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CALCULATION OF INSURANCE PREMIUM RESERVES FOR LIFE INSURANCE AND APPLICATION OF THE ZILLMER METHOD AGAINST NEGATIVE RESULTS IN THE FIRST YEAR

Abstract. The purpose of this article is to examine the application of the Zillmer method to mitigate or eliminate the negative reserve that arises during the first year when expenses are charged to the insurance premium reserves calculated for life insurance. The net premium reserve for whole life insurance and term insurance types has been calculated using both prospective and retrospective methods. The formulas for calculating the actuarial present value of insurance payments (paid), life annuities, and premiums, which are the main components of the insurance premium reserve, as well as substitution decrements and commutation functions, are provided. Expenses affecting the reserve are classified as initial expenses (α), collection expenses (β), and administrative expenses (γ). The methodology for converting net premium reserves into gross premium reserves by charging the α , β , and γ expenses is presented. Various approaches of the Zillmer method have been analyzed to address the negative premium reserve that arises in the first year when the commission, which is part of the initial expense (α), is added.

Keywords: life insurance, prospective and retrospective methods, initial expense, annuity, net premium reserve, Zillmer method.

INTRODUCTION

Life insurance is a type of insurance that provides compensation to individuals and their beneficiaries in cases of death, disability, critical illness, or at the end of the insurance period, in exchange for the payment of premiums over a specified period. Unlike other types of insurance, the insurance period for life insurance does not follow a short-term structure; it typically spans 15–20 years and sometimes even longer. Therefore, the economic conditions prevailing at the time of signing the insurance contract may undergo significant changes over time. These changes are particularly evident during periods of high inflation, which can result in the erosion of the value of insurance payments and cause premiums to lose their intended functions. Periods of high inflation, for various reasons, are considered deterrent factors for long-term life insurance. Most importantly, it is the continuous loss of the value of money. For individuals, paying insurance premiums with money that has high purchasing power and, in return, receiving life insurance payments in the future with money whose purchasing power is uncertain throughout the duration of the insurance contract, and whose value and circumstances in the future are unknown, is not appealing. Therefore, insurers were compelled to seek new methods to eliminate these

negative factors and to enhance people's interest in life insurance. They needed to provide advantages that would increase the sense of security for insureds. Therefore, insurers, to protect insureds from the diminishing value of money, directed the annually calculated premium reserves towards investments. The insurer would then allocate a portion of the income generated from these investments to the insured at the end of the insurance contract.

The insurer is also interested in calculating a more adequate reserve instead of a negatively calculated insurance premium reserve due to the high risks associated with long-term life insurance and the heavy responsibility it entails.

In life insurance, the insured pays a certain insurance premium to the insurer each year, and the insurer undertakes to pay the amount specified in the insurance contract to the insured (beneficiary) or their heirs in the event of occurrences such as death or disability. To fulfill its obligations in a timely manner, the insurer creates a certain amount of reserve from the collected insurance premiums, and this reserve is referred to as the premium reserve.

Every life insurance company establishes a premium reserve for its long-term obligations. The calculation formulas for mathematical reserves

differ depending on the characteristics of various types of insurance. Depending on whether the insurance company has historical data or is newly established, the premium reserve is calculated using either the prospective or retrospective method. Some countries of the European Union calculate net premium reserves along with a separate loss adjustment expense (LAE) reserve. However, in many countries, including ours, the net premium reserve is calculated first, and then the α , β , and γ expense components are added to obtain the gross premium reserve. Since the commission, which is a primary component of the initial expense (α), is charged, the first-year reserve of the gross premium reserve often results in a negative value. Since this problem has persisted over the years, various studies have been conducted to address it. In this article, we will explain that the most effective and impactful solution to this issue is the Zillmer method.

LITERATURE REVIEW

According to Article 27 C (2) of the European Union Directive No. 91/674/EEC (1991) insurance companies operating in the field of life insurance are required to calculate insurance premium reserves

In his book, Promislow (2014) demonstrates the calculation of net premium reserves for life insurance using both the prospective and retrospective methods.

In his book, Hans U. Gerber (2013) illustrates the calculation of gross premium reserves by adding expense components to net premiums for life insurance. Additionally, he provides an explanation of the Zillmer method to address negative reserves and presents the calculation of a new α coefficient.

The German actuary, August Zillmer (1989), proposed the method known as the Zillmer method to address negatively calculated insurance premium reserves.

In recent years, researchers [2; 7–9] have utilized Zillmer's actuarial approaches to conduct calculations that address the specific problems of their countries, adapting them to meet the requirements of modern times. Researchers [7] have conducted a joint analysis using the Zillmer method along with adequate premium reserve methods. Researchers [8] have also compared the Zillmer and Ohio methods in terms of insurance premium reserves specific to their countries. They [2], have analyzed joint life insurance contracts involving middle-aged spouses using both the Zillmer and Canadian methods. Researchers [9] have conducted an analysis of the Zillmer method to address the negative premium reserves that calculated for several years using the prospective method.

PROBLEM DEFINITION AND SOLUTION

When calculating the gross premium reserve for long-term life insurance using the prospective method, the reserve for the first year (and sometimes for several years) often results in a negative value. In cases where the insurance premium reserve is negative, it is replaced by zero. The primary reason for the negative reserve in the first year is the commission, which is the main component of the initial expenses (α).

Since the commission is the amount paid to insurance intermediaries at the time of signing the insurance contract, the insurer's responsibility increases due to the acquisition expense incurred for attracting a new insured, in addition to the insurance payments they are obligated to pay for future risks. This additional burden appears as a negative amount in the reserves. Furthermore, if the insurer establishes an inadequate reserve, they may lack resilience against future risks, thereby significantly increasing the risk of insolvency.

To resolve this problem, instead of replacing the negatively calculated reserve with zero, various approaches of the Zillmer method should be applied to calculate a more adequate insurance premium reserve that does not result in a negative value. Different approaches to the Zillmer method are analyzed in this article.

METHODOLOGY

In this article, net premium reserves calculated using prospective and retrospective methods, the conversion of net premiums to gross premium reserve by adding expenses, and the approach of the Zillmer method against the negatively calculated gross premium reserve have been analyzed by applying actuarial mathematics and calculations.

Calculation of net mathematical reserve using prospective and retrospective methods

The insurance premium reserve for long-term life insurance is calculated using both the prospective and retrospective methods. The calculation of reserves varies depending on the types of life insurance. The reserves for whole life insurance and term life insurance (n -year life insurance) are calculated using prospective and retrospective methods.

According to the prospective method, the insurance premium reserve is calculated by finding the difference between the actuarial present value of the insurer's future obligations and the actuarial present value of the future premiums to be paid by the insured. This method bases the calculation on the obligations that will be fulfilled in the future, and the estimation is made prospectively based on future indicators.

For a person aged x , the reserve for a whole life insurance contract for the k -th year according to the prospective method is calculated using the following formula [6]:

$${}_kV_x = A_{x+k} - P_x * \ddot{a}_{x+k}, \quad (1)$$

Where:

${}_kV_x$ — The insurance premium reserve at the end of the k -th year for a whole life insurance contract;

A_{x+k} — The calculated actuarial present value of the insurance payments in the k -th year for a person aged x under a whole life insurance contract;

P_x — The annual insurance premiums for a person aged x ;

\ddot{a}_{x+k} — The actuarial present value of the annuity at the beginning of the k -th year for a person aged x ;

$P_x * \ddot{a}_{x+k}$ — The actuarial present value of the insurance premiums to be paid by the person when they reach age $x+k$ in that year.

For a person aged x , the reserve for a term life insurance contract with a duration of n years for the k -th year according to the prospective method is calculated using the following formula:

$${}_kV_{x:n} = A_{x+k:n-k}^1 - P_{x:n}^1 * \ddot{a}_{x+k:n-k}. \quad (2)$$

Since the k -th year in formulas (1.1) and (1.2) represents any given year, we will calculate the reserve based on the initial point in time using commutation and decrement functions. Here, we will replace the indicators \ddot{a}_x and A_x with the following decrement functions [4]:

$$\ddot{a}_x = \frac{l_x + \vartheta * l_{x+1} + \vartheta^2 * l_{x+2} + \dots}{l_x}, \quad (3)$$

$$A_x = \frac{\vartheta * d_x + \vartheta^2 * d_{x+1} + \vartheta^3 * d_{x+2} + \dots}{l_x}, \quad (4)$$

Where:

l_x — the number of individuals alive at age x ;

l_{x+1} — the number of individuals alive at age $x+1$;

d_x — the number of individuals who die at age x ;

d_{x+1} — the number of individuals who die at age $x+1$;

ϑ — the interest rate for calculating the present value.

By multiplying the numerator and denominator of the decrement functions (1.3) and (1.4) by ϑ and replacing $l_x * \vartheta = D_x$ with $d_x * \vartheta^{x+1} = C_x$ we derive the following commutation functions:

$$\ddot{a}_x = \frac{\vartheta^x * l_x + \vartheta^{x+1} * l_{x+1} + \vartheta^{x+2} * l_{x+2} + \dots}{\vartheta^x * l_x} = \frac{D_x + D_{x+1} + D_{x+2} + \dots}{D_x} = \frac{N_x}{D_x}, \quad (5)$$

$$A_x = \frac{(\vartheta * d_x + \vartheta^2 * d_{x+1} + \vartheta^3 * d_{x+2} + \dots) * \vartheta}{l_x * \vartheta} = \frac{C_x + C_{x+1} + C_{x+2} + \dots}{D_x} = \frac{M_x}{D_x}. \quad (6)$$

Let's fully replace the indicators \ddot{a}_x and A_x from the main formula (1.1) with the commutation functions from formulas (1.5) and (1.6):

$${}_kV_x = A_{x+k} - P_x * \ddot{a}_{x+k} = \frac{M_{x+k} - P_x * N_{x+k}}{D_{x+k}}. \quad (7)$$

The actuarial present value of insurance payments, insurance premiums, and annuities, which are the main components of the insurance premium reserves for whole life insurance and n -year term life insurance, can be calculated using decrement formulas.

The actuarial present value of insurance payments for whole life insurance A_x and n -year term life insurance ($A_{x:n}^1$) is calculated using the following decrement formulas [5]:

$$A_x = \sum_{k=0}^{\infty} \vartheta^{k+1} * {}_kP_x * q_{x+k}, \quad (8)$$

$$A_{x:n}^1 = \sum_{k=0}^{n-1} \vartheta^{k+1} * {}_kP_x * q_{x+k}, \quad (9)$$

Where:

${}_kP_x$ — the probability that a person aged x will survive until age $x+k$;

q_{x+k} — the probability that a person aged x will die in the $x+k$ year;

ϑ — the interest rate used for calculating the present value.

The actuarial present value of insurance annuities for whole life insurance (\ddot{a}_x) and n -year term life insurance ($\ddot{a}_{x:n}$) is calculated using the following commutation and decrement functions [5]:

$$\ddot{a}_x = \frac{N_x}{D_x} = \frac{1}{D_x} \sum_{n=x}^{\infty} D_n = \frac{1}{\vartheta^x * l_x} * \sum_{n=x}^{\infty} \vartheta^n * l_n, \quad (10)$$

$$\ddot{a}_{x:n} = \frac{N_x - N_{x+n}}{D_x} = \frac{1}{l_x} * \sum_{k=0}^{n-1} \vartheta^k * l_{x+k}. \quad (11)$$

The annual insurance premiums for whole life insurance (P_x) and n -year term life insurance ($P_{x:n}^1$) are calculated as follows [1]:

$$P_x = \frac{A_x}{\ddot{a}_x} \quad (12) \quad v\vartheta \quad P_{x:n}^1 = \frac{A_{x:n}^1}{\ddot{a}_{x:n}}. \quad (13)$$

The retrospective method for calculating the insurance premium reserve is based on finding the difference between the total value of the premiums paid by the insured and the total value of the risks undertaken by the insurer. This method is calculated according to past indicators.

For a person aged x , the reserve for a whole life insurance contract for the k -th year according to the retrospective method is calculated using the following formula [6]:

$${}_kV_x = P_x * \ddot{s}_{x:k} - A_{x:k}^1 * \frac{(1+\vartheta)^k}{kP_x}. \quad (14)$$

For a person aged x , the reserve for an n -year term life insurance contract for the k -th year according to the retrospective method is calculated using the following formula:

$${}_kV_{x:n}^1 = P_{x:n}^1 * \ddot{s}_{x:k} - A_{x:k}^1 * \frac{(1+i)^k}{kP_x}, \quad (15)$$

Where:

${}_kV_{x:n}^1$ — the insurance premium reserve at the end of the k -th year for an n -year term life insurance contract for a person aged x ;

$P_{x:n}^1$ — the annual net insurance premium for a person aged x for an n -year term life insurance contract, payable upon death;

$\ddot{s}_{x:k}$ — the accumulated value of an annual annuity paid at the beginning of each year by a person aged x until the end of the k -th year;

$A_{x:k}^1$ — the actuarial present value of the insurance payment made upon death for an n -year term life insurance contract for a person aged x during the k -th year;

$(1+i)^k$ — the interest rate for the k -th year;

kP_x — the annual net premium for the k -th year for a person aged x .

When the actuarial mathematical reserve is calculated as negative, this value is considered zero.

Conversion of net premium reserve to gross premium reserve by expense loaded

The reserve calculated based on insurance premiums is called the net premium reserve. However, the insurance company is not only responsible for making insurance payments; it is also accountable for covering all expenses related to the execution of insurance operations. If only net premiums were collected from the insureds, the insurance company would consistently operate at a loss, ultimately leading to bankruptcy. Therefore, the costs associated with carrying out insurance operations under long-term life insurance contracts are referred to as expense loading. When expense loading is added to the net premium reserve, it is referred to as the gross premium reserve.

The composition of expense loading varies depending on the country and the company. Therefore, the expense items for long-term life insurance contracts are approximately classified as α , β , γ as follows [4]:

α — acquisition expenses or initial expenses;

β — collection expenses;

γ — administration expenses;

α — acquisition expenses are specifically related to the process of signing new insurance contracts.

Also, since the expenses for attracting new insureds are paid once at the time of signing the insurance contracts, they are often referred to as initial

expenses. The α expense component includes commission fees paid to insurance intermediaries (commission), costs related to the preparation, formalization, and registration of insurance contracts, costs of medical examinations of potential insureds, advertising expenses, and other related expenses. Sometimes, only commission fees are considered as α expenses. Commission is the amount paid to insurance intermediaries when the insurance contract is signed. This is an expense deducted from the first insurance premiums.

The β expenses include renewal expenses and maintenance expenses. Sometimes, commissions paid to insurance intermediaries at the beginning of each insurance year for the collection of annual premiums are also included. These expenses cover the costs associated with changing the beneficiary, implementing changes to the terms of the insurance contract, expenses related to correspondence with the insureds, and the costs associated with the execution of the insurance contract.

The γ expenses are administrative expenses related to the operations of the insurance company. Administrative expenses include salaries of staff, payments for utility services, license fees, taxes, rental payments, data processing costs, and other related expenses.

When expenses are added to net premiums, it is converted into the gross premium reserve. The gross premium reserve (${}_kV^g$) at the end of the k -th insurance year under the insurance contract can be expressed by the following formula [4]:

$${}_kV^g = {}_kV + {}_kV^\alpha + {}_kV^\gamma, \quad (16)$$

Where:

${}_kV^g$ — gross premium reserve at the end of the k -th year;

${}_kV$ — net premium reserve at the end of the k -th year;

${}_kV^\alpha$ — premium reserve at the end of the k -th year after applying α expenses (particularly, commission);

${}_kV^\gamma$ — premium reserve at the end of the k -th year after applying γ administrative expenses.

In the above formula, the α initial expense and γ administrative expense components are directly applied to the net premium reserve, while the β collection expense is applied to the net premium indirectly, thereby affecting the gross premium reserve. The classification of these expenses may vary depending on the company's strategy.

Since the expenses considered within the structure of expense loading are distributed over time, it is necessary to discount them (bring them to the present value) during the calculation process.

Application of the Zillmer method to prevent the negative reserve in the first year calculated using the prospective method

When calculating the mathematical reserve of long-term life insurance types using the prospective method, the mathematical reserve at the end of the first year is often negative. The primary factor contributing to this negative value is the α expense component. The main expense affecting the α initial expense component is the commission paid to the insurance intermediary. In long-term life insurance contracts where premiums are paid periodically, the commission is not distributed throughout the entire duration of the contract as premiums are paid by the insureds. Instead, the full commission is paid at the beginning of the insurance contract when the first premium is paid. A large portion of the initial premium is paid as a commission to the insurance intermediary. Therefore, the initial premium loaded with acquisition expenses (α expenses) is significantly smaller than the subsequent premiums for that contract or can even result in a negative value.

Additionally, when an insurance contract is terminated prematurely, it is economically reasonable to consider the negative impact created by the commission, which is the primary component of the α initial expense, on the insurance premium when calculating the mathematical reserve. This consideration ensures that there is no immediate deficiency in the insurer’s account when making refund payments.

The application of the Zillmer method to prevent the negative reserve in the first year of insurance premium reserves calculated using the prospective method for long-term life insurance contributes to a more adequate reserve calculation. The main purpose of the Zillmer method is to prevent the negative value of the insurance premium reserve caused by the α initial expense component, specifically the commission. This impact of the Zillmer method on the premium reserve can be demonstrated through various approaches:

- When calculating the insurance premium reserve, the commission expense within the α initial expense during the first year can be ignored. This is because the entire first year premium is spent on covering initial expenses. In other words, the Zillmer reserve is equivalent to the net premium reserve for an insurance contract that starts one year later and has a term reduced by one year. The Zillmer reserve protects the insurer from losses during the early years of the contract when the insurance contract is terminated prematurely, and refund payments must be made. By not allocating a reserve for an amount that does not actually

exist in the first year, and by directing this to investments, the creation of an inflated amount is prevented. In other words, by disregarding the commission in the first year and treating it as if the insurance contract starts one year later, the insurance premium reserve is calculated accordingly.

- The commission within the α initial expense can be calculated by treating it as a commission distributed over several years, like the β collection expense. However, there is a difference between the commission in the α initial expense and the commission in the β collection expense. Since the commission in the α initial expense is applied once from the first premium, the reserve calculated during that time results in a negative value. On the other hand, the commission in the β collection expense is distributed gradually over the premiums of subsequent years, contributing to the calculation of a more adequate reserve. In the Zillmer method, the total initial expenses can be represented as I , α initial expense can be expressed as $P_x + \frac{I}{\ddot{a}_x} - I$, and β can be represented as $P_x + \frac{I}{\ddot{a}_x}$: [3].

$${}_kV_x^Z = A_{x+k} - \beta * \ddot{a}_{x+k}$$

or

$${}_kV_x^Z = A_{x+k} - (P_x + \frac{I}{\ddot{a}_x}) * \ddot{a}_{x+k}$$

The net premium reserve can be reduced in advance by the actuarial present value of the α initial expenses considered within the expense loading portion of future premiums. The insurance premium reserve calculated using the following formula is called the Zillmer method or Zillmer reserve [7]:

$${}_kV_x^{1(Z)} = A_{x+k:n-k}^1 - \frac{\alpha}{\ddot{a}_{x:n}} * \ddot{a}_{x+k:n-k} - P_{x:n}^1 * \ddot{a}_{x+k:n-k}$$

If the α coefficient, representing initial expenses is sufficiently large, then the insurance premium reserve calculated using the Zillmer method can be negative for the first few years of the insurance contract [9]. Therefore, a maximum limit for α is determined for each contract. The individual α coefficient for each contract, based on its specific characteristics, is calculated as follows [4]:

$$\alpha = \frac{{}_1V_{x:n}}{(1 - {}_1V_{x:n})}$$

Where:

- α — the coefficient calculated individually based on the characteristics of each contract;
- ${}_1V_{x:n}$ — the net premium reserve calculated for each contract.

This α coefficient is calculated based on the net premium reserve according to the characteristics of each individual contract. The obtained coefficient is then reapplied as an initial expense coefficient to the net premium reserve to calculate the gross premium reserve.

To prevent the reserve from becoming negative during the initial years of calculation, the various approaches of the Zillmer method described above should be applied.

CONCLUSION

When calculating the net premium reserve using the prospective method for long-term life insurance and converting it into the gross premium reserve by adding expenses, the reserve for the first year often results in a negative value. Instead of replacing this negative reserve with zero, the approaches of the Zillmer method should be applied. A negative premium reserve in the first year indicates that the insurer lacks an amount that can be directed to investment on behalf of the insured. For long-term life insurance contracts, the insurer directs the gross premium reserve calculated annually to investments and provides a portion of the income obtained to the insured at the end of the contract. Therefore, a negative reserve adversely affects both the insurer and the insured.

The approaches of the Zillmer method can contribute to the calculation of an adequate reserve instead of negatively impacting the insurance premium reserve when the commission, which is the main component of the α initial expense, is applied in the following ways:

1. Ignoring the α initial expense during the calculation of the insurance premium reserve in the first year for long-term life insurance types.
2. Considering commission within the α initial expense as a commission distributed over several years, like the β collection expense, starting from the next year.
3. Calculating a new α coefficient based on the individual characteristics of each life insurance

contract, particularly in cases where the α initial expense is excessively high.

These approaches prevent the insurance premium reserve from being negative, enabling the insurer to apply appropriate methods based on the available indicators, calculate a realistic reserve, and maintain stability in fulfilling its obligations.

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РОЗРАХУНОК РЕЗЕРВІВ СТРАХОВИХ ПРЕМІЙ ЗІ СТРАХУВАННЯ ЖИТТЯ ТА ЗАСТОСУВАННЯ МЕТОДУ ЦІЛМЕРА З МЕТОЮ УСУНЕННЯ НЕГАТИВНИХ РЕЗУЛЬТАТІВ У ПЕРШІЙ РІК

Резюме. Метою цієї статті є дослідження застосування методу Цілмера для пом'якшення або усунення негативного резерву, що виникає протягом першого року, коли витрати зараховуються до резервів страхової премії, що розраховані для страхування життя. Чистий резерв премій за договорами страхування життя та термінового страхування обчислено з використанням як перспективних, так і ретроспективних методів. Наведено формули для розрахунку актуарної теперішньої вартості страхових внесків (сплачених), довічних анuitетів і премій, які є головними компонентами резерву страхової премії, а також функцій комутації та декрементів заміщення. Витрати, що впливають на резерв, класифіковано як початкові витрати (α), витрати на збір (β) та адміністративні витрати (γ). Описано методологію перетворення резервів чистої премії

у резерв валової премії шляхом урахування витрат α , β та γ . Проаналізовано різні підходи методу Цілмера щодо усунення негативного резерву премії, що виникає в перший рік через додавання комісійної винагороди, яка є частиною початкових витрат (α).

Ключові слова: страхування життя, проспективний і ретроспективний методи, початкові витрати, анuitет, резерв чистої премії, метод Цілмера.

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