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MASTER

ACTUARIAL SCIENCE

MASTER'S FINAL WORK

INTERNSHIP REPORT

PRICING, RESERVING AND PROFIT TESTING OF THE 'UPUPHIGH' LIFE INSURANCE PRODUCT

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ABSTRACT

This internship report documents my work at Product Actuarial Department of Guofu life insurance company, where I was asked to build a new pricing model and Excel templates of profit test for a newly-launched whole life insurance product named “UpUphigh”.

Aligned with the roles of the Product Actuarial Department, the objectives of the internship, under the framework of actuarial report for “UpUphigh”, see Guofu Life Insurance Co., Ltd. (2024. 2024a), were set as: (i) calculation of premiums; (ii) calculation of cash values at the end of each policy year; (iii) calculation of statutory unearned premium reserves (statutory UPR) and related reserves; (iv) validation of the accuracy of the developed pricing model by comparing it to the internal model provided by the company; (v) building Excel templates of profit test into the developed pricing model, after analyzing profit testing procedures in the internal model. The calculation of premiums, cash values and reserves were limited to the regulation for general life insurance under China Insurance Regulation Commission (CIRC). The calculation of cash flows and profit test indicators should conform to Solvency II regime. It must be noted that Guofu Life Insurance Co., Ltd. (2024. 2024a) are the main references, used throughout the whole work.

The work was strongly based on Excel, requiring us to build many sheets corresponding to the different layers of the pricing model, following the assumptions and formulas provided in the actuarial report. Also, it was necessary to create some VBA codes to organize every critical data into a whole sheet so that it was possible to make an efficient comparison with the critical data included in the internal model. It must be noted that profit testing is much more challenging than calculating premiums and reserves, as it requires parameters to be listed by every policy month rather than every policy year. Further, the calculation of profit test indicators like minimum capital requirement (total risk) (MC) involves matrix computation due to the fact that all types of risks should be considered and there are correlations between each pair of risks. This also makes profit testing a more complex task.

Overall, the development of our pricing model for “UpUphigh” is successful as its accuracy, simplicity and interpretability have been verified.

Keywords: life insurance; premiums; cash values; statutory unearned premium reserve; modified reserve; premium deficiency reserve; profit test; minimum capital requirement

RESUMO

Este relatório de estágio documenta o meu trabalho no Departamento Atuarial de Produtos da seguradora de vida Guofu, onde me foi pedido que, usando a ferramenta Excel, criasse um modelo de preços, reservas e profit testing especificamente desenhado para um produto vida recentemente lançado, chamado "UpUphigh". Naturalmente, a extensão a outros produtos é quase imediata.

Alinhados com as funções do Departamento Atuarial de Produtos, os objetivos do estágio, que teve como bibliografia fundamental o chamado relatório atuarial para o "UpUphigh", ver Guofu Life Insurance Co., Ltd. (2024. 2024a), foram definidos como: (i) cálculo de prémios; (ii) cálculo dos cash values no final de cada ano da apólice; (iii) cálculo das reservas estatutárias de prémios não vencidos e demais reservas relacionadas; (iv) validação da precisão do modelo de pricing desenvolvido, comparando-o com o modelo interno fornecido pela empresa; (v) construção de modelos Excel de profit testing, integrando-os com o modelo de pricing desenvolvido. O cálculo dos prémios, cash values e reservas foi naturalmente realizado ao abrigo das disposições emanadas da Comissão de Regulamentação de Seguros da China. O cálculo dos fluxos de caixa e dos indicadores de profit testing estão em conformidade com o regime de Solvência II. Deve salientar-se que Guofu Life Insurance Co., Ltd. (2024. 2024a) foram usadas ao longo de todo o trabalho.

O trabalho foi fortemente baseado na ferramenta Excel, exigindo a conceção de muitas folhas de cálculo, correspondentes às diferentes 'camadas' do modelo, seguindo as premissas e fórmulas fornecidas no relatório atuarial. Além disso, foi necessário criar códigos VBA para organizar todos os dados críticos numa folha de cálculo, para facilitar a comparação eficiente com os dados críticos incluídos no modelo interno. É importante salientar que o profit test é muito mais desafiante do que o cálculo de prémios e reservas, pois exige que os parâmetros sejam listados por mês da apólice e não por ano da apólice. Além disso, o cálculo de indicadores de teste de lucro, como o requisito de capital mínimo (risco total) (MC), envolve o cálculo matricial, devido ao facto de todos os tipos de riscos terem de ser considerados e existirem correlações entre cada par de riscos. Tudo isto contribuiu para tornar o profit test uma tarefa bastante mais complexa.

No geral, o desenvolvimento do nosso modelo para o "UpUphigh" foi bem-sucedido, uma vez que a sua precisão, simplicidade e interpretabilidade foram verificadas.

Palavras-chave: seguro de vida; prémios; cash value; reserva legal de prémios não ganhos; reserva modificada; reserva de deficiência de prémio; profit test; requisito de capital mínimo

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CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

CBIRC - China Banking and Insurance Regulatory Commission

CIRC - China Insurance Regulation Commission

TPD - Total and Permanent Disability

UPR - Unearned Premium Reserve

IBNR - Incurred but Not Reported

UPR - Statutory Unearned Premium Reserve

PDR - Premium Deficiency Reserve

SA - Sum Assured

IRR - Internal Rate of Return

NPV - Net Present Value

MC - Minimum Capital Requirement

VBA - Visual Basic for Applications

PVR – Policy Value Reserve

LIST OF TABLES

1.INTRODUCTION

1.1 Context and objectives

This report documents the whole journey that I have been through during my internship period at the 产品精算部 (Product Actuarial Department) of Guofu life insurance company, from the 7th of April to the 30th of June, 2025.

Guofu life insurance company was founded in June, 2018 with the approval of ChinBanking and Insurance Regulatory Commission (CBIRC). It is the first national life insurance corporation in GuangXi, a big city in the very southern part of China. In terms of the shareholder structure, generally it is co-financed by a number of well-known companies and one of its major shareholders is GuangXi Investment Group, which is the first state-owned capital enterprise to be listed among the world's top 500 enterprises in GuangXi.

Our department, Product Actuarial Department, is located in financial center of Beijing, the capital city of China. Its main responsibility is to design, calculate, monitor and manage new and already existing insurance products under China Insurance Regulation Commission (CIRC). My work focused on the whole development of a newly-launched life insurance product called "UpUphigh". Using Excel and VBA, I was asked to build a model from zero on basis of the product actuarial report and then to compare the outcome of the developed model with the results provided by the internal model the team built last year, verifying the accuracy of critical data information, adding some favorable elements into my own model and possibly giving some suggestions and adjustments to optimize the internal model.

The product actuarial report is one of the essential documents that an insurance company has to submit to CIRC in order to launch a new insurance product. Basically, the actuarial report includes every information about the insurance product with the signature of chief actuary:

a) Name of the product;
b) Characteristics of the product;
c) Data sources and pricing assumptions;
d) Pricing methodologies and formulas;
e) Calculation of cash value;
f) Calculation of statutory reserve for outstanding liabilities;
g) Illustration of the calculation method of benefit;
h) Profit test;
i) Main risks and related management suggestions;
j) Special statement from chief actuary.

Within the framework of the actuarial report, the objectives set for my internship were:

1) To calculate single-payment premiums or annual premiums corresponding to every 1000¥ sum assured (layer 1);
2) To calculate cash values corresponding to every 1000¥ sum assured at the end of each policy year (layer 2);
3) To calculate statutory unearned premium reserves (statutory UPR); adjusted liability reserves and premium deficiency reserves (PDR) must be calculated first, which are two most essential components of statutory reserves (layer 3);

4) To learn how to do profit test by analyzing internal model and let this block fit into my own model, which is the most challenging work that I have done throughout the whole internship.

Overall, the level of difficulty of objectives are increasing step by step. However, the first two parts are not easy as well since it takes some time to organize logics of how to build a new model in an accurate and efficient manner (plus it is always complex when you start building something from zero). The third part corresponds to f) part in the product actuarial report, which is advanced calculation on basis of premiums and cash values including some usage of VBA. And finally, the fourth part, profit test is a massive block, which is the extension of parts 1-3, considering more than just death benefits payment, almost all possible cash flows and all types of risks. Also, it is evaluated using different standards, such as CR (cross reserving), CR Solvency II and GAAP. CR is used in traditional Chinese actuarial profit testing and CR solvency II is an enhanced version of CR under solvency II regime.

1.2 Structure of the report

The structure of this report is: Chapter 2 begins with an introduction to regulations about whole life insurance under CIRC and some key concepts that will be used throughout this report; Chapter 3 illustrates the calculation of single-payment premiums or annual premiums corresponding to every 1000¥ sum assured and, more importantly, the methodology to build a pricing model from zero (layer 1); Chapter 4 explains the calculation of cash values corresponding to every 1000¥ sum assured at the end of policy year t, which is the second layer of pricing model for "UpUphigh" (layer 2); Chapter 5 covers the calculation of three kinds of reserves and some related coefficients, corresponding to the third layer of pricing model for "UpUphigh" (layer 3). Apart from this, VBA techniques were used to organize all critical data into one sheet so that it was possible to make a comparison with the internal model in a simple and accurate approach - checking the difference values are all zeros or not; Chapter 6 comprises the overall function of profit test, analyses the differences between profit test results and the calculations in previous chapters and discusses the methodology to adding profit test into the new pricing model for "UpUphigh"; Chapter 7 will be the conclusions about the developed model concerning "UpUphigh", for example, advantages and disadvantages comparing to the internal model, the accuracy of critical data, flexibility and universality of this pricing model and what else elements could be added into it if deciding to go further.

2. CHINESE REGULATIONS FOR LIFE INSURANCE

2.1 Life insurance contracts

Firstly, it is necessary to introduce some basic definitions and principles about life insurance. Life insurance is an insurance product that insures the life of a person. Life insurance contracts can be term life insurance, whole life insurance, and endowment insurance (for a general reference, see for instance Dickson *et al.* (2019)).

a) Term insurance is a contract to pay a sum assured on the policyholder's death, provided death occurs during a specified period, called the term of the contract.
b) Whole life insurance is a contract to pay a benefit that is an amount called the sum assured, which will be paid on the policyholder's death. It is the simplest life insurance contract.
c) Endowment insurance is a combination of a term assurance and a pure endowment contract. Under a pure endowment contract a sum assured is payable on survival to the end of the term. The sums assured payable on death or survival need not to be the same, although they often are.

Life insurance can include total and permanent disability (TPD) coverage. According to the Chinese legislation, the naming of life insurance should conform to the following format:

a) "the name of insurance company" + "explanatory text, like UpUphigh" + "type of insurance" + "type of design";
b) The name of the insurance company in the preceding paragraph may be either the full name or an abbreviation; explanatory text should be no more than 10 words in length;
c) Additional insurance should be named with the word "additional" after the "name of the insurance company";
d) Group insurance should have the word "group" in its name.

The types of life insurance designs are categorized into general, participating, investment-linked, universal, etc. Participating, investment-linked and universal life insurance should indicate the design type in the name, while general life insurance is not required to indicate the design type in the name. "UpUphigh", for which we built a pricing model, is a general whole life insurance.

2.2 Regulations for general life insurance under CBIRC

Secondly, the General Office of the China Banking and Insurance Regulatory Commission published some actuarial requirements for general life insurance products, to which new products must conform. It is also necessary to introduce key regulations on general life insurance. We based the entire pricing model for "UpUphigh" on these regulations, see China Banking and Insurance Regulatory Commission (2019, 2020, 2021, 2021a, 2021b), China Insurance Regulatory Commission (2015), Insurance Law of the People's Republic of China. (2015), Ministry of Finance & China Insurance Regulatory Commission (2015).

2.2.1 Sum assured

In terms of individual general life of insurance, the following Table 1 presents the ratio of the death benefit to the sum of premiums paid up to the time of death. It is worth noting that the arrival age is the age obtained by adding the insured's original policy age to the number of policy years at that time and subtracting one.

Age of arrival	Lower limit of ratio
18—40 years old	160%
41—60 years old	140%
61 years old or older	120%

Table 1: Lower limit of Ratio of Death benefit to Accumulated premiums paid

The death benefit liability of an individual general life insurance policy should include, at a minimum, a sickness death benefit liability and an accidental death benefit liability. (Unless stated otherwise, the sources for Table 1 and all the following tables are the actuarial report and the legislation.)

2.2.2 Basis of calculation of premiums

2.2.2.1 Interest rate

For products with an insurance period of more than one year, the insurance company shall set the predetermined interest rate, based on the company's historical investment return experience, reasonable expectations for the future, and the product characteristics, in accordance with the principle of prudence.

2.2.2.2 Mortality rates

When determining insurance premiums, companies should base on the company's actual mortality experience and also on the industry's publicly released mortality tables, taking into account future trends and changes in risk; again, the assumption about mortality rates must be set in accordance with the principle of prudence.

2.2.2.3 Expense loading rate

The assumed expense loading rate is incorporated in the premium calculation to cover administrative and distribution costs. It shall be set by the company for each policy at its own discretion when determining the premium, provided that the average expense loading rate shall not exceed the upper limits specified in Table 2 and Table 3. The average expense loading rate is a percentage calculated dividing the sum of the actuarial present value of the assumed expense loadings by the sum of the actuarial present value of the gross premiums, for the policy.

Type of business	Payment method	Whole life insurance
Individual	Regular payment	35%
	Single payment	18%
Group	Regular payment	15%
	Single payment	8%

Table 2: Upper limit of average expense loading rate for general life insurance with an insurance period of one year or more

individual	35%
group	25%

Table 3: Upper limit of average expense loading rate for general life insurance with an insurance period of less than one year

Insurers should regularly review and analyze the parameters related to pricing assumptions and adjust them in a timely manner based on the actual company experience.

When pricing products with an insurance period of more than one year, or products whose insurance period is not more than one year, but have a guaranteed renewal clause and a guaranteed rate for a period of more than one year, insurers should conduct a profit test. To be more specific, a contractual agreement containing a guaranteed renewal clause and a guaranteed rate means that during the guaranteed renewal period, if the policyholder applies for renewal before the expiration of the previous insurance period, the insurance company must continue to underwrite the policy according to the original terms and guaranteed rate.

2.2.3 Basis for calculating the cash values

Policy value reserve (PVR) at the end of the policy year is the value of the reserve for the purpose of calculating the minimum cash value（MCV）of the policy at the end of the policy year, in accordance with the calculation basis and calculation method described next.

2.2.3.1 Assumptions

- The mortality rate follows the same life table used for the calculation of premiums;
- The expense loading rate for individual general life insurance is calculated using the values specified in Table 4.

Type \ Policy year			First year	Second year	Third year	Subsequent years
Single payment	Whole life insurance		18%	/	/	/
Regular payment	Payment period up to 10 years	Whole life insurance	65%	50%	35%	10%
	Payment period from 10 to 19 years	Whole life insurance	80%	75%	60%	10%
	Payment period of 20 years and above	Whole life insurance	85%	80%	75%	10%

Table 4: Annual expense loading rates per payment period

- The interest rate is the predetermined rate used to determine the premium plus 2%.

2.2.3.2 Calculation method

As for the calculation of PVR, it is based on the liability of the policy and the net premiums of each policy year; the calculation is made using the "prospective method". When the "prospective method" is not feasible, the "retrospective method" may be used instead. Prospective method: The current cash value is determined by discounting the policy's expected future cash flows, including future premiums and future benefits, see Dickson *et al.* (2019) for further details.

The gross premium, denoted $CVGP_x^i$, is the premium recalculated using calculation formulas for premiums (Chapter 3) adjusting the expense loading rates according to the table above.

Regarding the calculation of MCV, which refers to the minimum standard for the insurance company to determine the cash value of the policy, it is

$$MCV = max(PVR, 0) \times r, \tag{1}$$

where:
MCV is the minimum cash value of the policy at the end of the policy year;
PVR is the policy value reserve at the end of the policy year;
The coefficient *r* is calculated by the following formula:

$$r = \begin{cases} k + t \times \dfrac{1-k}{\min(20, n)}, & t < \min(20, n) \\ 1, & t \geq \min(20, n) \end{cases}, \tag{2}$$

where n is the premium payment period of the policy ($n = 1$ for single premium) and *t* is the policy year that has elapsed, $t = 1,2, \ldots$
The value of parameter k is taken from to Table 5.

k value	
Type of business	Whole life insurance
Individual regular payment	0.8
Group regular payment	0.85
Individual single payment	1
Group single payment	1

Table 5: k value under different types of business

2.2.4 Basis for calculating the unearned premium reserve

2.2.4.1 Interest rate

Interest rate on products with a period of insurance of one year or more shall not be higher than the lower of the following:

- Interest rates published by the CBIRC for the unearned premium reserve;
- The assumed interest rates used to set premiums for this type of insurance.

2.2.4.2 Mortality rates

Mortality rates for life insurance are based on the data provided in the "Life Tables of China's Life Insurance Industry Experience (2010-2013)", see the Appendix. Insurance companies should consider all policies of the same product and select the life table applicable to them in accordance with the specific regulations of the Notice on Matters Concerning the Use of the Life Table of China's Life Insurance Industry Experience (2010-2013) (CIRC [2016] No. 108).

2.2.4.3 Calculation methodology for unearned premium reserve with level premiums

When there are level premiums, we must use the one-year fully modified method. In this method, the first-year net premium is denoted α, the modified net premiums for subsequent years are denoted β and the level net premium for the premium paying period, determined on the basis of the calculation of the statutory unearned premium reserve, is denoted P^{NL}. The following equation must hold.

$$\begin{aligned} &\text{PV of } \alpha + \beta \text{ at the beginning of the premium paying period} \\ &\qquad = \text{PV of } P^{NL} \text{ at the beginning of the premium paying period.} \end{aligned}$$

A reserve for premium deficiencies should also be provided if the net premiums for subsequent years under the modified approach are higher than the gross premiums. The premium deficiency reserve is the actuarial present value of the difference between net premiums and gross premiums for future policy years.

The unearned premium reserve of the policy at the end of the policy year shall be the sum of the above modified reserve and the premium deficiency reserve.

2.2.4.4 Calculation methodology for unearned premium reserve with non-level premiums

Now the unearned premium reserve at the end of the policy year is defined as the actuarial present value of future annual liability costs that exceed the gross premium of the current year. The calculation formula is as follows:

$$\sum_t APV\big(Max(B_t - P_t, 0)\big), \tag{3}$$

where:

APV means actuarial present value;

B_t represents the liability costs to be paid in the *t*-th future year;

P_t refers to gross premiums in the *t*-th future year.

3. CALCULATION OF PREMIUMS

3.1 Characteristics of the "UpUphigh" product

We start this section by highlighting some important characteristics of "UpUphigh", on basis of which the calculation formula for GP_x is designed. Also, the selection and range of input variables for the pricing model are determined according to these characteristics.

- "UpUphigh" is a general whole life insurance product.
- Insured person's age range: from 28 days to 70 years old.
- Period of insurance: lifetime.
- Payment period: single payment, 3 years, 5 years, 6 years, 10 years.
- Payment Method: annual.

According to those characteristics, three basic variables should be considered as inputs of pricing model: (insured person's) Age, Sex and payment period.

3.2 Insurance liabilities

It is also necessary to check insurance liabilities in detail, since insurance liabilities are directly associated with future benefit payments, from where the calculation formula of DB_{x+t} is derived. During the term of this contract, we assume the following insurance liabilities:

1. Death or Total Disability Benefit

When the insured dies or becomes totally and permanently disabled, the company will pay the death or total and permanent disability benefit and this contract will be terminated. Two possible cases can occur.

a) If the insured dies or becomes totally and permanently disabled before the first policy anniversary following their 18th birthday (excluding that anniversary), the benefit is

$$\max\{\text{Premiums paid, Cash Value of the Policy at the time of claim}\} \qquad (4)$$

b) If the insured dies or becomes totally and permanently disabled on or after the first policy anniversary following their 18th birthday, and before the first policy anniversary following the last scheduled premium due date (excluding that anniversary), the benefit is

$$\max\left\{\begin{matrix}\text{Premiums paid} \times \text{ Benefit Payout Factor Corresponding to Attained Age,} \\ \text{Cash Value of the Policy at the time of claim}\end{matrix}\right\} \qquad (5)$$

c) If the insured dies or becomes totally and permanently disabled on or after the first policy anniversary following his or her 18th birthday, and on or after the first policy anniversary following the last scheduled premium due date, the benefit is

$$\max\left\{\begin{matrix}\text{Premiums paid} \times \text{ Benefit Payout Factor Corresponding to Attained Age,} \\ \text{Cash Value of the Policy at the time of claim,} \\ \text{Effective Sum Assured of the Policy at the time of claim}\end{matrix}\right\} \qquad (6)$$

In b) and c), the $\text{Benefit Payout Factor Corresponding to Attained Age}$ is given in Table 6 below. In c), the $\text{Effective Sum Assured} = \text{Basic Sum Assured} \times 1.25^{K-1}$, where K is the number of complete years the policy is in force.

Age of arrival	Benefit payout factor
18—40 years old	160%
41—60 years old	140%
61 years old or older	120%

Table 6: Benefit payout factor for "UpUphigh"

3.3 Pricing assumptions

As referred in the previous chapter, there are some basic pricing assumptions to follow, namely the interest rate, the life table and the expense loading rate. The interest rate is set at 2.5% per annum, effective, the life table is China Life Insurance Industry Experience Life Tables (2010-2013) Non-Pension Business I Table ×65% and the expense loading rate is given in Table 7.

Payment period (years)	1	2	3	4	5	6+
Single payment	6.00%	-	-	-	-	-
Three-year payment	15.00%	1.00%	0.50%	-	-	-
Five-year payment	23.50%	1.00%	0.50%	0.50%	0.50%	-
Six-year payment	25.00%	2.00%	1.00%	0.50%	0.50%	0.50%
Ten-year payment	31.00%	5.00%	2.00%	1.00%	1.00%	0.50%

Table 7: Expense loading rate for "UpUphigh"

3.4 Notation and formulas

There is some notation which is used frequently during the calculation of the gross premium. It is appropriate to state the meanings of the symbols in advance:

x is the age of the insured life at policy issuance;

m is the policy term;

n is the payment period;

t is the *t-th* policy year;

e_t is the expense loading rate for the *t-th* policy year;

$v = \frac{1}{1+\text{interest rate}}$ is the annual discount factor;

q_x is the mortality rate at age x, i.e. the probability that a person aged x will die before reaching age $x + 1$;

l_{x+t} is the number of in-force policies at the end of policy year t for insured lives aged x at policy inception;

GP_x is the single or annual gross premium per 1,000 units of basic sum insured for insured lives aged x at policy inception;

${}_tCV_x^m$ is the cash value per 1,000 of basic sum insured at the midpoint of policy year t for insured lives aged x at policy inception;

DB_{x+t} is the death benefit per 1,000 of basic sum insured in policy year t for insured lives aged x at policy inception;

K_{x+t} is the death benefit payout factor in policy year t for insured lives aged x at policy inception;

SA_x^{1000} is the basic bum insured per 1,000 of single or annual premium for insured lives aged x at policy inception.

Applying the classic equivalence principle, see Dickson et al. (2019), the following formulas are derived, on basis of which the first layer of pricing model for "UpUphigh" is built.

$$GPx = \frac{\sum_{t=1}^{m} D\,B_{x+t} \times q_{x+t-1} \times l_{x+t-1} \times v^{t-0.5}}{\sum_{t=1}^{n}(1 - e_t) \times l_{x+t-1} \times v^{t-1}}, \tag{7}$$

where

$$DB_{x+t} = \begin{cases} \max\{GP_x \times \min(t,n) \times K_{x+t},\ {}_tCV_x^m\}, & x+t \le 18\ or\ t \le n \\ \max\{GP_x \times \min(t,n) \times K_{x+t},\ {}_tCV_x^m, 1000 \times 1.025^{t-1}\} & x+t > 18\ and\ t > n \end{cases} \tag{8}$$

and

$$k_{x+t} = \begin{cases} 100\%, & x+t \le 18 \\ 160\% & 18 < x+t \le 41 \\ 140\% & 41 < x+t \le 61 \\ 120\% & x+t > 61 \end{cases} \tag{9}$$

The basic sum insured per 1,000 units of single or annual premium is

$$SA_x^{1000} = \frac{1000}{GP_x} \times 1000. \tag{10}$$

To illustrate, according to the formulas above, GP_x for a male aged 40 at policy issuance with ten-year payment period, could be calculated immediately if the first layer of pricing model about GP_x is built systematically with some Excel work.

3.5 Building the first layer

The overall reasoning of building the model includes setting the input variables, listing charts to be looked up easily, making assumed values to temporary unknown items, listing each item in the calculation formula for GP_x and making sure it forms a closed loop so that Excel can calculate the final answer iteratively very fast. Further details about these different tasks are illustrated next.

3.5.1 Setting the input variables

Age of the insured	input range		**Input Box**
age x	between 【0 , 70】		40
sex	1--male 2--female		1
Payment period			
n	1、3、5、6、10		10

Table 8: Input variables - Own elaboration

Noting: Input Box is where input variables like age, sex and payment period could be changed manually.

3.5.2 Listing charts

Listing charts of expense loading rate, benefit payout factor and mortality rate, then select the exact value by VLOOKUP function is the next step.

assumed expense loading rate						
	1	2	3	4	5	6+
1	6.00%					
3	15.00%	1.00%	0.50%			
5	23.50%	1.00%	0.50%	0.50%	0.50%	
6	25.00%	2.00%	1.00%	0.50%	0.50%	0.50%
10	31.00%	5.00%	2.00%	1.00%	1.00%	0.50%

benefit payout factor	
x+t	K_x+t
1	1
…	…
18	1
19	1.6
…	…
41	1.6
42	1.4
…	…
61	1.4
62	1.2
…	…
106	1.2

life table normal mortality rate*0.65		
age	L10-13(1)M	L10-13(1)F
0	0.00056355	0.000403
1	0.00039975	0.0002964
2	0.00028925	0.00021905
…	…	…
104	0.36952305	0.30254055
105	1	1
106	1	1

Table 9: Charts prepared for Usage of VLOOKUP function

3.5.3 Making assumptions about temporary unknown parameters

For instance, when we calculate DB_{x+t} , GP_x and ${}_tCV_x^m$ are unknown. Therefore, it is necessary to assign initial values to those parameters, such as 300 to GP_x and 100,101,102,103…to ${}_tCV_x^m$, in order to effectively proceed with the pricing model. But they are not accurate values until Excel iterative procedure is finished.

3.5.4 Listing the parameters

Assuming the inputs are the same, a male aged 40 at policy issuance with ten-year premium payment period, GP_x numerator calculation comes

policy year t	t_CV_x_m	K_x+t	GPx*min(t,n	1000*1.025^	DB_x+t	q_x+t-1	l_x+t-1	1-q_x+t-1(re	v^(t-0.5)	N*O*P*R	GPx numerator
											sum(N*O*P*R)
1	16.0780831	1.6	186.510978	1000	186.510978	0.00107315	1	0.99892685	0.9877296	0.19769828	990.882513
2	43.5205528	1.4	326.394211	1025	326.394211	0.0011726	0.99892685	0.9988274	0.96363863	0.36841748	
3	96.4940822	1.4	489.591317	1050.625	489.591317	0.0012857	0.99775551	0.9987143	0.94013525	0.59045638	
…	…	…	…	…	…	…	…	…	…	…	
65	4856.99742	1.2	1398.83233	4856.54464	4856.99742	0.36952305	0.00605322	0.63047695	0.20338114	2.20956245	
66	4947.41748	1.2	1398.83233	4977.95826	4977.95826	1	0.00381641	0	0.19842063	3.76958441	
67	2488.97913	0	0	0	2488.97913	1	0	0	0.1935811	0	
…	…	…	…	…	…	…	…	…	…	…	
106	0	0	0	0	0	1	0	0	0.07389792	0	

Table 10: Calculation of GP_x numerator – Own elaboration

And the GP_x denominator calculation plus the calculated GP_x value come

policy year t	v^(t-1)	1-e_t	P*U*V	Gpx denominator
				sum(P*U*V)
1	1	0.69	0.69	8.50036839
2	0.97560976	0.95	0.92583464	
3	0.9518144	0.98	0.9306845	
...	...	...	...	GPx
65	0.20590771	0	0	116.5693612
66	0.20088557	0	0	
67	0.19598593	0	0	
...	...	...	...	
106	0.07481594	0	0	

Table 11: Calculation of GP_x– Own elaboration

By making the initial GP_x equivalent to the orange cell above, Excel iterates automatically to draw the accurate GP_x value. Of course, we could change the inputs as long as the value is valid and within the range of the insurance contract. This is a sensibility analysis of whether GP_x varies with the input variables in line with trends.

4.CALCULATION OF CASH VALUES

One main aspect in the calculation of cash values is that, to control surrender risk and improve business quality, while maintaining a smooth cash value curve throughout the policy period, a linear interpolation method is used to calculate the cash value during the initial policy years. Specifically, the cash value is determined by linearly interpolating between the cash value calculated using an interest rate of 2.5% and the minimum guaranteed cash value calculated using an interest rate of 4.5%. In the later policy years, the cash value is calculated solely based on the 2.5% interest rate. Throughout the entire policy term, the cash value is guaranteed to be no less than the minimum guaranteed cash value. In the next sections, we will present the assumptions used when calculating cash values, which are sometimes different from the ones used to calculate the premiums.

4.1 Cash values pricing assumptions

First, there are also some basic pricing assumptions to follow, including the interest rate, the mortality rates and the expense loading rate:

- mortality rates: using China Life Insurance Industry Experience Life Tables (2010-2013) Non-Pension Business I Table ×65%;
- interest rate: 2.5% and 4.5%;
- expense loading rate:

policy year	1	2	3	4	5	6+
Single payment	18%	-	-	-	-	-
Three-year payment	65%	50%	35%	-	-	-
Five-year payment	65%	50%	35%	10%	10%	-
Six-year payment	65%	50%	35%	10%	10%	10%
Ten-year payment	80%	75%	60%	10%	10%	10%

Table 12: Expense loading rates for “UpUphigh”

4.2 Notation and formulas

Again, it is appropriate to state the meanings of the symbols we are going to use:

${}_tPV_x^i$ is the policy value reserve per 1,000 of basic sum insured at the end of policy year *t* for an insured life aged *x* at policy inception, calculated at interest rate $i, i = 2{,}5\%$ or $i = 4.5\%$;

e_t^* is the expense loading rate in policy year *t*;

$CVGP_x^i$ is the premium recalculated using the policy value reserve basis at the end of the policy year using interest *i*;

${}_tCV_x^{2.5\%}$ is the cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception, calculated at interest rate $i = 2{,}5\%$;

${}_tCV_x^{min}$ is the minimum cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception, calculated at interest rate $i = 4{,}5\%$, as Determined in Accordance with the "Actuarial Regulation for General Life Insurance"

$_tCV_x$ is the cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception;

$_tCV_x^{1000}$ is the cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception.

The following formulas, like equation (7), are given in Guofu Life Insurance (2024) and are the tools to proceed to the second layer of pricing model for "UpUphigh".

4.2.1 Policy value reserve

4.2.1.1 Single payment

When $1 \le t < m$:

$$_tPV_x^i = \frac{\sum_{k=t+1}^{m} D\,B_{x+k} \times q_{x+k-1} \times l_{x+k-1} \times v_i^{k-0.5}}{l_{x+t} \times v_i^t} \tag{11}$$

When $t = m$:

$$_tPV_x^i = 1000 \times (1 + 2.5\%)^{m-1} \tag{12}$$

4.2.1.2 Regular payments

When $1 \le t < n$:

$$_tPV_x^i t = \frac{\sum_{k=t+1}^{m} D\,B_{x+k} \times q_{x+k-1} \times l_{x+k-1} \times v_i^{k-0.5} - \sum_{k=t+1}^{n} C\,VGP_x^i \times (1 - e_k^*) \times l_{x+k-1} \times v_i^{k-1}}{l_{x+t} \times v_i^t} \tag{13}$$

When $n \le t < m$:

$$_tPV_x^i = \frac{\sum_{k=t+1}^{m} D\,B_{x+k} \times q_{x+k-1} \times l_{x+k-1} \times v_i^{k-0.5}}{l_{x+t} \times v_i^t} \tag{14}$$

When $t = m$:

$$_tPV_x^i = 1000 \times (1 + 2.5\%)^{m-1} \tag{15}$$

4.2.2 Cash value

4.2.2.1 Cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception, calculated at interest rate $i = 2,5\%$

$$_tCV_x^{2.5\%} = r \times \max\{\,_tPV_x^{2.5\%}, 0\}, \tag{16}$$

where *r* is an coefficient, explained below.

4.2.2.2 Minimum cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception, calculated at interest rate $i = 4,5\%$

$$_tCV_x^{min} = r \times \max\{\,_tPV_x^{4.5\%}, 0\} \tag{17}$$

In terms of the coefficient *r*, when the policy is at a single premium, the value of *r* for each policy year is 1; when the policy is at regular premiums, then

$$r = \begin{cases} 0.8 + \dfrac{0.2 \times t}{\min(20, n)}, & t < \min(20, n) \\ 1, & t \ge \min(20, n) \end{cases} \tag{18}$$

4.2.2.3 Cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception

When $n = 1,3,5,6,10$:

$$_tCV_x = \begin{cases} _tCV_x^{2.5\%} \times \dfrac{t}{5} + \,_tCV_x^{min} \times \dfrac{5-t}{5}, & t < 5 \\ _tCV_x^{2.5\%}, & t \ge 5 \end{cases} \tag{19}$$

4.2.2.4 Cash value at the end of policy year *t* per 1,000 for an insured life aged *x* at policy inception

$$ {}_tCV_x^{1000} = \frac{{}_tCV_x}{GP_x} \times 1000 \qquad (20) $$

To illustrate the formulas above, ${}_tCV_x$ of a male aged 40 at policy issuance with ten-year payment period could be calculated immediately if the second layer of pricing model about ${}_tCV_x$ is built systematically with some further Excel work. Apart from this, ${}_tCV_x$ and ${}_tCV_x^m$ have direct correlation between each other. From the definitions we can tell that the former is calculated at the end of policy year while the latter is calculated at the midpoint of policy year. It is assumed naturally that if, within the payment period, ${}_tCV_x$ is converted to ${}_tCV_x^m$ by multiplying a fixed discount factor $v = (1+i)^{-0.5}$; otherwise, ${}_tCV_x^m$ is the average of ${}_{t-1}CV_x$ and ${}_tCV_x$.

4.3 Building the second layer

The overall reasoning of building the second layer of our pricing model includes calculating ${}_tPV_x^i$ when there is a single premium and also when there are regular premiums. In this last case, $CVGP_x^i$ should be calculated first by using the same formula used for GP_x, then we calculate PV_x^i for the 4.5% interest rate, ${}_tCV_x^{2.5\%}$ and ${}_tCV_x^{min}$, select the appropriate value of *r*, determine ${}_tCV_x$ by linear interpolation and finally convert it to ${}_tCV_x^m$.
It is noticeable that ${}_tCV_x^m$ calculated corresponds to ${}_tCV_x^m$ assumed when calculating the GP_x. Therefore, by making them equal, another closed loop is formed and after iteration, the exact ${}_tCV_x^m$ values are presented in a column plus GP_xvalue is renewed due to the fact that DB_{x+t} depends on ${}_tCV_x^m$ and GP_x depends on DB_{x+t}.
The whole procedure will be detailed in the following illustration.

1. Calculation of ${}_tPV_x^i$ when interest rate is 2.5%

										i=2.5%
	k=t+1									n=1
policy year t	DB_x+k	q_x+k-1	l_x+k-1	vi^(k-0.5)	J*K*L*M	t_PV_x_分子	l_x+t	vi_t	t_PV_x_分母	t_PV_x
1	326.394211	0.0011726	0.99892685	0.96363863	0.36841748	990.684815	0.99892685	0.97560976	0.97456278	1016.54284
2	489.591317	0.0012857	0.99775551	0.94013525	0.59045638	990.316397	0.99775551	0.9518144	0.94967806	1042.7917
3	652.788423	0.00141245	0.99647269	0.91720512	0.84270855	989.725941	0.99647269	0.92859941	0.92532396	1069.59939
…	…	…	…	…	…	…	…	…	…	…
65	4977.95826	1	0.00381641	0.19842063	3.76958441	3.76958441	0.00381641	0.20088557	0.00076666	4916.8767
66	0	1	0	0.1935811	0	0	0	0.19598593	0	4977.95826
…	…	…	…	…	…	…	…	…	…	…
106	0	1	0	0.07209553	0	0	0	0.07299116	0	0

Table 13: Calculation of ${}_tPV_x^i, n = 1, i = 2.5\%$ - Own elaboration

									i=2.5%		i=2.5%
									n>1		in all cases
policy year t	1-e_t**	P*U* (1-e_t**)	sum(P*U* (1-e_t**)	vi^(k-1)	CVGPx*U*X*L	期交分子	期交分母		t_PV_x		t_PV_x
			6.217165129								
1	0.2	0.2		0.97560976	38.8310909	31.6780037	0.97456278	1	32.5048363		32.5048363
2	0.25	0.243640695	CVGPx_2.5%	0.9518144	60.54330936	70.1406771	0.94967806	2	73.857321		73.857321
3	0.4	0.379871223	159.3785097	0.92859941	132.7290779	130.09353	0.92532396	3	140.592415		140.592415
…	…	…	…	…	…	…	…	…	…		…
65	0	0		0.20088557	0	3.76958441	0.00076666	65	4916.8767		4916.8767
66	0	0		0.19598593	0	0	0	66	4977.95826		4977.95826
…	…	…	…	…	…	…	…	…	…		…
106	0	0		0.07299116	0	0	0	106	0		0

Table 14: Calculation of ${}_tPV_x^i$, $n > 1$ and in all cases, $i = 2.5\%$ - Own elaboration

2. Calculation of ${}_tPV_x^i$ when interest rate is 4.5%

						i=4.5%
						n=1
policy year t	vi^(k-0.5)	J*K*L*AH	t_PV_x_分子	vi_t	t_PV_x_分母	t_PV_x
1	0.93610715	0.35789167	453.636819	0.956937799	0.95591086	474.55975
2	0.89579632	0.56260911	453.278927	0.915729951	0.9136746	496.105425
3	0.85722136	0.78759674	452.716318	0.876296604	0.87320564	518.45327
...	...	...	...	...	...	...
65	0.05596068	1.06313797	1.06313797	0.057205939	0.00021832	4869.59794
66	0.05355089	0	0	0.054742526	0	4977.95826
...	...	...	...	...	...	...
106	0.00920693	0	0	0.009411811	0	0

Table 15: Calculation of ${}_tPV_x^i, n = 1, i = 4.5\%$ - Own elaboration

											i=4.5%		i=4.5%
											n>1		in all cases
policy year t	v^(t-0.5)	N*O*P*Z	CVGPx分子	v^(t-1)	P*AC*(1-e_t**)	CVGPx分母	CVGPx*U*AO*L	期交分子	期交分母		t_PV_x		t_PV_x
			sum(N*O*P*Z)			sum(P*AC*(1-e_t**))							
1	0.97823198	0.19579729	453.832616	1	0.2	5.621054653	19.29457877	15.9517994	0.95591086	1	16.6875386		16.6875386
2	0.93610715	0.35789167		0.956937799	0.238977715		29.50729792	34.8884865	0.9136746	2	38.1848049		38.1848049
3	0.89579632	0.56260911		0.915729951	0.365469841		63.45077595	63.8331753	0.87320564	3	73.1021108		73.1021108
...	...	...	...	...	...	CVGPx_4.5%	...	...	...	...	...		...
65	0.05847891	0.63532342		0.059780207	0	80.73798325	0	1.06313797	0.00021832	65	4869.59794		4869.59794
66	0.05596068	1.06313797		0.057205939	0		0	0	0	66	4977.95826		4977.95826
...	...	...	...	...	...		...	...	...	...	...		...
106	0.00962125	0		0.009835343	0		0	0	0	106	0		0

Table 16: Calculation of ${}_tPV_x^i, n > 1$ in all cases, i=4.5% - Own elaboration

3. Listing the r value, ${}_tCV_x^{2.5\%}$and ${}_tCV_x^{min}$

	n=1	n>1					
	single	regular		总			
policy year t	r值	r值		r值		t_CV_x_2.5%	t_CV_x_min
1	1	0.82		0.82		26.65396578	13.6837816
2	1	0.84		0.84		62.04014964	32.0752361
3	1	0.86		0.86		120.9094772	62.8678153
...	...	...		...		...	...
65	1	1		1		4916.876701	4869.59794
66	1	1		1		4977.958257	4977.95826
...	...	...		...		...	...
106	1	1		1		0	0

Table 17: Calculation of r value and ${}_tCV_x^{2.5\%}$, ${}_tCV_x^{min}$ - Own elaboration

4. Converting to ${}_tCV_x$ and ${}_tCV_x^m$

	year end		year midpoint			
			尾			
policy year t	t_CV_x		t_CV_x_m	equal to prem part assume t_CV_x_m		
1	16.2778185		16.07808305			
2	44.0612015		43.52055281			
3	97.6928124		96.49408221			
...	...		...			
65	4916.8767		4856.99742			
66	4977.95826		4947.417479			
...	...		...			
106	0		0			

Table 18: Calculation of ${}_tCV_x$ and ${}_tCV_x^m$ - Own elaboration

The cash value calculation for the life insurance product is conducted using the prospective method, in accordance with applicable regulatory standards and actuarial principles. The methodology reasonably reflects the present value of future benefits minus future net premiums, ensuring consistency with the product design and contractual terms. Additionally, the cash value structure ensures compliance with statutory minimum cash value requirements and provides a transparent and fair surrender value to policyholders.

5. CALCULATION OF STATUTORY UPR

"Statutory unearned premium reserve" refers to the reserve set aside by insurance companies in accordance with regulatory requirements for the portion of insurance coverage that has not yet been fulfilled. It reflects the portion of premiums corresponding to the future coverage period that has not yet been "earned," and is a statutory liability that ensures the company has sufficient reserves for the remaining coverage period.

5.1 UPR pricing assumptions

Similar to Chapters 3 and 4, we start presenting the pricing assumptions to follow, including mortality rate, interest rate and calculation method.

- mortality rates: using China Life Insurance Industry Experience Life Tables (2010-2013) Non-Pension Business I Table;
- interest rate: 2.5%;
- expense loading rate: not considered because it is the net reserve;
- calculation method: one-year fully modified method (introduced in Chapter 2).

5.2 Notation and formulas

The new notation used in this chapter is as follows:

$_{t}V_{x}$ is the statutory unearned premium reserve at the end of policy year *t* per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

$_{t}TV_{x}$ is the modified reserve at the end of policy year *t* per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

$_{t}DV_{x}$ is the premium deficiency reserve at the end of policy year *t* per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

DB^{*}_{x+t} is the death benefit at the end of policy year *t* per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

$^{1000}_{t}CV^{m}_{x}$ is the cash value at the middle of policy year *t* per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

q^{*}_{x} is the probability that a person aged *x* dies before reaching age $x+1$;

l^{*}_{x+t} is the number of in-force policies at the end of policy year *t* for an insured life aged *x* at policy inception;

P^{NL}_{x} is the single net premium or level net premium per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

α_{x} is the modified first-year net premium per 1,000 of single or annual premium for an insured life aged *x* at policy inception;

β_{x} is the modified renewal net premium per 1,000 of single or annual premium for an insured life aged *x* at policy inception.

The following formulas are also given in the Guofu Life Insurance (2024) and are the tools to proceed to the third layer of pricing model for "UpUphigh". The statutory UPR is defined

$$_{t}V_{x} = max\{\,_{t}TV_{x} + \,_{t}DV_{x},\ _{t}CV^{1000}_{x}\} \tag{21}$$

5.2.1 Modified Reserve

5.2.1.1 Modified net premium

The single net premium or level net premium per 1,000 of single or annual premium for an insured life aged x at policy inception is

$$P_x^{NL} = \frac{\sum_{t=1}^{m} D\,B_{x+t}^* \times q_{x+t-1}^* \times l_{x+t-1}^* \times v^{t-0.5}}{\sum_{t=1}^{n} l_{x+t-1}^* \times v^{t-1}} \tag{22}$$

where:

$$DB_{x+t}^* = \begin{cases} \max(1000 \times \min(t,n) \times K_{x+t},\ {}_t^{1000}CV_x^m), & x+t \le 18\ \vee t \le n \\ \max(1000 \times \min(t,n) \times K_{x+t},\ {}_t^{1000}CV_x^m,\ SA_x^{1000} \times 1.025^{t-1}), & x+t > 18\ \wedge\ t > n \end{cases} \tag{23}$$

The modified net premium per 1,000 units of single or annual premium for an insured aged x at policy inception is:

Modified First-Year Net Premium

Single payment ($n = 1$): $\alpha_x = P_x^{NL}$ (24)

Regular payment ($n \ge 2$): $\alpha_x = DB_{x+1}^* \times q_x^* \times v^{0.5} \times l_x^*$ (25)

Modified Renewal Net Premium

Single payment ($n = 1$): $\beta_x = 0$ (26)

Regular payment ($n \ge 2$): $\beta_x = P_x^{NL} + \frac{P_x^{NL} - \alpha_x}{\sum_{t=2}^{n} l_{x+t-1}^* \times v^{t-1}} \times l_x^*$ (27)

5.2.1.2 Modified reserve

The modified reserve at the end of policy year t per 1,000 units of single or annual premium for an insured aged x at policy inception is:

Single payment ($n = 1$ and $1 \le t < m$)

$${}_tTV_x = \frac{\sum_{k=t+1}^{m} D\,B_{x+k}^* \times q_{x+k-1}^* \times l_{x+k-1}^* \times v^{k-0.5}}{l_{x+t}^* \times v^t} \tag{28}$$

When $t = m$ ${}_tTV_x = 0$

Regular payment ($n \ge 2$ and $1 \le t < n$)

$${}_tTV_x = \frac{\sum_{k=t+1}^{m} D\,B_{x+k}^* \times q_{x+k-1}^* \times l_{x+k-1}^* \times v^{k-0.5} - \sum_{k=t+1}^{n} \beta_x \times l_{x+k-1}^* \times v^{k-1}}{l_{x+t}^* \times v^t} \tag{29}$$

Regular payment ($n \ge 2$ and $n \le t < m$)

$${}_tTV_x = \frac{\sum_{k=t+1}^{m} D\,B_{x+k}^* \times q_{x+k-1}^* \times l_{x+k-1}^* \times v^{k-0.5}}{l_{x+t}^* \times v^t} \tag{30}$$

When $t = m$ ${}_tTV_x = 0$

5.2.2 Premium Deficiency Reserve

The premium deficiency reserve at the end of policy year t per 1,000 units of single or annual premium for an insured aged x at policy inception is:

Single payment ($n = 1$): $DV_x = 0$ (31)

Regular payment ($n \ge 2$ and $1 \le t < n$)

$${}_tDV_x = \frac{\sum_{k=t+1}^{n} max\,(\beta_x - 1000{,}0) \times l_{x+k-1}^* \times v^{k-1}}{l_{x+t}^* \times v^t} \tag{32}$$

When $n \le t \le m$ ${}_tDV_x = 0.$

5.3 Building the third layer

According to formulas above, ${}_tV_x$ of a male aged 40 at policy issuance with ten-year payment period, for example, could be calculated immediately if the third layer of pricing model about ${}_tV_x$ is built systematically with some further Excel work. To ensure this pricing model layer is built efficiently and accurately, it is necessary to organise the calculation steps bearing in mind that these equations have more parameters and are more complex.

Here we need to 'think backward', as ${}_tV_x$ mainly depends on ${}_tTV_x$ and ${}_tDV_x$, which are independently calculated using their own piecewise functions. However, there is a totally new parameter β_x in the numerator in the formulas for ${}_tTV_x$ and ${}_tDV_x$, see equations (29) and (32). And β_x depends on α_x (partially depends on P_x^{NL}) and P_x^{NL}; thus finding P_x^{NL} (Single Net Premium or Level Net Premium per 1,000 Units) is the first step of building this third layer. Similar to what has been done in Chapters 3 and 4, the whole procedure will be detailed in the following illustration.

1. Calculation of P_x^{NL} and $\alpha_x,\ \beta_x$

										原始mortality rate	assume lx*=1		
policy year t	K_x+t	1000*min(t,n)*K_x+t	1000_t_CV_m	SA_x_1000	1.025^(t-1)	K*L	DB_x+t*	q_x+t-1*	l_x+t-1*	1-q_x+t-1*(refer to O	v^(t-0.5)	N*O*P*R	Px_nl numerator
				8578.58									sum(N*O*P*R)
1	1.6	1600	137.9265609		1	8578.58	1600	0.001651	1	0.998349	0.98773	2.6091865	8512.21007
2	1.4	2800	373.3420329		1.025	8793.045	2800	0.001804	0.99835	0.998196	0.963639	4.8594952	
3	1.4	4200	827.7865431		1.050625	9012.871	4200	0.001978	0.99655	0.998022	0.940135	7.7833064	
...	...	...	...		...	...	...	...	...	...	...	...	
65	1.2	12000	41666.16		4.856544641	41662.26	41666.16	0.568497	0.0002	0.431503	0.203381	0.977755	
66	1.2	12000	42441.835		4.977958257	42703.81	42703.8131	1	8.8E-05	0	0.198421	0.7420702	
...	...	...	...		...	...	...	...	...	...	...	...	
106	0	0	0		0	0	0	0	0	1	0.073898	0	

Table 19: Calculation of P_x^{NL} numerator - Own elaboration

				modi 1st net prem	n>=2	special			
				α_x	from 2 to n	from2 to n			
policy year t	v^(t-1)	P*U	Px_nl 分母	2.609186503	sum(P*Z)	v^(t-1)	P*Z		
			sum(P*U)		7.888463879				
1	1	1	8.888463879			0	0	Px_nl	957.669423
2	0.97560976	0.973999024		modi renew net prem		0.97560976	0.97399902		
3	0.9518144	0.948528712		**β**_x		0.9518144	0.94852871		
...	...	...	Px_nl	1078.739919		...	...	**α**_x	2.6091865
65	0	0	957.6694226			0	0		
66	0	0				0	0	**β**_x	1078.73992
...	...	...				...	...		
106	0	0				0	0		

Table 20: Calculation of P_x^{NL} denominator, P_x^{NL} and α_x, β_x - Own elaboration

2. Calculation of modified reserve (${}_tTV_x$)

						n=1			n=1	n=1
						single pay			single pay	single pay
	k=t+1									
policy year t	DB_x+k*	q_x+k-1*	l_x+k-1*	v^(k-0.5)	H*I*J*K	t_TV_x 分子	l_x+t*	v^t	t_TV_x 分母	t_TV_x
1	2800	0.001804	0.998349	0.96363863	4.8594952	8509.6009	0.99835	0.97561	0.973999	8736.765305
2	4200	0.001978	0.996548	0.94013525	7.7833064	8504.7414	0.99655	0.95181	0.9485287	8966.245595
3	5600	0.002173	0.9945768	0.91720512	11.100756	8496.9581	0.99458	0.9286	0.9235634	9200.188904
...	...	...	...	...	...	...	...	...	...	...
65	42703.8	1	8.758E-05	0.19842063	0.7420702	0.7420702	8.8E-05	0.20089	1.759E-05	42179.82013
66	0	0	0	0.1935811	0	0	0	0.19599	0	0
...	...	...	...	...	...	...	...	...	...	...
106	0	0	0	0.07209553	0	0	0	0.07299	0	0

Table 21: Calculation of ${}_tTV_x$ when $n = 1$ - Own elaboration

							n>1 regular pay
policy year t	l_x+k-1*	v^(k-1)	β_x*S*T	期交分子	期交分母		t_TV_x
1	0.998349	0.97560976	1050.691628	-1.81899E-12	0.973999024	1	-1.868E-12
2	0.99654798	0.9518144	1023.215786	1045.832133	0.948528712	2	1102.58353
3	0.99457681	0.92859941	996.2847466	2061.264613	0.923563437	3	2231.86035
...	...	...	...	...	...	...	...
65	0	0.20088557	0	0.742070207	1.7593E-05	65	42179.8201
66	0	0.19598593	0	0	0	66	0
...	...	...	...	...	...	...	...
106	0	0.07299116	0	0	0	106	0

Table 22: Calculation of ${}_tTV_x$ when $n > 1$ - Own elaboration

Then combine two columns of ${}_tTV_x$ with condition of payment period $n = 1$ and $n > 1$ separately into a chart, which could be easily looked up by using VLOOKUP function so that a new column of ${}_tTV_x$ independent of payment period is listed:

		moving to be in a chart		
	regular	single		总
policy year t	t_TV_x	t_TV_x		t_TV_x
1	-1.868E-12	8736.76531		-1.868E-12
2	1102.58353	8966.24559		1102.58353
3	2231.86035	9200.1889		2231.86035
...	...	...		...
65	42179.8201	42179.8201		42179.8201
66	0	0		0
...	...	...		...
106	0	0		0

Table 23: Calculation of ${}_tTV_x$ when n in all cases - Own elaboration

3. Calculation of Premium Deficiency Reserve (${}_tDV_x$)

							moving to be in a chart		
						regular	single		总
policy year t	max(β_x-1000,0)	max(β_x-1000,0)*S*T	期交分子	t_DV_x分母		t_DV_x	t_DV_x		t_DV_x
	78.73991876								
1		76.69260405	621.137	0.97399902	1	637.7183	0		637.7183
2		74.68707375	544.4444	0.94852871	2	573.98832	0		573.98832
3		72.72130997	469.75733	0.92356344	3	508.63569	0		508.63569
...		...	...	...	...	...	...		...
65		0	0	1.7593E-05	65	0	0		0
66		0	0	0	66	0	0		0
...		...	...	...	...	...	...		...
106		0	0	0	106	0	0		0

Table 24: Calculation of ${}_tDV_x$ when n in all cases - Own elaboration

${}_tCV_x^{1000}$ can be easily calculated from ${}_tCV_x$. Since we have obtained columns of ${}_tTV_x$ and ${}_tDV_x$, now Statutory Unearned Premium Reserve ${}_tV_x$ can be calculated by using formula ${}_tV_x = max\{{}_tTV_x + {}_tDV_x, {}_tCV_x^{1000}\}$:

			Statutory Unearned Premium Reserve (UPR)		
	rounded				rounded
policy year t	t_CV_x_1000		t_V_x		t_V_x
1	139.64		637.718303		637.72
2	377.98		1676.57185		1676.57
3	838.07		2740.49604		2740.5
...	...		...		...
65	42179.84		42179.84		42179.84
66	42703.83		42703.83		42703.83
...	...		...		...
106	0		0		0

Table 25: Calculation of ${}_tV_x$ and ${}_tV_x$ after rounded - Own elaboration

5.4 Data accuracy validation

The pricing model built for "UpUphigh" has been already comprehensive with information of premiums, cash values and reserves. Nevertheless, the accuracy of critical data has not been verified yet. Obviously, it is impossible to check all, one by one, because it would be massive with three input variables changing together within their ranges. Consequently, some codes in VBA had to be written to help sort out all critical data into a new sheet in a systematic way, so that a comparison with data of the company's internal pricing model becomes possible and efficient. In the next section a short explanation of VBA coding and a presentation of the results after computation is provided.

5.4.1 Summary sheet of premiums

First, it was necessary to write some VBA coding to help organize critical data of GP_x with the assumption of fixed 1000¥GP_x rather than fixed sum assured 1000¥. The function of this VBA coding includes: (i) read configuration data from the "output" sheet (including start age, end age, gender, etc.); (ii) modify parameters one by one in the "premium&cf" sheet to trigger premium calculation; (iii) retrieve corresponding outputs (such as GP, SA, Avg_Loading, etc.); (iv) store the results into the gp array; (v) finally, output the array to the "gp" sheet, starting from column B3.

Results after computation are listed in a new sheet called "gp":

n-to-106-sex-age							
tag	pt	bt	sex	age	gp	sa	Avg_Loading
1-to 106-1-0	1	106	1	0	1000	951.21	0.06
1-to 106-1-1	1	106	1	1	1000	951.18	0.06
...	...	...	...	...	...	...	...
1-to 106-1-70	1	106	1	70	1000	909.18	0.06
1-to 106-2-0	1	106	2	0	1000	951.34	0.06
...	...	...	...	...	...	...	...
1-to 106-2-70	1	106	2	70	1000	928.98	0.06
3-to 106-1-0	3	106	1	0	1000	2795.71	0.05622265
...	...	...	...	...	...	...	...
3-to 106-1-70	3	106	1	70	1000	2656.34	0.05711635
3-to 106-2-0	3	106	2	0	1000	2796.16	0.05621578
...	...	...	...	...	...	...	...
10-to 106-2-64	10	106	2	64	1000	8528.78	0.04766501
10-to 106-2-65	10	106	2	65	1000	8508.43	0.04783044

Table 26: New sheet "gp" generated by VBA code - Own elaboration

5.4.2 Summary sheet of cash values and reserves

Second, it was necessary to write some VBA coding to help organize critical data of cash value series and practical death benefits with the assumption of fixed 1000¥ GP_x rather than fixed sum assured 1000¥ as well. The function of VBA coding includes: (i) read configuration data from the "output" sheet (including start age, end age, gender, etc.); (ii) modify parameters one by one in the "CVV Cal" sheet to trigger premium and reserve calculation; (iii) retrieve corresponding outputs (such as cv, mdnp, rsv_e, pdr,etc.); (iv) store the results into the cv array; (v) finally, output the array to the "cv" sheet, starting from column B3.

Results after computation are listed in a new sheet called “cv”:

much more rows(49958 in total)due to varying with py as we													
n-to-106-sex-age													
tag	pt	bt	sex	age	py	gp	cv	cv_b	mdnp	rsv_e	rsv_b	pdr	db
1-to 106-1-0	1	106	1	0	1	1000	363.71		940.06	963.52		0	1000
1-to 106-1-0	1	106	1	0	2	1000	528.86	363.71	0	987.59	963.52	0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...
1-to 106-1-0	1	106	1	0	106	1000	12714	12557.94	0	12713.95	12558	0	12714
1-to 106-1-1	1	106	1	1	1	1000	366.82		940.08	963.55		0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...
1-to 106-1-1	1	106	1	1	105	1000	12403.5	12251.35	0	12403.54	12251.4	0	12403.54
1-to 106-1-2	1	106	1	2	1	1000	370.07		940.09	963.57		0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...
10-to 106-2-65	10	106	2	65	41	1000	22845.7	22565.36	0	22845.69	22565.4	0	22845.69

Table 27: New sheet “cv” generated by VBA code - Own elaboration

5.4.3 Calculation of difference in value

With the two new sheets of critical data, “gp” and “cv”, comparing our results with the standard value set in the internal pricing model of “UpUphigh” becomes much more straightforward.

n-to-106-sex-age	GP					
tag	sa（me)	Avg_Loading(me)	sa(标）	Avg_Loading（标）	D_sa	D_avg_loading
1-to 106-1-0	951.21	0.06	951.21	0.06	0	0
1-to 106-1-1	951.18	0.06	951.18	0.06	0	0
...	...	...	...	...	...	...
1-to 106-1-70	909.18	0.06	909.18	0.06	0	0
1-to 106-2-0	951.34	0.06	951.34	0.06	0	0
...	...	...	...	...	...	...
1-to 106-2-70	928.98	0.06	928.98	0.06	0	0
3-to 106-1-0	2795.71	0.056222648	2795.71	0.056222648	0	0
...	...	...	...	...	...	...
3-to 106-1-70	2656.34	0.05711635	2656.34	0.05711635	0	0
3-to 106-2-0	2796.16	0.056215779	2796.16	0.056215779	0	0
...	...	...	...	...	...	...
10-to 106-2-64	8528.78	0.047665005	8528.78	0.047665005	0	0
10-to 106-2-65	8508.43	0.047830438	8508.43	0.047830438	0	0

Table 28: Accuracy test of Critical data within GP - Own elaboration

n-to-106-sex-age	CV														
tag	py	cv(me)	cv_b(me)	mdnp(me)	rsv_e(me)	rsv_b(me)	pdr(me)	db(me)	cv(标）	cv_b（标）	mdnp（标）	rsv_e（标）	rsv_b（标）	pdr（标）	db（标）
1-to 106-1-0	1	363.71		940.06	963.52		0	1000	363.71		940.06	963.52	0	0	1000
1-to 106-1-0	2	528.86	363.71	0	987.59	963.52	0	1000	528.86	363.71	0	987.59	963.52	0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1-to 106-1-0	106	12713.95	12557.9	0	12713.95	12558	0	12714	12714	12557.94	0	12713.95	12558	0	12714
1-to 106-1-1	1	366.82		940.08	963.55		0	1000	366.82		940.08	963.55	0	0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
1-to 106-1-1	105	12403.54	12251.4	0	12403.54	12251.35	0	12403.54	12403.5	12251.35	0	12403.54	12251.35	0	12403.54
1-to 106-1-2	1	370.07		940.09	963.57		0	1000	370.07		940.09	963.57	0	0	1000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10-to 106-2-65	41	22845.69	22565.4	0	22845.69	22565.36	0	22845.69	22845.7	22565.36	0	22845.69	22565.36	0	22845.69

Table 29: Accuracy test of Critical data within CV part a - Own elaboration

n-to-106-sex-age	CV							
tag	py	D_cv	D_cv_b	D_mdnp	D_rsv_e	D_rsv_b	D_pdr	D_db
1-to 106-1-0	1	0	0	0	0	0	0	0
1-to 106-1-0	2	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...
1-to 106-1-0	106	0	0	0	0	0	0	0
1-to 106-1-1	1	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...
1-to 106-1-1	105	0	0	0	0	0	0	0
1-to 106-1-2	1	0	0	0	0	0	0	0
...	...	...	...	...	...	...	...	...
10-to 106-2-65	41	0	0	0	0	0	0	0

Table 30: Accuracy test of Critical data within CV part b - Own elaboration

It is shown in these charts that the pricing model I built for “UpUphigh” is completely corresponding to calculation formulas and liability conditions in the official actuarial report. That’ why the difference of each critical data category between my pricing model and internal pricing model is all zero. I think that all these data presented in these charts are more persuasive than any words, which verifies the accuracy of my pricing model perfectly.

6. PROFIT TEST

Profit Testing is the process of calculating and evaluating the profitability of an insurance product by simulating the entire life cycle of a contract, namely by modelling the annual cash inflows and outflows based on certain assumptions (mortality rates, expense ratios, surrender rates, investment yields, etc.). The function of profit test is also to test insurance products for compliance with regulatory requirements, help companies determine whether a product is attractive and competitive in the marketplace, verify whether the insurance product is robust and sustainable across a range of risks and provide an actuarial basis for pricing and reserve assessment; for a complete discussion, see Dickson *et al.* (2019), for instance,

Basically, the steps to perform a profit test are:

1. Determination of underlying assumptions: mortality rates, surrender rates, expense ratios, investment yields, discount rates, taxation rules;
2. Simulation of cash flows: this can be done on a yearly basis for each policy year or a monthly basis for each policy month. The most two typical cash inflows are premium income and investment income, while cash outflows are diversified, like claim expenses, surrender payments, expenses, changes in reserves, etc.; profit after tax is equivalent to cash inflows minus cash outflows minus income tax;
3. Indicators: common profit test indicators are IRR (internal rate of return), NPV (net present value) of cash flows, profit margin (profit as a percentage of premium income), etc. Different life insurance companies may use different indicators or even some unique indicators due to their own preference, it is not compulsory to use the common indicators above;
4. Stress testing: to test the sensitivity of insurance products under different assumptions such as increase in mortality rates, decrease in investment yields, increase in surrender rates, expense overruns, etc.

6.1 Profit test *versus* pricing

During my internship period in the Guofu life insurance company, I also learned how to build Excel templates of profit test, which is different from the layers of pricing seen in the previous chapters. The reasons for this are:

- Each parameter in the template is calculated per policy month rather policy year, giving great detail (and huge spreadsheets)
- Listing all possible cash flows makes this test closer to practical situations.
- The number of parameters we can use in the layers of the pricing model is quite limited; in profit testing a larger number of new parameters need to be calculated such us all types of potential risks, different category of cash flows, profit test indicators and so on.

In the next sections the reasoning and results backing the Excel templates to perform the profit test for “UpUphigh” are described.

6.2 Profit test assumptions

- Mortality rates: China Life Insurance Industry Experience Life Tables (2010-2013) Non-Pension Business I Table ×65%;
- Surrender rates:

Policy year	1	2	3	4	5-9	10+
Single payment	3%	3%	3%	3%	3%	3%
Regular payment	15%	6%	5%	5%	5%	5%

Table 31: Surrender rate assumption - Profit test

Noting: The surrender rate after the premium payment period is 3%.

- Expected investment yields: 4.5%;
- Risk discount rate: 11%;
- Total bancassurance expenses;

Policy year	1	2	3	4	5	6+
Single payment	6.00%	-	-	-	-	-
Three-year payment	15.00%	1.00%	0.50%	-	-	-
Five-year payment	23.50%	1.00%	0.50%	0.50%	0.50%	-
Six-year payment	25.00%	2.00%	1.00%	0.50%	0.50%	0.50%
Ten-year payment	31.00%	5.00%	2.00%	1.00%	1.00%	0.50%

Table 32: Total bancassurance expense assumption - Profit test

The total bancassurance expenses mentioned above include the following four items:

1. Commission paid to the bank selling the policy: partner bank commission (refers to the total amount paid to the bank).
2. Remuneration incentives for bancassurance agents: including basic allowance, service allowance, managerial allowance, post allowance, year-end bonuses, employee benefits, and incentive payments under business plans.
3. Training and customer service expenses: Expenses incurred during bancassurance channel operations for training and customer service, including costs related to business training such as accommodation, meals, miscellaneous office expenses, venue rental, transportation, external lecturer fees, and other costs associated with providing services to customers.
4. Allocated fixed expenses: (i) operating and administrative expenses directly attributable to the bancassurance business line, including salaries and benefits of back-office staff, office-related expenses (e.g., rent, renovation, utilities), system development costs, entertainment expenses, travel expenses, printing costs, advertising and promotional expenses, policy issuance fees, mailing fees, etc.; (ii) a proportion of operating and administrative expenses allocated from supporting departments to the bancassurance business line, including staff salaries and benefits, office expenses (e.g., rent, renovation, utilities), system development costs, entertainment expenses, travel expenses, and depreciation and amortization of company assets.

The specific rates for each expense item are as follows:

1. The upper limit of the commission rate paid to the bank is in Table 33.

payment period	business share	commission cap		
		1st year	2nd year	3rd year
Single payment	0.2%	3.0%	-	-
Three-year payment	49.0%	9.0%	-	-
Five-year payment	50.0%	14.0%	-	-
Six-year payment	0.5%	14.8%	-	-
Ten-year payment	0.3%	18.0%	-	-

Table 33: Commission cap - Profit test

2. and 3. The combined expense ratio of bancassurance officers’ remuneration incentives and training and customer service fees is in Table 34.

Payment period	Expense ratio					
	1	2	3	4	5	6+
Single payment	2.70%	-	-	-	-	-
Three-year payment	5.10%	0.50%	0.00%	-	-	-
Five-year payment	8.00%	0.50%	0.00%	0.25%	0.25%	-
Six-year payment	8.40%	1.50%	0.50%	0.25%	0.25%	0.25%
Ten-year payment	10.00%	4.50%	1.50%	0.75%	0.75%	0.25%

Table 34: Combined expense ratio - Profit test

4. The allocated fixed expense ratio is in Table 35.

Payment period	Expense ratio					
	1st	2	3	4	5	6
Single payment	0.30%	-	-	-	-	-
Three-year payment	0.90%	0.5%	0.5%	-	-	-
Five-year payment	1.50%	0.5%	0.5%	0.25%	0.25%	-
Six-year payment	1.80%	0.5%	0.5%	0.25%	0.25%	0.25%
Ten-year payment	3.00%	0.5%	0.5%	0.25%	0.25%	0.25%

Table 35：Allocated fixed expense ratio - Profit test

If there is a surplus in the commissions paid to banks, it can be used for bancassurance officers' remuneration incentives, training and customer service expenses, and the allocation of fixed expenses; if there is a surplus in the bancassurance officers' remuneration incentives, training, and customer service expenses, it can be used for the allocation of fixed expenses.

Finally, four additional assumptions need to be set.

- Annual inflation rate: 2%.
- Insurance protection fund regulatory fee, see Table 36.

Item	Insurance Protection Fund	Regulatory Fee
Percentage of Premium	0.3%	0.04%

Table 36: Ratio of insurance Protection fund & Regulatory fee

- Income tax rate: 25%;

- Average premium: this assumption is required because in profit testing we make direct use of the relationship between the sum assured and the average premium. Therefore: Single/three-year/five-year/six-year payment period: the average premium is 20 000¥; Ten-year payment period: 10000¥.

6.3 Listing all cash flows

The first step is to list all cash inflows and outflows of each category. In terms of cash inflows, there is only one category: premium income. In terms of cash outflows, there are commission, acquirement expense, maintenance expense, Circ (refers to insurance protection fund) charge, death benefit and surrender payment.

The timing of cash flows is consistently assumed. Premium income, commission and Circ charge count at the beginning of each policy year. Acquirement expense counts at the beginning of each policy month only for the first year while maintenance expense counts at the beginning of each policy month for subsequent years. Death benefit counts at the midpoint of each policy month for all policy years within insurance period. Surrender payment counts at the end of each policy year within insurance period.

As a result of different timing of cash flows, different discount factors are assigned to each category to calculate the present value of all possible cash flows at 0 and at t.

Similar to what has been done in the previous chapters, the whole procedure will be detailed in an illustration. We will assume the input variables are the same: a 40 years old male policyholder with payment period of 10 years. Results are in Tables 37 and 38.

Num of policy months	policy year	policy month	age	Prem	Commissior	Acq expense	Maintain exp	Circ charge	Surrender payment	Death Benefit
0										
1	1	1	40	10000	3100	1008.33333	0	34	0	1.431570936
2	1	2	40	0	0	8.34634967	0	0	0	1.431442849
3	1	3	40	0	0	8.35938634	0	0	0	1.431314773
…	…	…	…	…	…	…	…	…	…	…
12	1	12	40	0	0	8.47763649	0	0	209.235218	1.430162607
13	2	1	41	8490.8782	424.54391	0	304.3979844	28.868986	0	2.324410388
…	…	…	…	…	…	…	…	…	…	…

Table 37: Cash inflows and outflows

Num of policy months	policy year	policy month	age	Cash Outgo BOM	Cash Outgo MOM	Cash Outgo EOM	Cash In BOM	DiscRate	DiscFactor BOM	DiscFactor MOM	PV CF at 0	PVCF at t
0									1		-16046.605	-16046.6
1	1	1	40	4142.3333	1.4315709	0	10000	0.0036748	0.99633865	0.99816764	-10227.815	-10266.32
2	1	2	40	8.3463497	1.4314428	0	0	0.0036748	0.9926907	0.994513	-10275.211	-10314.82
3	1	3	40	8.3593863	1.4313148	0	0	0.0036748	0.9890561	0.99087173	-10322.795	-10363.51
…	…	…	…	…	…	…	…	…	…	…	…	…
12	1	12	40	8.4776365	1.4301626	209.235218	0	0.0036748	0.9569378	0.95869447	-10968.82	-12965.83
13	2	1	41	757.81088	2.3244104	0	8490.878225	0.0036748	0.95343411	0.95518435	-3249.9719	-3842.045
…	…	…	…	…	…	…	…	…	…	…	…	…

Table 38: Present value of all cash flows at 0 and at t

6.4 Profit test indicators

The calculation results presented in Table 38 above contains an essential profit test indicator: PVCF at *t*. however, only one indicator is not enough to reflect everything about this insurance product's expected performance. So, liability at *t* is another important profit test indicator, which is the sum of PVCF at *t* plus the risk margin plus the surplus margin, see China Association of Actuaries（2016）. Therefore, extra columns related to calculating risk margin and surplus margin are listed to find the value of liability at time *t*.

Another critical profit test indicator is the minimum capital requirement for life insurance business, which is the sum of total risks. In terms of calculating this part, we have to list all possible types of risks, to input the correlation matrix between different types of risks and then use Excel to do some matrix calculations in order to calculate the final MC values at each policy month. The measurement of minimum capital must reflect the diversification effects among various types of risks.

The insurance company shall measure the minimum capital requirements for insurable risks, market risks, and credit risks in accordance with the relevant solvency regulatory rules. The calculation shall consider the effects of risk diversification and the loss-absorbing capacity of specific types of insurance contracts. The formula is as follows:

$$MC^* = \sqrt{MC_{向量} \times M_{相关系数} \times MC_{向量}^T} - LA, \quad (33)$$

where:

MC* is the minimum capital requirement for the overall capitalizable risks;

$MC_{向量}$ is the row vector (1×4) of minimum capital requirements for insurance risk in life business, insurance risk in non-life business, market risk, and credit risk.

$M_{相关系数}$ is the correlation coefficient matrix (4×4).

LA is the loss absorption adjustment for certain categories of insurance contracts. For "UpUphigh", $LA = 0.1\sqrt{MC_{向量} \times M_{相关系数} \times MC_{向量}^T}$.

Due to the fact that "UpUphigh" is a life insurance product, we need to consider that $MC_{向量}$ is composed of $MC_{寿险保险}$, $MC_{非寿险保险}$, $MC_{市场}$ and $MC_{信用}$, where $MC_{寿险保险}$ refers to the minimum capital required for insurance risk in life business, $MC_{非寿险保险}$ refers to the minimum capital required for insurance risk in non-life business, $MC_{市场}$ refers to the minimum capital required for market risk, and $MC_{信用}$ refers to the minimum capital required for credit risk. Table 39 displays the correlation matrix $M_{相关系数}$.

Correlation coefficients	$MC_{寿险保险}$	$MC_{非寿险保险}$	$MC_{市场}$	$MC_{信用}$
$MC_{寿险保险}$	1.00	0.20	0.30	0.15
$MC_{非寿险保险}$	0.20	1.00	0.10	0.10
$MC_{市场}$	0.30	0.10	1.00	0.35
$MC_{信用}$	0.15	0.10	0.35	1.00

Table 39: Correlation coefficients between risks under Total risk

In the next section we will calculate in a very detailed manner the minimum capital for life insurance risk, which is the most important one. For the other three risks, $MC_{非寿险保险}$, $MC_{市场}$ and $MC_{信用}$, we only present the results, since they are calculated in a straightforward way and this report has a limited length.

6.4.1 Measuring $MC_{寿险保险}$, the minimum capital for life insurance risk

The insurance risk of life insurance business includes claims risk, expense risk, and surrender risk. Especially, claims risk is a big category, including mortality risk, mortality catastrophe risk, longevity risk (not relevant here), morbidity risk, medical and health claims ratio risk, and other claims occurrence risks. Also important is the surrender risk.

6.4.1.1 Measuring the minimum capital for claims risk

Mortality risk refers to the risk that the actual mortality rate is higher than expected, resulting in unexpected losses for the insurance company. Catastrophic mortality risk refers to the risk that a catastrophic event (such as a pandemic, earthquake, tsunami, etc.) causes a sharp increase in the mortality rate over a short period, resulting in unexpected losses for the insurance company. Longevity risk refers to the risk that actual improvements in mortality experience exceed expectations, leading to unexpected losses for the insurance company. Morbidity risk refers to the risk that actual incidence of disease exceeds expectations, leading to unexpected losses for the insurance company. Morbidity risk includes morbidity incidence risk and morbidity trend risk. Morbidity incidence risk is the risk that the actual incidence rate of disease is higher than expected, resulting in unexpected losses. Morbidity trend risk is the risk that the actual trend of disease deterioration exceeds expectations, causing the insurance company to incur unexpected losses. Medical and health claim loss ratio risk refers to the risk that the actual experience of medical or health benefit costs (including claims related to accident medical, nursing care, disability income, etc.) exceeds expectations, resulting in unexpected losses for the insurance company. The formula for calculating the minimum capital requirement for claims risk in life insurance business is:

$$MC_{损失发生} = \sqrt{MC_{向量} \times M_{相关系数} \times MC_{向量}^{T}}, \quad (34)$$

where:

$MC_{损失发生}$ is the Minimum Capital for the claims risk;

$MC_{向量}$ is a row vector (6×1) composed of $MC_{死亡}$ (minimum capital requirement for mortality rate risk), $MC_{死亡巨灾}$ (minimum capital requirement for catastrophe mortality risk)，$MC_{长寿}$ (minimum capital requirement for longevity risk)，$MC_{疾病}$ (minimum capital requirement for morbidity risk)，$MC_{医健}$ (minimum capital requirement for medical and health claims loss ratio risk)， and $MC_{其他}$ (minimum capital requirement for other claims occurrence risks);

$M_{相关系数}$ is the correlation coefficient matrix (6×6).

Table 40 displays the correlation matrix $M_{相关系数}$.

	$MC_{死亡}$	$MC_{死亡巨灾}$	$MC_{长寿}$	$MC_{疾病}$	$MC_{医健}$	$MC_{其他}$
$MC_{死亡}$	1.00	0.25	-0.25	0.25	0.25	0.25
$MC_{死亡巨灾}$	0.25	1.00	0.00	0.25	0.25	0.25
$MC_{长寿}$	-0.25	0.00	1.00	0.00	0.00	0.00
$MC_{疾病}$	0.25	0.25	0.00	1.00	0.25	0.25
$MC_{医健}$	0.25	0.25	0.00	0.25	1.00	0.25
$MC_{其他}$	0.25	0.25	0.00	0.25	0.25	1.00

Table 40: Correlation coefficients of risks under claims risk

As already said, apart from claims risk, there are other two components of insurance risk in life business, the expense risk and the surrender risk, the most significant of the two. Expense risk refers to the risk that the actual level of policy maintenance expenses exceeds expectations, causing the insurance company to incur unexpected losses. Surrender risk refers to the risk that the actual experience of policy surrenders deviates from expectations, causing the insurance company to incur unexpected losses.

6.4.1.2 Measuring the minimum capital for surrender risk

Surrender risk includes surrender rate risk and mass lapse risk. Surrender rate risk refers to the risk that the actual experience of surrender rates deviates from expectations, causing the insurance company to suffer unexpected losses. Mass lapse risk refers to the risk that due to special events (such as financial crises, reputational crises, etc.), the surrender rate sharply increases in a short period, causing the insurance company to suffer unexpected losses.

The calculation formula for the minimum capital requirement for lapse risk is:

$$MC_{退保} = \max\left(MC_{退保率}，\ MC_{大规模退保}\right), \qquad (35)$$

where:

$MC_{退保}$ is the minimum capital requirement for lapse risk of the insurance company.

$MC_{退保率}$ is the minimum capital requirement for surrender rate risk of the company.

$MC_{大规模退保}$ is the minimum capital requirement for mass lapse risk of the company.

6.4.1.3 Minimum capital for life insurance risk

Finally, the calculation formula for the insurance risk minimum capital requirement of the life insurance business is

$$MC_{寿险保险} = \sqrt{MC_{向量} \times M_{相关系数} \times MC^{T}_{向量}}, \qquad (29)$$

where

$MC_{向量}$ is a row vector (1×3) composed of $(MC_{损失发生}, MC_{费用}, MC_{退保})$;

$MC_{费用}$ is the Minimum Capital Requirement for expense risk of the company;

$M_{相关系数}$ is the correlation coefficient matrix (3×3).

The other symbols have the meanings defined before.

$M_{相关系数}$ is displayed in Table 41.

	$MC_{损失发生}$	$MC_{费用}$	$MC_{退保}$
$MC_{损失发生}$	1.0	0.4	0.0
$MC_{费用}$	0.4	1.0	0.5
$MC_{退保}$	0.0	0.5	1.0

Table 41: Correlation coefficients of risks under Life insurance risk

Proceeding with the illustration, Tables (42)-(44) show the results of the template to calculate minimum capital requirements at each policy month.

Num of policy months	policy year	policy month	age	mortality rate risk	catastrophe mortality risk	longevity risk	morbidity risk	medical&health claims loss ratio risk	other claims risk	claims risk
0				285.369091	70.1296065	0	0	0	0	310.4192179
1	1	1	40	287.453055	70.3067642	0	0	0	0	312.5335935
2	1	2	40	288.49224	70.4779927	0	0	0	0	313.6257272
3	1	3	40	289.535336	70.643269	0	0	0	0	314.7189917
...	...	...	...	...	...	...	...	...	...	...
12	1	12	40	351.884354	84.7897713	0	0	0	0	382.007854
13	2	1	41	353.12983	85.4788849	0	0	0	0	383.5360333
...	...	...	...	...	...	...	...	...	...	...

Table 42: Calculation of Claims risk

Num of policy months	policy year	policy month	age	surrender rate risk	mass lapse risk	claims risk	expense risk	surrender risk	life insurance risk
0				1219.56381	0	310.419218	433.9613863	1219.563809	1552.10503
1	1	1	40	1228.65354	0	312.533593	326.638883	1228.653539	1482.212618
2	1	2	40	1233.27895	0	313.625727	326.9666024	1233.278952	1487.118815
3	1	3	40	1237.92178	0	314.718992	327.2940659	1237.921778	1492.041808
...	...	...	...	...	...	...	...	...	...
12	1	12	40	1495.31276	0	382.007854	388.5048835	1495.312761	1797.913275
13	2	1	41	1500.9545	0	383.536033	351.2323885	1500.954498	1777.155182
...	...	...	...	...	...	...	...	...	...

Table 43: Calculation of Life insurance risk

Num of policy months	policy year	policy month	age	life insurance risk	non-life insurance risk	market risk	credit risk	total risk(MC)
0				1552.10503	0	0	0	1396.894527
1	1	1	40	1482.212618	0	1306.80217	219.3996275	2093.976245
2	1	2	40	1487.118815	0	1279.69128	214.8479677	2076.92083
3	1	3	40	1492.041808	0	1252.47501	210.2786157	2059.963757
...	...	...	...	...	...	...	...	...
12	1	12	40	1797.913275	0	1127.61576	189.3159375	2205.974762
13	2	1	41	1777.155182	0	3189.16251	535.4299864	3870.739738
...	...	...	...	...	...	...	...	...

Table 44: Calculation of Total risk (MC)

7. CONCLUSIONS

In summary, the whole internship report illustrates the process of building a pricing model for a whole life insurance product called "UpUphigh", from which I learned that the development of a new life insurance product must conform to strict regulations under China Insurance Regulation Commission (CIRC), rather than setting parameters and assumptions randomly. The building of a pricing model for a life insurance product is done on basis of information provided in the actuarial report of the product, which is the most important file that a life insurance company has to submit to CIRC to be assessed and approved.

The pricing model has to be built step by step, layer by layer, due to the fact that critical data include premiums, cash values, statutory unearned premium reserves, modified reserves, premium deficiency reserves and so on. Apart from this, calculation formulas are complicated with different conditions of input variables like age, sex and payment period and involves many parameters, which are often varying with policy years. That means each layer of this pricing model needs to be organized sequentially and is destined to be a long sheet containing values at each policy year.

It was also necessary to write some VBA code to help organize all critical data into a new sheet, sequentially, so that it makes comparison with that in the internal model provided by Guofu Company both possible and efficient. It was reassuring that values of all critical data in the developed pricing model were the same as those in the internal model, validating the accuracy of the 'new' model and the ability to develop the whole procedure independently.

Particularly challenging was the experience of performing the profit test for a life insurance product, especially adding Excel templates into the developed pricing model. The fact that it takes all possible cash flows into consideration, and each parameter is calculated monthly rather than annually, which is a more meticulous approach, results in a much more comprehensive perspective, compared to the sequential building of the three layers of pricing model to calculate premiums, cash values and reserves. Besides, during the calculation process for minimum capital requirements, a large number of different types of risks are included and there are correlation matrixes between them, making it more practical and persuasive. It was rewarding to be able to build Excel templates into the pricing model, the workload of which proved to be massive. In this internship report, I only illustrate the profit test using the cross-reserve method, but I actually performed profit test using multiple methods like CR, CR Solvency II, GAAP.

Overall, the result of the work for "UpUphigh" was very satisfying. In terms of the simplicity and interpretability, I think the developed model is an improvement to the existing model. The step by step approach supplies critical data like premiums, cash values and all types of reserves, while the internal model is more universal, to be applicable to all different types of life insurance products, with minor adjustments. And it is quite easy to check that the assumptions and formulas provided in the actuarial report of this particular product have been strictly followed.

In general, the model works quite well, but it still has some limitations. If I had an extra half month to continue my internship work, I would definitely go further on writing VBA code to

compare critical data in the profit test part with the internal model, which would be a challenging task.
From this internship journey, I realized that many of the concepts and techniques I learned in the curricular part of the Master program, in the field of life insurance and other related actuarial knowledge, were very useful to develop the whole process in an almost independent way. It also reminds me that I am passionate about being an actuarial analyst and could perhaps develop a new type of life insurance product in the future. Also, I learned the history of life insurance products development in China, Japan, European countries, and America, see MA DONG DONG. (2025).
To conclude, I believe that I have had a glimpse of the past, present and already of what are the expected future developments of the insurance business in China and I have my own thoughts as well.

REFERENCES

China Association of Actuaries. （2016）. *Industry pilot program for embedded value (EV) evaluation in life insurance*. ../节节高 D 款/节节高 D 转 E+VBA 利润测试/附件 1-1：人身险内含价值评估行业测试方案.pdf

China Banking and Insurance Regulatory Commission. (2019). *Order No. 3 of 2019 of the China Banking and Insurance Regulatory Commission (CBIRC)*. ../保险法规/健康保险管理办法（2019 年第 3 号）.docx

China Banking and Insurance Regulatory Commission. (2020, January 21). *Notice of the General Office of the China Banking and Insurance Regulatory Commission on Issuing the Actuarial Provisions for General Type Personal Insurance*.

China Banking and Insurance Regulatory Commission. (2021). *Notice of the China Banking and Insurance Regulatory Commission on Issuing Insurance Company Solvency (II) Regulation Rules* (CBIRC Document No. 51 [2021]). ***../节节高 D 款/节节高 D 转 E+VBA 利润测试/保险公司偿付能力监管规则（II）.pdf***

China Banking and Insurance Regulatory Commission. (2021a). *Notice of the General Office of the China Banking and Insurance Regulatory Commission on Further Standardizing Insurance Institutions' Internet-based Personal Insurance Operations* (CBIRC Office Notice No. 108 [2021]).

China Banking and Insurance Regulatory Commission. (2021b). *Notice of the General Office of the China Banking and Insurance Regulatory Commission on Issuing the "Measures for the Regulation of Accident Insurance Business"* (CBIRC Office Notice No. 106 [2021]).

China Insurance Regulatory Commission. (2015). *Notice on Matters Concerning the Promotion of Reform of Premium Rate Policies for Participating Life Insurance* (CIRC Order No. 93 [2015]).

Dickson, D. C. M., Hardy, M. R., & Waters, H. R. (2019). *Actuarial mathematics for life contingent risks* (3rd ed.). Cambridge University Press.

Guofu Life Insurance Co., Ltd. (2024, September 26). *Actuarial report on the "UpUphigh" whole life insurance product (Plan E)* **../节节高 D 款/节节高 D 转 E+VBA 利润测试/05 国富人寿节节高终身寿险（E 款）产品精算报告.pdf**

Guofu Life Insurance Co., Ltd. (n.d.). *Product description on the "UpUphigh" whole life insurance product (Plan E)*. **../节节高 D 款/节节高 D 转 E+VBA 利润测试/08 国富人寿节节高终身寿险（E 款）产品说明书.docx**

Insurance Law of the People’s Republic of China. (2015). *Insurance Law of the People's Republic of China (Amended in 2015)*.

MA DONG DONG. (2025). *Introduction to the development and management of life insurance products*. Internal document.
../节节高 D 款/节节高 D 转 E+VBA 利润测试/人身保险产品开发管理培训 PPT.pptx

Ministry of Finance & China Insurance Regulatory Commission. (2015). *Administrative measures for the regulation of insurance clauses and premium rates of life insurance companies (2015 revision)*.

APPENDIX

Table A1 presents the Life Tables of China's Life Insurance Industry Experience (2010-2013)”

	MORTALITY RATES	
age	L10-13(1)M	L10-13(1)F
0	0.000867	0.00062
1	0.000615	0.000456
2	0.000445	0.000337
3	0.000339	0.000256
4	0.00028	0.000203
5	0.000251	0.00017
6	0.000237	0.000149
7	0.000233	0.000137
8	0.000238	0.000133
9	0.00025	0.000136
10	0.000269	0.000145
11	0.000293	0.000157
12	0.000319	0.000172
13	0.000347	0.000189
14	0.000375	0.000206
15	0.000402	0.000221
16	0.000427	0.000234
17	0.000449	0.000245
18	0.000469	0.000255
19	0.000489	0.000262
20	0.000508	0.000269
21	0.000527	0.000274
22	0.000547	0.000279
23	0.000568	0.000284
24	0.000591	0.000289
25	0.000615	0.000294
26	0.000644	0.0003
27	0.000675	0.000307
28	0.000711	0.000316
29	0.000751	0.000327
30	0.000797	0.00034
31	0.000847	0.000356
32	0.000903	0.000374
33	0.000966	0.000397
34	0.001035	0.000423
35	0.001111	0.000454
36	0.001196	0.000489
37	0.00129	0.00053
38	0.001395	0.000577
39	0.001515	0.000631
40	0.001651	0.000692
41	0.001804	0.000762
42	0.001978	0.000841
43	0.002173	0.000929
44	0.002393	0.001028
45	0.002639	0.001137
46	0.002913	0.001259
47	0.003213	0.001392
48	0.003538	0.001537
49	0.003884	0.001692
50	0.004249	0.001859
51	0.004633	0.002037
52	0.005032	0.002226
53	0.005445	0.002424
54	0.005869	0.002634
55	0.006302	0.002853
56	0.006747	0.003085
57	0.007227	0.003342
58	0.00777	0.003638
59	0.008403	0.00399
60	0.009161	0.004414
61	0.010065	0.004923
62	0.011129	0.005529
63	0.01236	0.006244
64	0.013771	0.007078
65	0.015379	0.008045
66	0.017212	0.009165
67	0.019304	0.01046
68	0.021691	0.011955
69	0.024411	0.013674
70	0.027495	0.015643
71	0.030965	0.017887
72	0.034832	0.020432
73	0.039105	0.023303
74	0.043796	0.026528
75	0.048921	0.030137
76	0.054506	0.034165
77	0.060586	0.038653
78	0.067202	0.043648
79	0.0744	0.049205
80	0.08222	0.055385
81	0.0907	0.062254
82	0.099868	0.06988
83	0.109754	0.07832
84	0.120388	0.087611
85	0.131817	0.097754
86	0.144105	0.108704
87	0.157334	0.120371
88	0.171609	0.132638
89	0.187046	0.145395
90	0.203765	0.158572
91	0.221873	0.172172
92	0.241451	0.186294
93	0.262539	0.201129
94	0.285129	0.21694
95	0.30916	0.234026
96	0.334529	0.252673
97	0.361101	0.273112
98	0.388727	0.295478
99	0.417257	0.319794
100	0.446544	0.345975
101	0.476447	0.373856
102	0.50683	0.403221
103	0.537558	0.433833
104	0.568497	0.465447
105	1	1
106	1	1

Table A1: Life Tables of China's Life Insurance Industry Experience (2010-2013)