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Comparison of Zillmer and Premium Sufficiency Reserve Method using the Vasicek Stochastic Interest Rate Model

Muhammad Ibrahim Rachman, Anasya Daffa Pertiwi

School of Risk Management and Insurance
Jl. Perintis Kemerdekaan No 14-16, Pulo Gadung Jakarta Timur 13260
Email: muhammad.ibrahim@sbm-itb.ac.id, anasya.daffa66@gmail.com.

Abstrak
Perhitungan cadangan premi yang akurat akan dapat memastikan kemampuan perusahaan asuransi untuk membayar klaim. Cadangan premi adalah dana yang dikumpulkan oleh perusahaan asuransi yang merupakan selisih antara uang pertanggungan dan nilai tunai pembayaran selama masa pertanggungan yang dipersiapkan untuk pembayaran klaim. Terdapat beberapa metode untuk menghitung cadangan premi, namun metode yang menjadi fokus penelitian ini adalah metode Zillmer dan metode *Premium Sufficiency* yang merupakan perluasan dari metode prospektif. Tujuan dari penelitian ini adalah untuk membandingkan kedua metode tersebut dengan menggunakan model Vasicek untuk menentukan tingkat bunga stokastik. Kemudian metode *Ordinary Least Square* digunakan untuk mengestimasi parameter suku bunga Vasicek. Dalam membandingkan kedua metode cadangan premi tersebut, penelitian ini membangun simulasi untuk tertanggung laki-laki dan perempuan dengan menggunakan data suku bunga acuan Bank Indonesia periode 2017-2021 dan Tabel Mortalita Indonesia IV tahun 2019. Hasil penelitian ini menunjukkan bahwa cadangan premi dengan menggunakan perhitungan cadangan metode Zillmer menghasilkan nilai yang lebih kecil dibandingkan dengan metode *Premium Sufficiency*, baik untuk tertanggung pria maupun wanita. Walaupun tertanggung pria memiliki tingkat mortalita yang lebih tinggi dibandingkan wanita pada perhitungan cadangan tidak hanya mengandalkan tingkat mortalita saja, melainkan juga memperhitungkan unsur biaya, di mana penggunaan unsur biaya pada metode Zillmer berfokuskan pada biaya komisi agen sedangkan pada metode *Premium Sufficiency* berfokus pada biaya komisi agen dan biaya pemeliharaan polis.

Kata kunci: Cadangan Premi, Metode Premium Sufficiency, Metode Zillmer, Tingkat Suku Bunga Stokastik, Tingkat Suku Bunga Vasicek.

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Abstract
An accurate calculation of premium reserves will ensure that the insurance company can pay claims. Premium reserves are funds collected by insurance companies which are the difference between the sum insured and the value of payments during the insurance period prepared for claim payments. There are several methods for calculating premium reserves, but the methods that are the focus of this study are the Zillmer method and the Premium Sufficiency method, extensions of the prospective method. This study aims to compare the two methods using the Vasicek model to determine the stochastic interest rate. Then the Ordinary Least Square method is used to estimate the Vasicek interest rate parameter. In comparing the two premium reserve methods, this study builds a simulation for reference male and female insureds using Bank Indonesia reference rate data for 2017-2021 and the Indonesian Mortality Table IV from 2019. The results of this study indicate that the premium reserve using the Zillmer method of reserve calculation produces a smaller value than the Premium Sufficiency method for both male and female insured. Although male insureds have a higher mortality rate than women, the measure of reserves does not only rely on the mortality rate but also takes into account the cost element, where the use of the cost element in the Zillmer method focuses on agent commission fees. In contrast, the Premium Sufficiency method focuses on agent commission fees and policy maintenance costs.

Keywords: Premium Reserve, Premium Sufficiency Method, Stochastic Interest Rate, Vasicek Interest Rate, Zillmer Method.

1. Introduction

As of August 2022, 157,000 people died due to Covid-19 in Indonesia. This number will continue to grow, considering that new variants of this virus are still emerging, even though they are no longer as lethal as the variants that infected in the beginning. The prolonged pandemic will have a direct impact on the life insurance industry. Deloitte [6] notes that insurance companies may not see many life claims because many of those who die from the disease are from age groups that may not have coverage. However, there is a risk that mortality for other cohorts may increase arising from the fear of seeking hospital or medical care or the general stress of self-isolation that requires insurance companies to be prepared for future claims. To ensure the readiness of insurance companies to pay claims, since 2016, the Indonesia Financial Authority Services (OJK *Otoritas Jasa Keuangan*) has issued regulation No. 71/POJK.05/2016 concerning Financial Health of Insurance and Reinsurance Companies. In this regulation, OJK requires insurance companies to build technical reserves according to the type of insurance product. One of the technical reserves mentioned in the regulation is the premium reserves which will be the focus of this study. This regulation aims to avoid the non-payment of claims caused by the unhealthy financial situation of insurance companies due to inaccurate technical reserve calculations.

Premium reserves estimate the amount of funds insurance companies collects for future claim payments. In the technical guideline for the valuation of life insurance companies' obligations to policyholders following the solvency provisions issued by the Indonesian Actuaries Association (PAI *Persatuan Aktuaris Indonesia*), actuaries are expected to use the prospective method for calculating reserves for all future policy benefits. In his study, Norberg [11] confirmed that the prospective method is commonly used to calculate the premium reserves. Theoretically, there are several types of expansion to the prospective methods, and the Zillmer and the premium sufficiency methods are part of it. The Zillmer method is concerned with the capitalization element of the first year's policy costs to minimize the impact of surplus strain on the insurance company at the beginning of the policy year (Zillmer, [27]). Meanwhile, the premium sufficiency method does not pay attention to the capitalization element of the first-year policy costs but instead to the elements of the costs contained in the policy, such as agent commission fees and policy maintenance costs (Oktavian *et al.* [13]).

In calculating actuarial values, the interest rate assumption is crucial besides the mortality/morbidity and cost elements. In theory, the calculation of interest rates generally uses the assumption of constant interest, although, in fact, interest rates always move over time. Therefore, it is necessary to use stochastic interest rates to calculate actuarial values (Noviyanti and Syamsudin [12]). One of the popular stochastic interest rate models is the Vasicek stochastic interest rate model developed by Oldrich Vasicek to estimate the short rate of bonds which is the development of the Black and Scholes model (Vasicek [23]). According to Qiu *et al.* [15], Vasicek's interest rate has a negative drift from the average, so the movement of interest rates will return to its average. This characteristic results in Vasicek's stochastic interest rate better conforming to the economic law of supply and demand. When interest rates increase, the creditor will reduce the demand for capital, and then interest rates will decrease due to low demand. The same thing also happens if interest rates decrease, i.e., the demand for loanable funds will increase, then interest rates will move down because the demand for loans increases. Vasicek's stochastic interest rate model is easier to use in the analysis, but because the model is normally distributed for each t, it will produce negative interest rate results (Bech and Malkhozov [3]). The problem of negative interest rates has been mentioned by Bech and Malkhozov [3], where several developed countries apply negative interest rate policies for various purposes, but negative interest rates are generally applied during the economic recession.

Previous study on the calculation of premium reserves using stochastic interest rates has been carried out by Rinawati [16] using the Zillmer modified with Makeham method using Randleman-Bartter's stochastic interest rate model. In other studies, Sukanasih *et al.* [19] compared joint life insurance premium reserves using fixed and stochastic interest rates. This study aims to compare the Zillmer method and premium sufficiency using the Vasicek stochastic interest rate model. Similar studies has been conducted by Rinawati [16] and Sukanasih *et al.* [19], but this study calculates premium reserves without modification of the method and is intended for the individual insured. This research provides an alternative for calculating premium reserves for term life insurance products using the Vasicek stochastic interest rate and mortality rates available in Indonesia.

2. Actuarial Present Value of Term Life Insurance, Term Life Annuity, and Net Premiums of Term Life Insurance

Term life insurance provides benefit payments if the insured dies within the coverage period. Benefit payment can be paid either at the moment of death or at the end of the year [4]. However, in the actual implementation, the available information is generally in discrete form, so it can be said that the calculation of life insurance is generally discrete distribution, so the payment of benefits is made at the end of the year. The present value of an n-year term life insurance benefit with a benefit of 1 paid at the end of the year the insured dies is defined in Equation (1).

$$A^{1}_{x:\bar{n}|} = \sum_{k=0}^{n-1} v^{t+1}\ {}_{t|}q_x. \tag{1}$$

The payment of insurance product premiums by the policyholder is linked to the probability of the policyholder's life and how long the premium payment is. The concept of premium payment is connected to a life annuity; in practice, premiums are paid at the beginning of the period (Bowers *et al.* [4]). A term life annuity paid at the beginning of the period is described in Equation (2).

$$\ddot{a}_{x:\bar{n}|} = \sum_{t=0}^{n-1} v^t \; {}_tp_x. \tag{2}$$

A policyholder can pay the term life insurance premium as long as the coverage lasts or is shorter than the coverage period. The value of the premium rate can be calculated as follows (Bowers *et al.* [4]):

$$P^1_{x:\bar{n}|} = \frac{A^1_{x:\bar{n}|}}{\ddot{a}_{x:\bar{n}|}}. \tag{3}$$

If the premium payment is made in a shorter period than the insurance coverage period, where $m > n$, the premium rate can be calculated as follows (Bowers *et al.* [4]):

$$_mP^1_{x:\bar{n}|} = \frac{A^1_{x:\bar{n}|}}{\ddot{a}_{x:\bar{m}|}}. \tag{4}$$

3. Premium Reserve

The design of funding benefits paid to the beneficiary when the insured dies by the insurance company is called a reserve (Norberg [11]), and one type of reserve is a premium reserve. The premium reserve is the expected loss at the time t where the insured is still alive with the sum insured paid when the claim occurs, in this case, the insured's death. Premium reserves for term life insurance prospectively whose benefits are paid at the end of the year of the insured's death are calculated using the following formula (Bowers *et al.* [4]):

$$_tV^1_{x:\bar{n}|} = A^1_{x+t:\overline{n-t}|} - P^1_{x:\bar{n}|}\ddot{a}_{x+k:\overline{n-t}|}. \tag{5}$$

For term life insurance with a shorter premium payment period than the coverage period, the formula is described as follows (Bowers *et al.* [4]):

$$^m_tV^1_{x:\bar{n}|} = A^1_{x+t:\overline{n-t}|} - \; _mP^1_{x:\bar{n}|}\ddot{a}_{x+k:\overline{n-t}|} \tag{6}$$

4. Zillmer Method of Premium Reserve

Zillmer [27] states the mathematical notation I as the sum of the closing costs of the policy, P_x as the annual premium, a_x as the net premium for the first year, and β_x as the premium for the second year, and so forth. Then he explained the formulation of premium reserves for whole life insurance as follows (Zillmer, [27]):

$$_tV'_x = A_{x+t} - \beta\ddot{a}_{x+t}, \tag{7}$$

alternatively, it can also be formulated as follows (Zillmer, [27]):

$$_tV'_x = A_{x+t} - \left(P_x + \frac{I}{\ddot{a}_x}\right)\ddot{a}_{x+t}. \tag{8}$$

Because the equation described by Zillmer was first intended for whole life insurance, for the formulation of the Zillmer method by substituting Equation (8) with Equation (6) and Equation (7), we get an n-year term life insurance premium reserve with the insured aged x years with an annual premium paid for m years where $m < n$ and the benefits are paid at the end of the year of death, is formulated in Equation (9).

$$^m_tV^{1(Z)}_{x:\bar{n}|} = A^1_{x+t:\overline{n-t}|} - \frac{\alpha}{\ddot{a}_{x:\bar{n}|}}\ddot{a}_{x+t:\overline{n-t}|} - {}_m P^1_{x:\bar{n}|}\ddot{a}_{x+t:\overline{m-t}|}. \tag{9}$$

5. Premium Sufficiency Method of Premium Reserve

The premium sufficiency method extends the prospective reserve method by adding management costs, such as agent commission and maintenance costs (Oktavian *et al.* [13]). Premium sufficiency method for n-year term life insurance with the insured aged x years whose annual premium is paid for m years where $m < n$ and benefits are paid at the end of the year of death, is described in Equation (10).

$$ {}^{m}_{t}V^{1(PS)}_{x:\bar{n}|} = A^{1}_{x+t:\overline{n-t}|} - (1-\beta)_{m}\, {P'}^{1}_{x:\bar{n}|}\ddot{a}_{x+t:\overline{m-t}|} + \gamma\ddot{a}_{x+t:\overline{m-t}|} + \gamma' \left(\ddot{a}_{x+t:\overline{n-t}|} - \ddot{a}_{x+t:\overline{m-t}|}\right). \quad (10) $$

By reformulating Equation (10), we get the calculation of premium reserves using the premium sufficiency method for n-year term life insurance with the insured aged x whose annual premium is paid for m years where $m < n$ and the benefits are paid at the end of the year of death. The new formula is described in Equation (11).

$$ {}^{m}_{t}V^{1(PS)}_{x:\bar{n}|} = A^{1}_{x+t:\overline{n-t}|} - \left({}_{m}P^{1}_{x:\bar{n}|} + \frac{\alpha}{\ddot{a}_{x:\bar{m}|}}\right)\ddot{a}_{x+t:\overline{m-t}|} + \gamma' \left(\ddot{a}_{x+t:\overline{n-t}|} - \frac{\ddot{a}_{x:\bar{n}|} - \ddot{a}_{x:\bar{m}|}}{\ddot{a}_{x:\bar{m}|}}\ddot{a}_{x+t:\overline{m-t}|}\right). \quad (11) $$

6. Vasicek Stochastic Interest Rate

Oldrich Vasicek developed the Vasicek stochastic interest rate model in 1977, which aims to forecast short rates based on market risk and is usually used to determine future interest rate movements. The movement of interest rates in the next period is predicted by looking at the interest rate movement from the previous periods. A unique feature of this model is the result of the calculation of interest rates which can be negative. Vasicek illustrates the stochastic interest rate model as follows (Vasicek, [23]):

$$ dr = a(\gamma - r) + \rho\, dz. \quad (12) $$

Vasicek assumes a stochastic interest rate using the Ornstein-Uhlenbeck process with constant coefficients (Zeytun and Gupta, [25]). To simplify the calculation in finding the value of the Vasicek stochastic interest rate, Zeytun and Gupta [25] rewrite the equation that Vasicek has previously stated as follows:

$$ dr(t) = k(\theta - r(t))\,dt + \sigma\, dW(t). \quad (13) $$

In Equation (12), Vasicek [23] states that $a > 0$ so that the Ornstein-Uhlenbeck process in the equation is said to be an elastic random walk. Random walk is a stochastic process where the rate of change t is discrete (Sukarnasih *et al.*, [19]). Furthermore, elastic random walk is a Markov process customarily distributed (Szabados, [21]). The Markov process is a stochastic process for predicting the future, and it is known that current conditions do not affect the predictions carried out in the past (Hull, [7]). Bayazit [2] states that $W(t)$ in the Vasicek model is a Wiener process. To solve stochastic differential equations, we generally use the itô process (Szabados, [21]), so that the stochastic interest rate of the Vasicek model is formulated as follows (Medikasari, [9]):

$$ r(t) = re^{-kt} + \theta\left(1 - e^{-kt}\right) + \sigma \int_0^t e^{-k(t-s)}\, dW(s). \quad (14) $$

In Equation (13), the values of k, θ, and σ are the interest rate parameters of the Vasicek model, which have a constant positive value. Then the Ordinary Least Square (OLS) method is used to get the value of the parameters needed in this study. Sypkens [20] exemplifies the formula as follows:

$$ S_x = \sum_{i=1}^{n} x_{t_{i-1}} \qquad S_y = \sum_{i=1}^{n} x_{t_i}. $$

$$ S_{xx} = \sum_{i=1}^{n} x^2_{t_{i-1}} \qquad S_{yy} = \sum_{i=1}^{n} x^2_{t_i} \qquad S_{xy} = \sum_{i=1}^{n} x_{t_{i-1}} x_{t_i}. \quad (15) $$

The x_{t_i} value in this study refers to Bank Indonesia's reference interest rate data for 2017-2021. Then Equation (12) is transformed into:

$$x_{t_{i+1}} = ax_{t_{i+1}} + b + \varepsilon. \tag{16}$$

Then the calculation for parameter estimation of k, θ, and σ are obtained as follows (Sypkens, [20]):

$$\begin{aligned}\check{k} &= -\frac{\ln\left(\frac{nS_{xy}-S_xS_y}{nS_{xx}-S^2{}_x}\right)}{\Delta t}\\ \check{\theta} &= -\frac{S_y - \left(\frac{nS_{xy}-S_xS_y}{nS_{xx}-S^2{}_x}\right)S_x}{n\left(1-\left(\frac{nS_{xy}-S_xS_y}{nS_{xx}-S^2{}_x}\right)\right)}\\ \check{\sigma} &= \check{\varepsilon}_{sd}\sqrt{\frac{-2\ln\left(\frac{nS_{xy}-S_xS_y}{nS_{xx}-S^2{}_x}\right)}{\Delta t\left(1-\left(\frac{nS_{xy}-S_xS_y}{nS_{xx}-S^2{}_x}\right)^2\right)}}\end{aligned} \tag{17}$$

where

$$\check{\varepsilon}_{sd} = \sqrt{\frac{nS_{yy} - S_y^2 - \check{a}\left(nS_{xy} - S_xS_y\right)}{n\left(n-2\right)}}, \tag{18}$$

and

$$\check{a} = \frac{nS_{xy} - S_xS_y}{nS_{xx} - S_x^2}. \tag{19}$$

After getting the parameter values from the Vasicek stochastic interest rate model, the values of the Vasicek stochastic interest rate can be calculated using the formula described by Hull [7] in the Equation (20).

$$r\left(t+1\right) = r\left(t\right) + k\left(\vartheta - r\left(t\right)\right)\Delta t + \sigma\varepsilon\Delta t. \tag{20}$$

Then the discount rate for the stochastic interest rate model is as follows (Bowers *et al.* [4]):

$$v^t = \frac{1}{\left(1 + \left(r(t) + k\left(\vartheta - r(t)\right)\Delta t + \sigma\varepsilon\sqrt{\Delta t}\right)\right)^t}. \tag{21}$$

7. Premium Reserve Calculation

In this study, the calculation of the actuarial value of term life insurance, term life annuities, and term life insurance premiums is applied to male and female insureds aged 30 years with an insurance period of 20 years and a premium payment duration of 10 years and using mortality data from TMI IV 2019. At the same time, we are calculating the estimated value of the Vasicek stochastic interest rate using the OLS method as a parameter determination and the Bank Indonesia reference rate for the 2017-2021 calculation of the Vasicek stochastic interest rate. From the reference interest rate data from Bank Indonesia, the Vasicek stochastic interest rate can be calculated by first calculating the estimated parameters of the Vasicek model, where $\Delta t = 1$ and $r\left(0\right) = 3.50\%$. From Equation (15) and Equation (17), the parameter estimation is described in Table 1.

Table 1. Vasicek parameter estimation value.

$\check{k}$	0.175234355
$\check{\theta}$	0.008451327
$\check{\sigma}$	0.06325327859
$\check{\varepsilon}_{SD}$	0.05809542181
Δt	1

So the estimated value of the Vasicek interest rate for 20 years is given in Table 2.

Table 2. Vasicek Interest Rate Estimation.

t	$r(t)$	v^t
1	3.40%	0.967096957
2	3.32%	0.936736688
3	2.45%	0.929859104
4	2.54%	0.904562889
5	2.61%	0.879131662
6	2.67%	0.853859596
7	2.72%	0.828951660
8	2.76%	0.804546302
9	2.79%	0.780732953
10	2.82%	0.757565381
11	2.84%	0.735071752
12	2.86%	0.713262152
13	2.87%	0.692134152
14	2.88%	0.671676753
15	2.89%	0.651874036
16	2.90%	0.632705921
17	2.91%	0.614151041
18	2.92%	0.596187113
19	2.92%	0.578791789
20	2.92%	0.561943126

If depicted on a graph, as shown in Figure 1, Vasicek's stochastic interest rate will be close to the average, following the theory proposed by Hull [7].

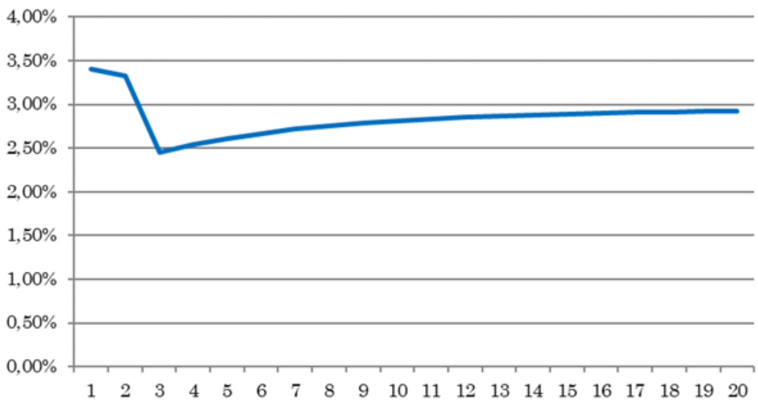

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Figure 1. Vasicek stochastic interest rate.

From the Vasicek model stochastic interest rate data and mortality table data, the actuarial present value of term life insurance can be calculated according to Equation (1). However, based on Equation (9) and Equation (11), it is necessary to calculate the actuarial present value of term life insurance benefits for the insured aged $30 - t$ years with an insurance period of $20 - t$ years where $t = 0, 1, 2, \ldots, 20$. The calculation results are available in Table 3.

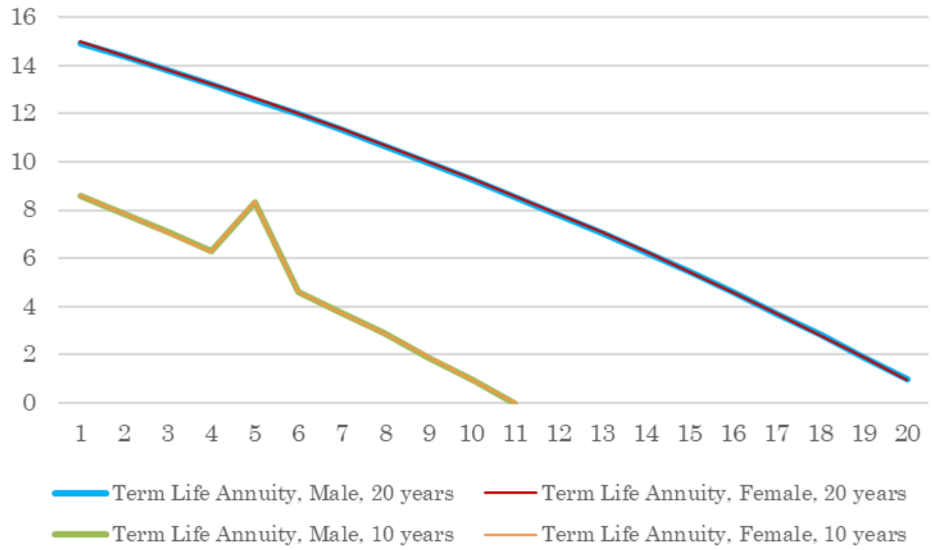
The premium paid in this study is 10 years, while the term life insurance contract is 20 years. Therefore, to calculate premiums and premium reserves based on Equation (9) and Equation (11), it is necessary to calculate the present value of a term life annuity with a period

TABLE 3. Actuarial present value of 20 year term life insurance.

t	x	$A^{1}_{30+t:\overline{20-t}\vert}$ Male	Female
0	30	0.026986	0.018058
1	31	0.027077	0.018052
2	32	0.027113	0.018007
3	33	0.027092	0.017921
4	34	0.027013	0.017783
5	35	0.026874	0.017592
6	36	0.026652	0.017335
7	37	0.026334	0.017011
8	38	0.025898	0.016607
9	39	0.025329	0.016119
10	40	0.024584	0.015536
11	41	0.023636	0.014832
12	42	0.022458	0.014006
13	43	0.021011	0.013021
14	44	0.019266	0.011872
15	45	0.017171	0.010533
16	46	0.014684	0.00897
17	47	0.011751	0.007135
18	48	0.008325	0.005028
19	49	0.004458	0.002679
20	50	0	0

of $20-t$ years with $t = 0, 1, 2, \ldots 20$ and $10-t$ with $t = 0, 1, 2, \ldots, 10$. The calculation results for the present value of a $20-t$ years with $t = 0, 1, 2, \ldots 20$ is available in Table 4.

Furthermore, the calculation results for the present value of a $10-t$ term life annuity with $t = 0, 1, 2, \ldots, 10$ is available in Table 5.



2.png

FIGURE 2. Term life annuity.

TABLE 4. Present value of 20 year due life annuity.

t	x	$\ddot{a}_{x+t:\overline{20-t}\rvert}$	
		Male	Female
0	30	14.92363	14.97355
1	31	14.36744	14.41616
2	32	13.79497	13.84229
3	33	13.20561	13.25135
4	34	12.59873	12.64284
5	35	11.97364	12.01612
6	36	11.32989	11.37062
7	37	10.66684	10.70563
8	38	9.983905	10.02049
9	39	9.280353	9.314448
10	40	8.555662	8.586777
11	41	7.809055	7.836819
12	42	7.039708	7.063724
13	43	6.246816	6.26686
14	44	5.42948	5.445375
15	45	4.5869	4.598606
16	46	3.718243	3.725976
17	47	2.822784	2.827052
18	48	1.899918	1.901464
19	49	0.967097	0.967097
20	50	0	0

TABLE 5. Present value of a 10-year due life annuity.

t	x	$\ddot{a}_{x+t:\overline{10-t}\rvert}$	
		Male	Female
0	30	8.609195	8.617925
1	31	7.856538	7.864034
2	32	7.08071	7.086937
3	33	6.280951	6.285916
4	34	8.326174	8.330332
5	35	4.606859	4.609602
6	36	3.73146	3.733266
7	37	2.879104	2.879104
8	38	1.902532	1.902896
9	39	0.967097	0.967097
10	40	0	0

The calculation of the actuarial present value of term life insurance and term life annuity values shows that these values are higher for male insureds due to the higher mortality rate for men than women. According to Lemaitre *et al.* [8], the cause of the higher male mortality rate is due to the biological structure of the human body. In addition to biological factors, according to Shmerling [18], men tend to take high risks, have dangerous jobs, are more prone to depression, and are less likely to see a doctor immediately when experiencing illness. Then it can be seen in Figure 3 that the actuarial present value of term life insurance decreases over time, and this is because if the contract ends, then the insurance coverage period ends so that the actuarial present value of life insurance is no longer needed.

Based on Equation (4), the annual premium rate for term life insurance with a payment period of 10 years can be calculated as follows:

3.png

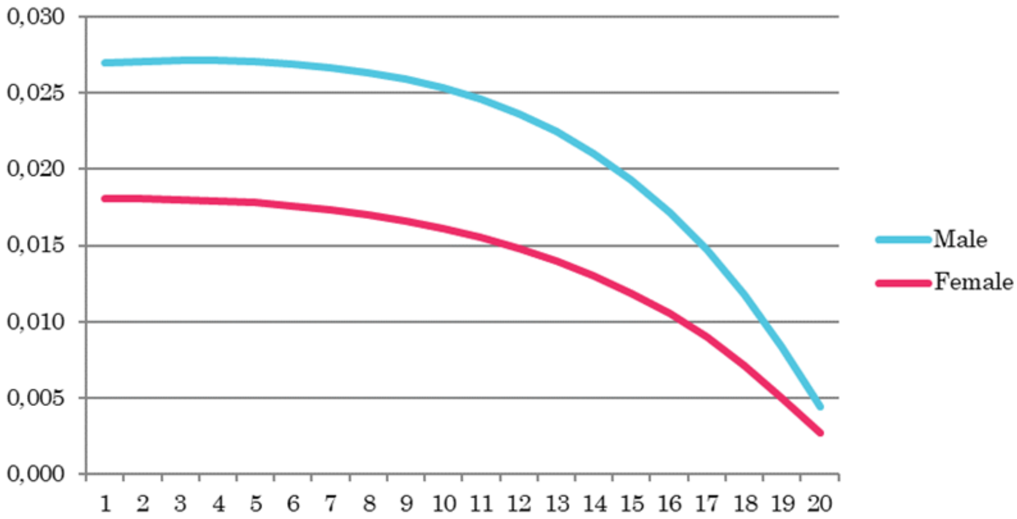


Figure 3. Actuarial present value of term life insurance

(a) Male Insured

$$ {}_{10}P^{1}_{30:\overline{20}|} = \frac{0.026986}{8.609195} = 0.003135. $$

With a sum insured of 1, the annual net premium is 0.003135.

(b) Female Insured

$$ {}_{10}P^{1}_{30:\overline{20}|} = \frac{0.018058}{8.617925} = 0.002095. $$

With a sum insured of 1, the annual net premium is 0.002095.

The premium reserve of the Zillmer method can be calculated using Equation (9), while the premium reserve of the sufficiency premium method uses Equation (11). The following are the results of calculating premium reserves for male and female insured using the Zillmer method and the premium sufficiency method.

The calculation of premium reserves using the Zillmer method in this study indicates that this policy had a negative reserve value at the beginning of the year. The negative reserve value at the beginning of the year can happen because the accumulated insurance costs exceed the accumulated net premiums, or it can be said that the value of future premiums is borrowed to pay policy costs, so it is assumed that all future premiums will be paid by the policyholder (Wurren, [24]). A study by Roach [17] stated that Zillmer reserves produced a negative value at the beginning of the year, and this value was not included in the series of premium reserves and was considered zero. While the calculation of premium reserves using the premium sufficiency method in this study seemed to decrease over time but had increased in the middle of the policy year but, in the end, decreased. This finding is also similar to research conducted by Ariza [1], where the premium reserve of the premium sufficiency method increases at the beginning of the policy year, but over time the value of the premium reserve decreases. The calculation of premium reserves in this study indicates that using the Zillmer method, the premium reserves produced are lower than using the premium sufficiency method due to the use of different cost elements. By using both methods, the value of the premium reserve for male is higher than for female because the mortality factor for male is higher than for female.

Table 6. The results of the calculation of premium reserves using the Zillmer Method and the Premium Sufficiency Method for the Male and Female Insured.

t	Zillmer Method		Premium Sufficiency Method	
	Male	Female	Male	Female
0	-0.0250000	-0.0250000	0.061092	0.061179
1	-0.0216187	-0.0224956	0.065686	0.064926
2	-0.0181919	-0.0199541	0.070372	0.068756
3	-0.0147179	-0.0173754	0.075153	0.072670
4	-0.0201910	-0.0207807	0.041655	0.041155
5	-0.0076251	-0.0121290	0.085003	0.080727
6	-0.0040248	-0.0094718	0.090050	0.084857
7	-0.0005598	-0.0068957	0.094500	0.088450
8	0.0032094	-0.0041102	0.100295	0.093271
9	0.0067512	-0.0014587	0.105200	0.097300
10	0.0102513	0.0011991	0.11014	0.101403
11	0.0105540	0.0017480	0.101726	0.093201
12	0.0106647	0.0022125	0.092855	0.084643
13	0.0105464	0.0025574	0.083479	0.075689
14	0.0101705	0.0027806	0.073561	0.066326
15	0.0094874	0.0028554	0.063040	0.056519
16	0.0084556	0.0027488	0.051867	0.046229
17	0.0070222	0.0024148	0.039979	0.035405
18	0.0051421	0.0018535	0.027324	0.024043
19	0.0028382	0.0010648	0.014129	0.01235
20	0.0000000	0.0000000	0	0

4.png

Figure 4. Comparison of the Zillmer Method and the Premium Sufficiency Method for the Male and Female Insured

8. Effect of Reserves on the Balance Sheet

According to Das *et al.* [5], insurance companies have different characteristics compared to other financial service companies because the purpose of insurance companies is to earn profits by protecting customers from the risk of financial loss. To be able to protect customers, insurance companies need the ability to meet ongoing obligations or what is called solvency (Thorbun, [22]). This solvency provision causes regulations for insurance companies to differ from other financial service companies. OJK Regulation No. 71/POJK.05/2016 (POJK No. 71/POJK.05/2016) concerning Financial Soundness of Insurance Companies and Reinsurance Companies regulates the level of solvency. The regulation stated that the solvency level is the difference between the amount of admitted assets to be reduced by the total liabilities, or in other words, a measurement of the ability of an insurance company to fulfill its obligations to policyholders.

The calculation of the solvency level includes two things, namely, assets and liabilities. The assets referred to in POJK No. 71/POJK.05/2016 are admitted assets, which are considered in calculating the solvency level. The admitted assets can be divided into two types, namely, in the form of investment and non-investment. Then, the liabilities referred to in the calculation of the solvency level are all company liabilities, including technical reserves. Technical reserves include premium reserves, reserves for unearned premiums, reserves for PAYDI, claims reserves, and reserves for catastrophic risk. From the explanation above, it can be concluded that assets have a relationship with liabilities. This conclusion follows the basic accounting equation theory: assets equal liabilities plus equity (Prot, [14]). If there are changes in assets, it will undoubtedly affect liabilities and equity and vice versa. In this study, premium reserves are made based on the stochastic interest rate so that it is expected to reflect actual liabilities.

5.png

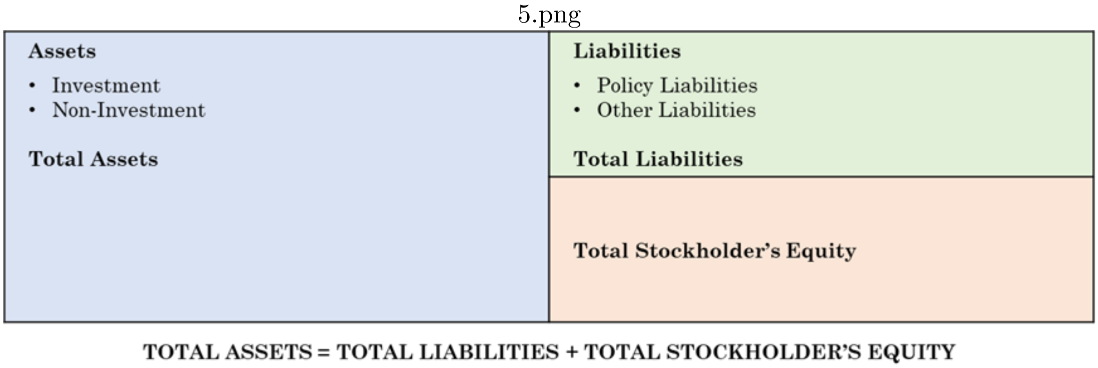


FIGURE 5. Basic accounting equation

Source: Ellizabeth Mulligan and Gene Stone,Accounting and Financial Reporting in Life and Health Insurance Companies, [10]

The calculation of premium reserves in this study indicates that the value of the premium reserve of the Zillmer method is smaller than the premium sufficiency method for both male and female insured. Considering conservatism's principle that estimates the lowest possible assets and income while the highest possible liabilities and expenses (Zhang, [26]), the premium sufficiency method is better than the Zillmer method. Zhang [26] suggests that insurance companies apply the principle of conditional conservatism, where insurance companies will evaluate reserves by reducing the value of reserves at the end of the period when there is a possible scenario that the insurance company overvalued reserves in the previous period. According to Zhang [26], insurance companies apply the principle of conditional conservatism in order to comply with regulations regarding solvency. Furthermore, when referring to the basic accounting equation, the valuation of reserves will certainly impact the value of assets and/or equity. If the reserve value has to be increased, the company's assets must also be increased because it can impact the equity reduction. The reduced equity of the insurance company will impact the decrease in the company's solvency level.

9. Conclusion

Vasicek's interest rate model is influenced by the parameter's value so that interest moves over time, and the movement of interest rates approaches the average value. The results of this study indicate that the reserve of term life insurance premiums with the Vasicek stochastic interest rate on the premium sufficiency method produces a higher value than the Zillmer method. This difference is caused by using fees in the Zillmer method, which focuses on the agent commissions only, while the premium sufficiency method emphasizes agent commission fees and policy maintenance costs. Based on the principle of conservatism, the premium sufficiency method is better than the Zillmer method because it produces a higher reserve value. The Zillmer method is more suitable for insurance companies that are more concerned about capital adequacy because a surplus strain condition in companies that are not appropriately capitalized will cause the surplus to fall past the minimum limit and lead to insolvency.

References

[1] Ariza, F., 2019, Penentuan cadangan premi menggunakan metode premium sufficiency pada asuransi jiwa berjangka. *Bachelor thesis, Universitas Islam Negeri Sultan Syarif Kasim Riau.*

[2] Bayazit, D., 2004, Yield curve estimation and prediction with vasicek model. *Master thesis, The Graduate School of Applied Mathematics of The Middle East Technical University.*

[3] Bech, M.L., and Malkhozov, A., 2016, How have central banks implemented negative policy rates?, *BIS Quarterly Review March, Pages 31–42.*

[4] Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A., Nesbitt, C.J., *Actuarial mathematics, The Society of Actuaries, Schaumburg.*

[5] Das, U.S., Davies, N., and Podpiera, R., 2003, Insurance and issues in financial soundness, *IMF Working Paper, Volume 2003, Issue 138.*

[6] Deloitte, 2020, Impact of Covid-19 on the Insurance Industry, *https://www2.deloitte.com/ie/en/pages/covid-19/articles/impact-COVID-19-insurance-industry.html, on August 2022.*

[7] Hull, J.C., 2014, *Options, futures, and other derivatives*, 9th ed., Prentice Hall, Upper Saddle River.

[8] Lemaitre, J-F., Ronget, V., Tidiere, M., Allaine, D., Berger, V., Cohas., Aurelie., Colchero, Fernando., Conde, Dalia A., Garratt, M., Liker, A., Marais, G.A.B., Scheuerlein, A., Szekely, T., and Gaillard, J-M., 2020, Sex differences in adult lifespan and aging rates of mortality across wild mamals, *Proceedings of The National Academy of Sciences of the United States of America, Volume 117, Issue 15.*

[9] Medikasari, W., 2020, Aplikasi suku bunga konstan dan suku bunga stokastik dalam perhitungan aktuaria asuransi dwiguna. *Bachelor thesis, Universitas Islam Negeri Jakarta Syarif Hidayatullah Jakarta.*

[10] Mulligan, E.A., Stone, G., 1997, *Accounting and financial reporting in life and health insurance companies*, Life Office Management Association Inc, New York.

[11] Norberg, R., 1991, Reserves in life and pension insurance, *Scandinavian Actuarial Journal, Pages 3-24.*

[12] Noviyanti, L., Syamsuddin, M., 2016. Life insurance with stochastic interest rate, *Persatuan Aktuaris Indonesia.*

[13] Oktavian, M.R., Devianto, D., and Yanuar, F., 2014, Kajian metode zillmer, full preliminary term dan premium sufficiency dalam menentukan cadangan premi pada asuransi jiwa dwiguna, *Jurnal Matematika UNAND, Volume 3, Issue 4, Pages 160-167.*

[14] Prot, N.P., 2013, Evolution of accounting equation: evidence of companies quoted on dar es salaam stock exchange-tanzania, *Journal of Finance and Accounting, Volume 1, Issue 4, Pages 55-63.*

[15] Qiu, D., Hu, Y., and Wang, L., 2011, The application of option theory in participating life insurance pricing based on vasicek model, *Quantitative Financial Risk Management, Pages 39-46.*

[16] Rinawati, R.N., Hasriati, 2017, Cadangan zillmer berdasarkan distribusi makeham dengan menggunakan tingkat bunga model rendleman-bartter, *Student Paper Degree, Repository Universitas Riau.*

[17] Roach, W., Alksnis, G., 1991, Controversies surrounding zillmer reserves, *actuarial research clearing house, Pages 321-334.*

[18] Shmerling, R.H., 2020, Why Men Often Die Earlier Than Women, Harvard Health Blog, *https://www.health.harvard.edu/blog/why-men-often-die-earlier-than-women-201602199137.*

[19] Sukanasih, N.K., Widana, I.N., and Jayanegara, K., 2018, Cadangan Premi Asuransi Joint-Life dengan Suku Bunga Tetap dan Berubah Secara Stokastik, *E-Jurnal Matematika, Volume 7, Issue 2, Pages 79-87.*

[20] Sypkens, R., 2010, Risk properties and parameter estimation on mean reversion and garch models. *Master thesis, University of South Africa.*

[21] Szabados, T., 1996, An elementary introduction to the wiener process and stochastic integrals, *Studia Scientiarum Mathematicarum Hungarica, Pages 249-297.*

[22] Thorbun, C., 2004, *On the measurement of solvency of insurance companies: recent developments that will alter methods adopted in emerging markets*, World Bank Policy Research Working Paper, Washington, D.C.

[23] Vasicek, O., 1977, An equilibrium characterization of the term structure, *Journal of Financial Economics, Pages 177-188.*

[24] Wurren, D.B., 1986, A discussion of negative reserves, *The Actuary, Volume 11, Issue 2, Pages 83-86*.
[25] Zeytun, S., Gupta A., 2007, A comparative study of the vasicek and the cir model of the short rate, *Fraunhofer-Institut für Techno- und Wirtschaftsmathematik*.
[26] Zhang, J., 2020, Essays on loss reserving and accounting conservatism. *PhD thesis, the Temple University Graduate Board*.
[27] Zillmer, A., 1863, *Contributions to the theory of life insurance premium reserves*, Press of Theodore von der Nahmer.