illness insurance exists, the medical insurance loss (Y) can be represented as:

$$Y=\left\{\begin{array}{cc} 0 & 0<X\le CD_1 \\ (1-\beta_1)(X-CD_1) & CD_1<X\le TL_1 \\ (1-\beta_1)(TL_1-CD_1) & X>TL_1 \end{array}\right\} \tag{3.3}$$

The cumulative distribution function and probability density function are as follows: $0<y\le(1-\beta_1)(TL_1-CD_1)=a$.

$$\begin{aligned} F_Y(y)=P(Y\le y)&=P((1-\beta_1)(X-CD_1)\le y|X>CD_1) \\ &=\tfrac{P((1-\beta_1)(X-CD_1)\le y,X>CD_1)}{1-F(CD_1)} \\ &=\tfrac{F(y/(1-\beta_1)+CD_1)-F(CD_1)}{1-F(CD_1)} \end{aligned} \tag{3.4}$$

$$f_Y(y) = \frac{1}{1-\beta_1} \cdot \frac{f(y/(1-\beta_1) + CD_1)}{1 - F(CD_1)} \tag{3.5}$$

Based on the critical illness insurance loss and its probability distribution, the average loss can be calculated as follows:

$$\begin{aligned} EY(CD_1, TL_1) &= \int_0^a y f_Y(y)\,dy + a\left[1 - F_Y(a)\right] \\ &= \int_0^a y \cdot \tfrac{1}{1-\beta_1} \cdot \tfrac{f(y/(1-\beta_1)+CD_1)}{1-F(CD_1)} dy + a\left[1 - \tfrac{F(a/(1-\beta_1)+CD_1)-F(CD_1)}{1-F(CD_1)}\right] \\ &= \tfrac{1-\beta_1}{1-F(CD_1)}\left[\Lambda_1 - CD_1\left(F(TL_1) - F(CD_1)\right)\right] + a\left[1 - \tfrac{F(TL_1)-F(CD_1)}{1-F(CD_1)}\right] \end{aligned} \tag{3.6}$$

Here, $\Lambda_1 = \int_{CD_1}^{TL_1} x f(x)\,dx$, $f(x)$ is the probability density function of the lognormal distribution. Because the integral is non-integral, we can only approximate Λ_1.

$$\Lambda_1 = \int_{CD_1}^{TL_1} x f(x)\,dx = \int_{CD_1}^{TL_1} \left[x f(x) + F(x)\right] dx - \int_{CD_1}^{TL_1} F(x)\,dx = xF(x)\,|_{CD_1}^{TL_1} - \int_{CD_1}^{TL_1} F(x)\,dx \tag{3.7}$$

$F(x)$ is the cumulative distribution function of the lognormal distribution. Because the function is more complicated, differential ideas can be introduced for the convenience of calculation. $\int_{CD_1}^{TL_1} F(x)\,dx$ equals the figure acreage enclosed by the curve of $F(x)$ and the x-axis in the range of CD_1 and TL_1; thus, its approximate value can be calculated by dividing the acreage into several parts.

$EY(CD_1, TL_1)$ represents the average insurance loss in the critical illness insurance pricing I, namely, expected expenditure per capita of the insurance fund in the next year. Moreover, if N_1 represents the number of the insured that had medical expenditures in the past year, and N is the total number of insured, then the expected claim frequency of the first level of critical illness insurance can be represented as $\frac{N_1}{N}\left[1 - F(CD_1)\right]$. The risk premium per capita can be calculated as:

$$p_{risk-1}(CD_1, TL_1) = EY(CD_1, TL_1) \times \frac{N_1}{N}\left[1 - F(CD_1)\right] \tag{3.8}$$

$$p_{risk-1}(CD_1, TL_1) = \left\{(1-\beta_1)\left[\Lambda_1 - CD_1\left(F(TL_1) - F(CD_1)\right)\right] + a\left[1 - F(TL_1)\right]\right\} \times \frac{N_1}{N} \tag{3.9}$$

By Eq.3.9, the calculation of the risk premium is based on the compensation mechanism of critical illness insurance (deductible, compensation ratio and cap amount) and the distribution function of individual annual cumulative medical expenses. Because it is difficult to obtain medical expense data that fully meet the actuarial requirements, and in the consideration of other possible impacts on the insurance fund balance, we add a security surcharge, 30%[2] of risk premium, to obtain the pure premium on the basis of the risk premium. Furthermore, the rising coefficient of medical expense must be taken into account due to the continued growth of medical costs in recent years.

$$p_{pure-1} = (1 + 30\%) \times (1 + k) \times p_{pure-1} \tag{3.10}$$

Currently, the average operating expense ratio set by private health insurers is approximately 20% (individual medical insurance business) or 15% (group medical insurance business). Considering the critical illness insurance as a mixed model of social and private health insurance, the additional premium ratio is set at 15%, which is a certain incentive to improve the management efficiency of the commercial health insurer and strengthen risk management.

$$p_{gross-1} = p_{pure-1} / (1 - 15\%) \tag{3.11}$$

3.1.2 Critical Illness Insurance-Pricing II

Pricing II is the pricing for the higher coverage at the first and second levels of critical illness insurance and covers the annual cumulative medical expenses (X) between CD_1 and TL_2. The medical insurance loss (Y) can be represented as:

$$Y = \left\{ \begin{array}{cc} 0 & 0 < X \leq CD_1 \\ (1 - \beta_1)(X - CD_1) & CD_1 < X \leq TL_1 \\ a + (1 - \beta_2)[K + (X - TL_1)] & TL_1 < X \leq TL_2 \\ a + (1 - \beta_2)[K + (TL_2 - TL_1)] & X > TL_2 \end{array} \right\} \tag{3.12}$$

Here, $K = \alpha CD_1 + \beta_1 (TL_1 - CD_1)$. The deductible of basic medical insurance is not considered here because it has a lesser effect on the medical insurance loss.

The cumulative distribution function and probability density function of medical insurance loss(Y) between CD_1 and TL_1, TL_1 and TL_2 are as follows, respectively:

$$\left\{ \begin{array}{l} F_{Y1}(y) = \frac{F(y/(1-\beta_1)+CD_1) - F(CD_1)}{F(TL_1) - F(CD_1)} \\ f_{Y1}(y) = \frac{1}{1-\beta_1} \cdot \frac{f(y/(1-\beta_1)+CD_1)}{F(TL_1) - F(CD_1)} \end{array} \quad 0 < y \leq (1 - \beta_1)(TL_1 - CD_1) = a \right\} \tag{3.13}$$

$$\left\{ \begin{array}{l} F_{Y2}(y) = \frac{F((y-a)/(1-\beta_2)-K+TL_1) - F(TL_1)}{1 - F(TL_1)} \\ f_{Y2}(y) = \frac{1}{1-\beta_2} \cdot \frac{f((y-a)/(1-\beta_2)-K+TL_1)}{1 - F(TL_1)} \end{array} \quad a < y \leq a + (1 - \beta_2)[K + (TL_2 - TL_1)] = b \right\} \tag{3.14}$$

[2] In general, a security surcharge can be calculated as 10%-30% of the simple pure premium (China Association of Actuaries, 2011). In view of the high medical expense insurance pricing discussed in the paper, we set the security coefficient at 30%.

Based on the critical illness insurance loss and its probability distribution, the average loss can be calculated as follows. Once the annual cumulative medical expense exceeds the second deductible of the critical illness insurance, the compensation for individual OOP payments is in the form of coinsurance; therefore, the lower limit of the second level of critical illness insurance loss is $c = a + (1 - \beta_2) K$.

$$EY(CD_1, TL_2) = EY_1(CD_1, TL_1) + EY_2(TL_1, TL_2) \tag{3.15}$$

$$EY_1(CD_1, TL_1) = \int_0^a y f_{Y1}(y)\, dy = \frac{1-\beta_1}{1-F(CD_1)}\left[\Lambda_1 - CD_1\left(F(TL_1) - F(CD_1)\right)\right] \tag{3.16}$$

$$\begin{aligned} EY_2(TL_1, TL_2) &= \textstyle\int_c^b y f_{Y_2}(y)\, dy + b\left[1 - F_{Y_2}(b)\right] \\ &= \tfrac{a+(1-\beta_2)(K-TL_1)}{1-F(TL_1)}\left(F(TL_2) - F(TL_1)\right) + \tfrac{1-\beta_2}{1-F(TL_1)}\Lambda_2 + b\left[1 - \tfrac{F(TL_2)-F(TL_1)}{1-F(TL_1)}\right] \end{aligned} \tag{3.17}$$

Here, $\Lambda_2 = \int_{TL_1}^{TL_2} x f(x)\, dx$, where $f(x)$ is the probability density function of the lognormal distribution. Because the integral is non-integral, we approximate Λ_2.

$$\Lambda_2 = \int_{TL_1}^{TL_2} x f(x)\, dx = \int_{TL_1}^{TL_2} \left[x f(x) + F(x)\right] dx - \int_{TL_1}^{TL_2} F(x)\, dx = xF(x)\,|_{TL_1}^{TL_2} - \int_{TL_1}^{TL_2} F(x)\, dx \tag{3.18}$$

$F(x)$ is the cumulative distribution function of the lognormal distribution. $\int_{TL_1}^{TL_2} F(x)\, dx$ equals the figure acreage enclosed by the curve of $F(x)$ and x-axis in the range of TL_1 and TL_2; thus, its approximate value can be calculated by dividing the acreage into several parts.

$EY(CD_1, TL_2)$ represents the average insurance loss in the pricing II model, namely, expected expenditure per capita of the insurance fund in the next year. There are two levels of compensation models of critical illness insurance in pricing II, and the corresponding medical insurance loss and claim frequency differ. Therefore, the expected claim frequencies can be represented as $\frac{N_1}{N}\left[F(TL_1) - F(CD_1)\right]$ and $\frac{N_1}{N}\left[1 - F(TL_1)\right]$, respectively. The risk premium per capita can be calculated as follows:

$$p_{risk-2}(CD_1, TL_2) = EY_1(CD_1, TL_1) \times \frac{N_1}{N}\left[F(TL_1) - F(CD_1)\right] + EY_2(TL_1, TL_2) \times \frac{N_1}{N}\left[1 - F(TL_1)\right] \tag{3.19}$$

$$p_{risk-2}(CD_1, TL_2) = \left\{ \begin{array}{c} (1-\beta_1)\left[\Lambda_1 - CD_1\left(F(TL_1) - F(CD_1)\right)\right] \\ + \left[a + (1-\beta_2)(K - TL_1)\right]\left(F(TL_2) - F(TL_1)\right) \\ + (1-\beta_2)\Lambda_2 + b\left(1 - F(TL_2)\right) \end{array} \right\} \times \frac{N_1}{N} \tag{3.20}$$

The medical expenses growth coefficient k, and the additional premium rate of 15% are consistent with pricing I. However, the coverage scope of pricing II, including both the first and second levels of critical illness insurance, is broader than that of the pricing I. Furthermore, it is more difficult to obtain medical cost data that meets the actuarial requirements. Therefore, a higher surcharge is applied to the risk premium. We increase the security surcharge by 10% compared to that in pricing I; namely, the safety factor is 40%. The gross premium of pricing II is as follows:

$$p_{gross-2} = (1 + 40\%) \times (1 + k) \times p_{risk-2} / (1 - 15\%) \tag{3.21}$$

3.2 Sustainable Performance of the Critical Illness Insurance Fund

This section mainly discusses the operation balance of the critical illness insurance fund. First, the income of the critical illness insurance is calculated based on the pricing mechanism in 3.1. In the pricing process, there is an understood premise that all the residents are forced to participate in the insurance. In addition, the balance of the basic medical insurance at the end of the previous year serves as the main source of critical illness insurance premium. The social medical insurance administration pays the insurance by pricing I or pricing II for all residents. Therefore, the income of the critical illness insurance fund can be represented as:

$$INCOME = P_{gross} \times N \tag{3.22}$$

Here, N represents the total number of insured residents.

Second, the expenditure of the critical illness insurance fund is based on the compensation mechanisms that were designed in section 2. In the pricing process, only the deductible, compensation ratio and cap amount of critical illness insurance are considered, but the regional and urban and rural differences are not distinguished. However, to calculate the actual expenditure of funds, it is necessary to take the OOP expense adjustment coefficient into account, which reflects the income gaps between different regions and between urban and rural residents.

$$EXPENDITURE = \sum EXP_{mn} \quad m = S, M, N; n = U, R \tag{3.23}$$

$$EXP = x_i - \gamma_i \times OOP_i - (1 - \alpha) \left(CD_1 - n_i De - \sum x_{ij}^{'} \right) \tag{3.24}$$

Table 6: Descriptive statistics of individual annual cumulative hospitalisation expenses of urban and rural residents of China (samples), 2012

Individual annual cumulative hospitalisation expenses				
Percentiles		Smallest		
1%	200	10		
5%	500	20		
10%	900	20	Obs	2,568
25%	1,800	40	Sum of Wgt.	2,568
50%	3,800		Mean	8,091.483
		Largest	Std. Dev	16,086.07
75%	7,800	184,750		
90%	17,000	195,000	Variance	2.59e+08
95%	30,000	200,000	Skewness	6.912276
99%	78,700	288,000	Kurtosis	75.42077

Note: The first and the second columns show the different values of x in different percentiles. In the third column, the four values under the "Smallest" are the smallest four values along the distribution of x, and the "Largest" represents the largest four values.

4 Empirical Analysis of the Critical Illness Insurance for the Urban and Rural Residents

4.1 Data and Statistic Analysis

The CFPS dataset includes detailed survey data for counties, households and family members in 25 provinces, cities and autonomous regions in China. The mixed models of the critical illness insurance that we constructed and the pricing determined in the above sections are empirically tested using the dataset.

4.1.1 Inpatient Medical Expenditures

Based on the CFPS adult database, there were 35,729 adult resident data samples in 2012, of which 2,568 effective samples had inpatient experiences during the previous year.

Table 6 shows that the average individual annual cumulative inpatient medical expenditure for residents in 2012 was 8,091.483 CNY; the highest, the 50th percentile and the 99th percentile inpatient medical expenses were 288,000 CNY, 3,800 CNY and 78,700 CNY, respectively. Therefore, we concluded that the occurrence probability of an extraordinarily high inpatient medical

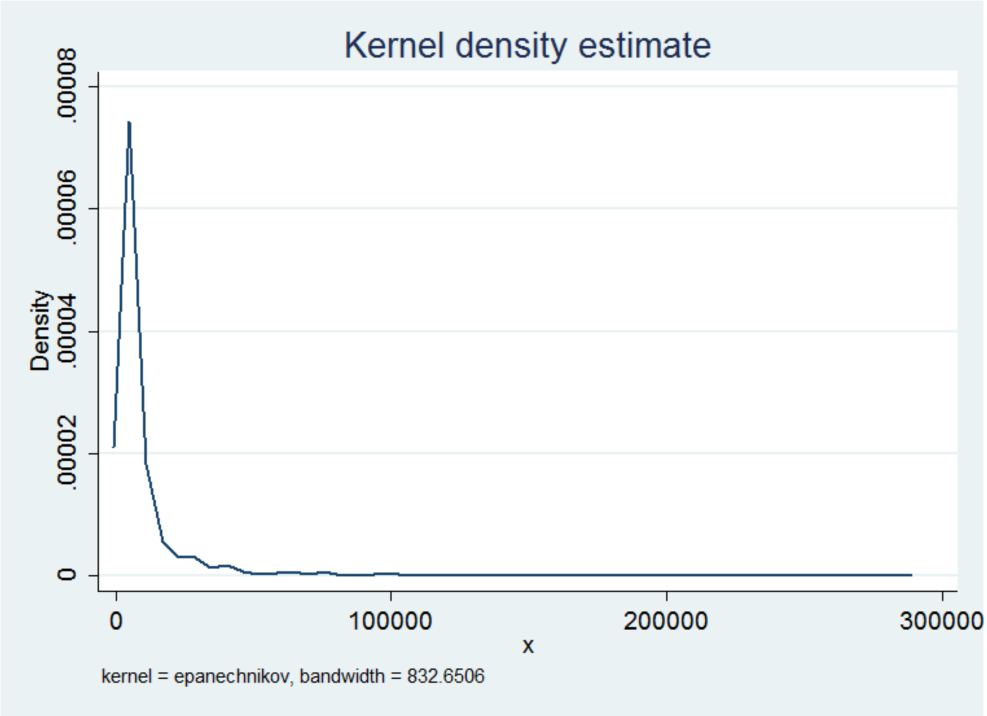

Figure 2: Probability density function of individual annual cumulative hospitalisation expenses of urban and rural residents of China (samples), 2012

expenditure was small, and the probability density distribution of the inpatient medical expenditure was significantly right-skewed. (As shown in Figure 2)

4.1.2 Standards of Household Catastrophic Medical Expenditures

International Standard The international standard for a household catastrophic expenditure is 40% of household capacity to pay, which can be represented by household non-food consumption—i.e., the difference between household consumption expenses and food consumption. There were 13,316 samples in the CFPS (2012). Pre-processing resulted in 11,681 effective samples, with which we conducted a descriptive statistical analysis. (As shown in Table 7)

We concluded that according to the international standard, the household catastrophic expenditure should be 9,379 CNY, as for urban-rural residents in China in 2011, the average household capacity to pay was 23,446.31 CNY. That is, $CAT_{f2011} = 9379$ CNY.

China's Standard After pre-processing, we obtained 12,793 effective samples with which we could perform a descriptive statistical analysis. (As shown in Table 8) We concluded that according to the China's standard, the family catastrophic expenditure should be 14,125 CNY because the average household gross income per capita of China's urban-rural residents between

Table 7: Descriptive analysis of household non-food consumption expenditure of urban and rural residents of China (samples), 2012

Mean estimation		Number of obs=11681		
	Mean	Std. Err.	[95% Conf. Intervall]	
CTP	23,446.31	393.4039	22,675.17	24,217.44
CAT	9,378.522	157.3616	9,070.067	9,686.977

Note: CTP (Household non-food consumption expenditure) =Household size×Consumption expenditure per capita –Food consumption expenditure correction per capita) ; CAT(Household catastrophic medical expenditure)=40%×CTP.

Table 8: Descriptive analysis of household income per capita of urban and rural residents of China (samples), 2012

Mean estimation		Number of obs =12793		
	Mean	Std. Err.	[95% Conf. Intervall]	
family income correction per capita	14,124.75	217.0966	13,699.21	14,550.29

2011 and 2012 was 14,125 CNY. That is, $CAT_{d2011} = 14125$ CNY.

We selected the China's standard to define the catastrophic medical expense. First, the critical illness insurance makes a second reimbursement for the individual cumulative annual medical expenditure, and the standard of catastrophic medical expenditure is the threshold of the second reimbursement. Therefore, China's standard, which is the average disposable income of urban residents (or average net income of rural residents), is more suitable for measuring the catastrophic medical expenditure. Second, according to the expression of capacity to pay in Table 7, we found that household size, consumption expenditure per capita and food consumption expenditure per capita affected household non-food consumption expenditure. However, China is a country in which people largely contribute to their savings (Kraay, 2000); excessive saving inhibits residents' consumption levels, which means that household consumption expenditure underestimates the residents' consumption ability. Therefore, household non-food consumption expenditure also underestimates the household capacity to pay, which means that using the international standard to measure the household capacity to pay is not appropriate for the Chinese data.

Table 9: Indicators according to the four proposed mechanisms

Mechanism	CD		TLorTL_2	$1-\beta$	
Mode I	45,702			35%	
Mode II	14,125			84%	
	CD_1	TL_1	160,000	$1-\beta_1$	$1-\beta_2$
Mode III	14,125	88,036		87%	48%
Mode IV	14,125	72,287		36%	79%

4.2 Indicators of the Mechanisms

We simulated the indexes of critical illness insurance and the four models in section 3 using the data of Chinese urban-rural residents' previous annual inpatient medical expenditures from the CFPS (2012). (As shown in Table 9) Based on China's current policies of basic medical insurance, we assumed that the deductible for urban-rural residents' integrated basic medical insurance in 2012 was 500 CNY, and the compensation ratio $(1-\alpha)$ was 30%.

According the above indicators, we can calculate individual cumulative OOP payments under different models. Because the corresponding n_i and $\sum x_{ij}^{'}$ differ for each insured individual, we cannot obtain the accurate function between cumulative individual annual medical expenditures and individual cumulative annual OOP expenses under each critical illness insurance model. The following functions assume that n_i and $\sum x_{ij}^{'}$ are the average numbers $\overline{n_i}$ and $\overline{\sum x_{ij}^{'}}$ in the range of the corresponding x_i. Details are shown in Table 10.

4.3 Adjustment coefficient for Individual Cumulative Annual OOP Expenses

Based on the calculation method of the adjustment coefficient in section 2.4, we simulated the adjustment coefficient of OOP payments. The per capita incomes (2012) of urban, rural, eastern, middle and western residents are shown in Table 11. In addition, the adjustment coefficients of individual cumulative OOP expenses are presented in Table 12.

4.4 Performance Evaluation of the Mechanisms

The 2,568 adult residents with inpatient experience were treated as a group, and all were insured. Based on the calculation (as shown in Table 13), the incidence of household catastrophic medical expenditure was approximately 1.5%. The lowest overall severity (Model II) was only 230.78 CNY, and the highest local severity (Model III) was less than 20,000 CNY. These results demonstrate that the four models can effectively reduce the incidence and severity of catastrophic

Table 10: Benchmark of individual cumulative OOP expenses (CNY)

Mechanism	Individual cumulative annual medical expenditures	Individual cumulative OOP expenses
Mode I	$x_i < 45,702$	$OOP_i = 0.3xi + 414.358$
	$45,702 \leq x_i \leq 157,400$	$OOP_i = 0.195xi + 407.225$
	$x_i > 157,400$	$OOP_i = xi - 126,434$
Mode II	$x_i < 14,125$	$OOP_i = 0.3xi + 399.721$
	$14,125 \leq x_i \leq 157,400$	$OOP_i = 0.16xi + 2,485$
	$x_i > 157,400$	$OOP_i = xi - 129,818$
Mode III	$x_i < 14,125$	$OOP_i = 0.3xi + 399.721$
	$14,125 \leq x_i < 88,036$	$OOP_i = 0.13xi + 2,908.75$
	$88,036 \leq x_i \leq 157,400$	$OOP_i = 0.52xi - 38,314.9$
	$x_i > 157,400$	$OOP_i = xi - 113,912$
Mode IV	$x_i < 14,125$	$OOP_i = 0.3xi + 399.721$
	$14,125 \leq x_i < 72,287$	$OOP_i = 0.192xi + 324.8$
	$72,287 \leq x_i \leq 157,400$	$OOP_i = 0.21xi - 976.37$
	$x_i > 157,400$	$OOP_i = xi - 125,322$

Table 11: Descriptive analysis of family income per capita of different regional and urban and rural residents (samples, 2012)

	Number of obs	Mean	Std.Err.	[95% Conf.Interval]	
Urban	4,154	20,721.64	563.8317	19,616.23	21,827.05
Rural	8,639	10,952.68	162.0983	10,634.93	11,270.43
East	5,823	16,494.85	395.5606	15,719.41	17,270.3
Middle	3,795	12,944.85	309.5045	12,338.04	13,551.66
West	3,173	11,191.61	309.4342	10,584.9	11,798.33

Note: There are12,793 valid samples of family per capita net income in the CFPS (2012), but there are two samples without province GB code, so the total number of samples in the three regions is 12,791.

Table 12: Adjustment coefficients of individual cumulative OOP expenses

Adjustment coefficients γ_i	East	Middle	West
Urban	1.7199	1.3524	1.1613
Rural	0.9126	0.7176	0.6162

Table 13: Performance evaluation of the four proposed mechanisms

Mechanism	IncidenceI_{cat}(%)	Overall severityS_{cat}(CNY)	Local severityS_{cat-a}(CNY)
Model I	1.40	249.10	17,769.15
Model II	1.60	230.78	14,454.88
Model III	1.29	256.04	19,924.69
Model IV	1.52	252.26	16,610.23

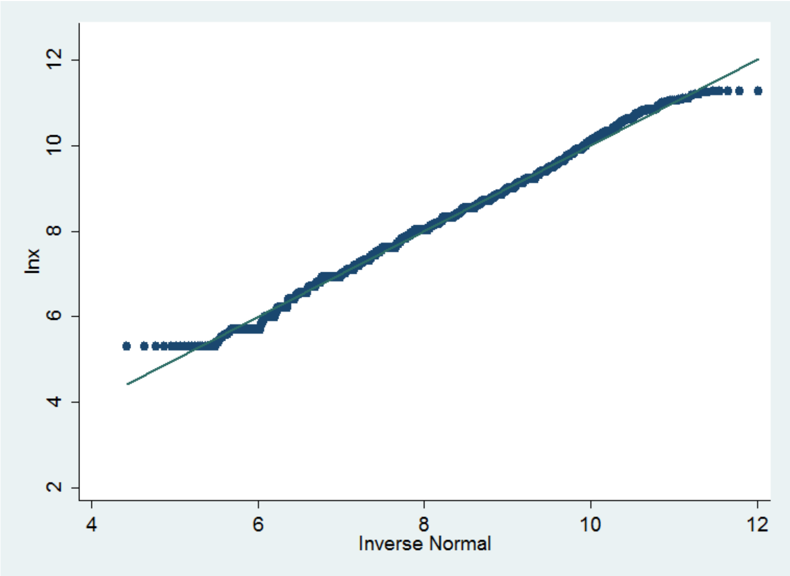

Figure 3: The logarithmic normal distribution fitting of the residents' individual annual cumulative hospitalisation medical expenses (samples, 2012)

medical expenditures.

4.5 Differential Pricing of the Mechanisms–Model III

We performed a fitting analysis of the logarithms of the annual cumulative hospitalisation medical expenses of the residents with hospitalisation experience over the past year in CFPS (2012), and then the normal distribution test was conducted. The analysis results of samples within 1%-99% are shown in Figure 3 and Table 14.

The results showed that the annual cumulative hospitalisation medical expenses of the residents (samples) in 2012 obeyed the logarithmic normal distribution, with mean $\mu = 8.22$ and standard deviation $\sigma = 1.13$.

Table 14: The logarithmic normal distribution test of the residents' individual annual cumulative hospitalisation medical expenses (samples, 2012)

Skewess/Kurtosis tests for Normality					
Variable	Obs	Pr(Skewness)	Pr(Kurtosis)	adj chi2(2)	Prob>chi2
$\ln x$	2519	0.9826	0.7394	0.11	0.9460

Table 15: The critical illness insurance pricing simulation based on the distribution of the residents' individual annual cumulative hospitalisation medical expenses (samples, Model III, CNY)

	Coverage scope	Risk premium	Pure premium	Gross premium
Pricing I	(14,125,88,036)	103	145	171
Pricing II	(14,125,157,400)	107	162	191

Note: 1.In the pricing process, the rising coefficient of medical expenditure k is based on the the national per capita inpatient medical expenses during 2008-2011. 2.The results of the pricing analysis are the premiums of 2012 based on the data of 2011.

$$f(x,\mu,\sigma) = \frac{1}{\sqrt{2\pi}\sigma x} e^{-\frac{1}{2.55}(\ln x - 8.22)^2} \tag{4.1}$$

$$F(x,\mu,\sigma) = \Phi\left(\frac{\ln x - 8.22}{1.13}\right) \tag{4.2}$$

According to the premium calculation formulas of pricing I and pricing II and the inpatient (samples) medical expenses data, two pricing mechanisms of model III can be simulated. The values of $\int_{CD_1}^{TL_1} F(x)\,dx$ and $\int_{TL_1}^{TL_2} F(x)\,dx$ need to be estimated by infinitesimal element method. According to Figure 4, the cumulative distribution function of x, the top of $\int_{CD_1}^{TL_1} F(x)\,dx$ is an arc with larger radian. In addition, the more segmentation, the fewer errors in the process of approximate solving based on the regular graphics. Therefore, the approximate value was made available by segmenting it into several parts. When the gap between $F(A)$ and $F(B)$ was small, $\int_A^B F(x)\,dx \approx (B-A)\times(F(B)-F(A))/2$. In addition, the results of approximate solving were: $\int_{14125}^{88036} F(x)\,dx \approx 72284.6296$, $\int_{88036}^{157400} F(x)\,dx \approx 72284.6296$. The results of pricing simulation are shown in Table 15.

Although the coverage scope of pricing II is larger than that of prcing I, there is not an overly large gap between the premiums. On the one hand, the probability of medical expenses risk in the second level of critical illness insurance covering 88,036 CNY (TL_1) to 157,400 CNY (TL_2) was only 0.21%. Thus, there is no obvious difference in the average insurance loss in the

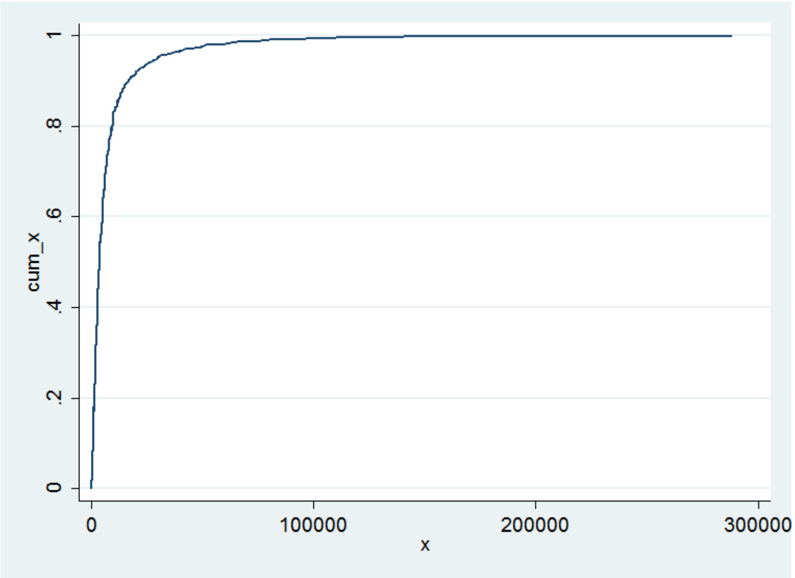

Figure 4: The cumulative distribution function of the residents' individual annual cumulative hospitalisation medical expenses (samples, 2012)

corresponding coverage scopes between pricing II and pricing I. On the other hand, under the assumption that all the residents are forced to purchase the critical illness insurance, all insured residents share the loss of medical expenditures with the coverage of the second level critical illness insurance. Therefore, the risk premiums would not increase sharply. However, based on the national population, the number of residents whose annual cumulative hospitalisation medical expenses extend beyond the second deductible of critical illness insurance cannot be ignored, and the total compensation of medical expenditure is higher, 70,000-110,000 CNY. Therefore, it is necessary to consider two types of pricing.

4.6 Fund Balance of the Mechanisms–Model III

The balance performance of critical illness insurance was simulated using the CFPS (2012) data of 35,729 residents. The data included 2,568 effective samples with hospitalisation experiences. There were 303 samples with medical expenditures within the coverage scope of critical illness. Of these samples, 281, 17 and 5 samples had total medical expenses within the scope of the first level, the second level and over the scope of critical illness insurance, respectively. In this paper, the fund balance analysis was performed when all the residents paid the pricing I or pricing II, and the medical insurance compensation was consistent with the premium type. The benchmark of OOP payments are shown in Table 4.5, in which n_i and $\sum x'_{ij}$ were the average numbers $\overline{n_i}$ and $\overline{\sum x'_{ij}}$ in the range of the corresponding x_i. In addition, the results of the pricing analysis

Table 16: The fund balance of the critical illness insurance based on the resident samples–pricing I (CNY)

Fund income		Fund expenditure	
The number of the insured	35,729	The sum of cumulative hospitalisation medical expenses	11,499,856
Gross premium (pricing I)	158	The sum of adjusted OOP expenses	3,459,196
		The sum of basic medical insurance loss	2,842,578
		The insurance operation management expenses	564,518
The total income	5,645,182	The total expenditure	5,762,600

Note: It is assumed that the insurance operation management expense is 2/3 of the additional premium rate (15%), namely, 10%; and the profits of commercial health insurance and the other expenses are 1/3 of the additional premium rate, namely, 5%. Hereinafter, these are inclusive.

were the premiums of 2012 based on the data of 2011, but the balance performance in this paper was based on the fund expenditure in 2011. Therefore, premiums I and II were 158 CNY and 177 CNY, respectively, after excluding the effect of the rising medical expenses in the balance measurement process.

The results of the balance calculation (as shown in Table 16 and Table 17) showed that in the case of all insured individuals paying pricing I, the expenditure of the fund was slightly higher than its income. If all the insured paid prcing II, the critical illness insurance fund was fairly balanced and had a slight surplus. This indicates that the prices of the proposed critical illness insurance design can achieve a sustainable fund.

5 Conclusions and Discussions

This paper mainly focuses on the prepayment of catastrophic health expenditures under the urban-rural integrated system in China. Four models were constructed based on the reinsurance and coinsurance approaches. In addition, we analysed differentiation pricing for critical illness insurance and the balance performance of the insurance fund. Moreover, our models were tested using the data from CFPS. The evidence indicates that the four models could effectively alleviate the incidence and severity of catastrophic health expenditures. In addition, the fund balance under the designed mechanism can be maintained, which indicates that the new mechanism can lead to the sustainable performance of critical illness insurance.

Table 17: The fund balance of the critical illness insurance based on the resident samples–pricing II (CNY)

Fund income		Fund expenditure	
The number of the insured	35,729	The sum of cumulative hospitalisation medical expenses	11,499,856
Gross premium (pricing II)	177	The sum of adjusted OOP expenses	3,024,690
		The sum of basic medical insurance loss	2,842,578
		The insurance operation management expenses	632,403
The total income	6,324,033	The total expenditure	6,264,991

Several recommendations that merit discussion arise from these conclusions. First, the interactive mechanisms based on the coinsurance and reinsurance approaches can improve China's critical illness insurance schemes. Critical illness insurance has been developed experimentally in several cities using Model I, providing a second compensation for OOP expenses for residents with catastrophic medical expenditures. Although this model can decrease the incidence and severity of catastrophic medical expenses, the deductible is relatively high. Additionally, with the right-skewed characteristic of the medical expenditure distribution, the possibility of the insured having a relatively high individual cumulative annual OOP expenses, even close to the catastrophic expenditure, is relatively high.

Second, it is necessary to increase the pooling level of the critical illness insurance and gradually construct the urban-rural integrated system nationwide. We retained the cap amount in the design process because we considered that the operation of the funds might be unstable at first. As the development of the critical illness insurance becomes more mature and its pooling level improves, the cap amount can be eliminated. In addition, based on the differences in the developing level of social economics throughout the country, adjustment coefficients can be designed for the coverage level.

Third, the pricing method of private health insurance, which determines the insurance premium for the following year based on the individual cumulative annual inpatient medical expenses during the previous year, can achieve sustainable development of the critical illness insurance funds. In addition, continuing to optimise the cumulative medical expenses distribution function is one of our future research directions.

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References

[1] K. Xu, D. B. Evans, G. Carrin, et al., Design health financing systems to reduce catastrophic health expenditure[J], Technical Brief for Policy-Makers, vol.2, pp.1-5, 2005.

[2] K. Xu, D. B. Evans, G. Carrin, et al., Protecting households from catastrophic health spending[J], Health Affairs, vol.26, pp.972-983, 2007.

[3] X.Y. Sun, S. Jackson, G. Carmichael, et al., Catastrophic medical payment and financial protection in rural China: evidence from the new cooperative medical scheme in Shandong province[J], Health Economics, vol.18, pp.103-119, 2009.

[4] The State Council of China, Guidance on carrying out the work of critical illness insurance for urban and rural residents in China, 2012.

[5] World Health Organization, Health systems financing: the path to universal coverage[R], 2010.

[6] K. Kawabata, K. Xu and G. Carrin, Preventing impoverishment through protection against catastrophic health expenditure[J], Bulletin of the World Health Organization, vol.8, pp.612, 2002.

[7] Y. Zhang, A study on the cooperative mechanisms between social health insurance and private health insurance[M], Beijing: China Social Sciences Publishing House, 2014.

[8] M. Rothschild and J. Stiglitz, Equilibrium in competitive insurance market: an essay on the economics of imperfect information[J], Quarterly Journal of Economics, vol.4, pp.629-649, 1976.

[9] R. Verlaak and J. Beirlant, Optimal reinsurance programs: an optimal combination of several reinsurance protections on a heterogeneous insurance portfolio[J], Insurance: Mathematics & Economics, vol.2, pp.381-403, 2003.

[10] K. Xu, D. B Evans, K. Kawabata, et al., Household catastrophic health expenditure: a multicountry analysis[J], Lancet, vol.362, pp.111-117, 2003.

[11] M.L. Zhu, Z.J. Song and X. Wang, The interpretation and analysis of the compensation patterns for major illness medical insurance policies–an empirical study based on the hospitalisation data of residents in Tianjin[J], Insurance Studies, vol.1, pp.97-105, 2013.

[12] S.E. Berki, A look at catastrophic medical expenses and the poor[J], Health Affairs, vol.4, pp.138-145, 1986.

[13] C. Bredenkamp, M. Mendola and M. Gragnolati, Catastrophic and impoverishing effects

of health expenditure: new evidence from the Western Balkans[J], Health Policy and Planning, vol.26, pp.349-356, 2011.

[14] A. Wagstaff and E. Van Doorslaer, Catastrophe and impoverishment in paying for health care: with applications to Vietnam 1993-1998[J], Health Economics, vol.11, pp.921-934, 2003.

[15] China Association of Actuaries, Health insurance[M], Beijing: China Financial Economic Publishing House, 2011.

[16] A. Kraay, Household saving in China[J], World Bank Economic Review, vol.14(3), pp.545-570, 2000.