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Analysis of Term Life Insurance Reserves Using the Full Preliminary Term and Fackler Method with an Extended Vasicek Interest Rate Based on Ordinary Least Squares

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Abstract

Premium reserves have an essential role in maintaining financial sustainability and risk control in life insurance companies. This study aims to analyze the calculation of premium reserves for term life insurance products using the Full Preliminary Term (FPT) and the Fackler method under stochastic interest rates modelled by the Extended Vasicek model. The novelty of this study lies in integrating an Ordinary Least Squares (OLS) estimated Extended Vasicek interest rate model with two different premium reserve methods, namely FPT and Fackler, using historical Bank Indonesia benchmark interest rate data for 2010-2025. The results show that the FPT method produces a zero reserve in the first year and reaches a maximum reserve of IDR 2,308,267 in the 9th year, whereas the Fackler method reaches a maximum reserve of IDR 2,507,184 in the 9th year. Both methods produce a reserve of zero at the end of the 15-year coverage period. These results demonstrate that the Fackler method generates higher reserves than the FPT method during policy years 1 to 14, while the absolute difference between the two methods gradually decreases as the policy approaches maturity.

Keywords: *Extended vasicek, fackler, full preliminary term, life insurance reserves, ordinary least squares*

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1. INTRODUCTION

Life insurance is one of the main instruments in the community's financial protection system, providing financial guarantees to policyholders and heirs in the event of death or other risks covered in the insurance contract. In the midst of increasingly dynamic and uncertain economic and social conditions, life insurance is an essential means of managing long-term financial risks and providing individuals and families with a sense of security. Along with increasing public awareness of the importance of risk protection, the role of life insurance in maintaining household economic stability and supporting the development of the national financial sector is becoming increasingly significant [1].

Reserve calculations play an essential role because they reflect the company's obligations to policyholders. Reserves are prepared to ensure the company's ability to meet future claims payments in accordance with the applicable policy, thereby serving as one of the leading indicators of insurance companies' financial health [2]. Therefore, the accuracy of reserve calculations significantly influences the company's sustainability and policyholders' confidence.

The calculation of premium reserves can be done by various methods, including the Full Preliminary Term (FPT) and Fackler methods. The FPT method sets the reserve at the end of the first policy year to zero, with the first-year net premium used to cover death claims occurring during the first year. The method defers the formation of reserves at the beginning of the contract and is commonly associated with the treatment of high initial acquisition costs, such as agent commissions and administrative expenses This approach can reduce the initial financial burden associated with reserve formation and is considered to better reflect the financial condition of companies, particularly for newly issued policies [3]. Meanwhile, the Fackler method calculates reserves based on the accumulated value of premiums and benefits, resulting in a reserve pattern that may differ from that of the FPT method.

Although the reserve calculation method has an important role, the accuracy of the calculation results is also heavily influenced by interest rate assumptions. Higher interest rates will result in a lower present value of liabilities, and vice versa, thus directly affecting the amount of reserves that must be formed [4]. Therefore, determining the appropriate interest rate is a crucial factor in calculating premium reserves. Previous studies have incorporated stochastic interest rate models into life insurance reserve calculations to account for interest rate uncertainty. Ratam and Marisa [19] applied the Extended Vasicek model to term life insurance reserve calculations using the Fackler method. However, their study focused on the Fackler method and did not compare the resulting reserves with those obtained using the Full Preliminary Term (FPT) method. In addition, previous studies using stochastic interest rate models have employed different parameter estimation approaches, which may produce different interest rate dynamics and consequently affect reserve calculations. Therefore, a comparative analysis of FPT and Fackler reserve methods under the same Extended Vasicek interest rate framework remains relevant. This study addresses this gap by applying the Extended Vasicek model with Ordinary Least Squares (OLS) parameter estimation and comparing the reserve patterns generated by the FPT and Fackler methods using Bank Indonesia benchmark interest rate data for 2010–2025.

One of the most widely used models in interest rate modeling is the Extended Vasicek, which can capture stochastic interest rate movements and more realistically reflect market dynamics. In this study, the parameters of the Extended Vasicek model are estimated using the Ordinary Least Squares (OLS) approach based on historical data on Bank Indonesia's benchmark interest rate (BI Rate) for the period 2010–2025. The OLS method was chosen for its simple structure, ease of interpretation, and ability to capture short-term linear trends relevant to domestic financial market conditions [5]. The BI Rate was first introduced and used as a benchmark interest rate to increase transparency and accountability in monetary policy and to facilitate public understanding [6]. In addition, the BI Rate is used as a basis for interest rate data due to the availability of adequate historical data and its role as Indonesia's benchmark interest rate.

This research focuses on term life insurance products widely used by the public as a financial protection instrument, so the analysis of premium reserves is essential to support healthy, sustainable life insurance industry practices. To the author's knowledge, previous studies have examined the use of stochastic interest rates modeled by the Extended Vasicek process, with parameters estimated using the Ordinary Least Squares method. However, the application of the interest rate model in calculating life insurance premium reserves, especially when combined with the Full Preliminary Term and Fackler methods, has not been widely studied. The combination of these methods is motivated by the need to consider both interest rate uncertainty and differences in reserve calculation approaches. The Extended Vasicek model is used to capture the stochastic behaviour of interest rates, while the Full Preliminary Term and Fackler methods are applied to examine differences in reserve patterns under the same interest rate assumptions. Comparing these two reserve methods within a common stochastic interest rate framework provides a basis for evaluating how the choice of reserve method affects the development of term life insurance reserves. In addition, this study incorporates the BI rate data for 2010-2025, including the latest available observations for 2025. Therefore, this study aims to calculate and analyze term life insurance premium reserves using the Full Preliminary Term and Fackler methods with interest rates obtained from the OLS-based Extended Vasicek model. The results of the research are expected to contribute both academically and practically, especially in supporting reserve management and risk management in the life insurance industry in Indonesia.

2. METHOD

2.1 Descriptive Statistical Analysis

Statistics used to analyze data by describing the data collected are called descriptive statistics [7]. The purpose of descriptive statistical analysis is to find out the characteristics of the data before further analysis is carried out. Descriptive statistics include presenting data center measures, such as the mean, median, maximum, minimum, and standard deviation.

2.2 Classical Assumtion Tests

The classical assumption test are conducted to assess whether the OLS regression model used to estimate the parameters of the Extended Vasicek model satisfies the relevant assumptions. Based on the discretized Extended Vasicek model, the regression involves the BI Rate at the current period and the following periode. The relevant classical assumption tests include normality, autocorrelation, and heteroscedasticity tests. A multicollinearity test is not required because the regression model contains only one independent variable.

1. Normality test

   The normality test is conducted to determine whether the residuals of the regression moder are normally distributed. The the Jarque-Bera test is used to examine the normality of the model residuals [10]. The null hypothesis states that the residuals are normally distributed. If the $p - value$ of the Jarque-Bera test is greater than 0.05, the null hypothesis is not rejected, indicating that the residual are normally distributed.

2. Autocorrelation test
The autocorrelation tests is used to determine whether the residuals of the regression model are correlated across observations [11]. The Breusch-Godfrey test is employed to detect autocorrelation. The null hypothesis states that there is no autocorrelation in the residuals. If the $p - value$ is greater than 0.05, the null hypothesis is not rejected, indicating that there is no significant autocorrelation. Conversely, if the the $p - value$ is less than or equal to 0.05, the null hypothesis is rejected, indicating the presence of significant autocorrelation.
3. Heteroscedasticity test
The heteroscedasticity test was conducted to determine whether the variance of the regression model residuals is constant across observations. The Glejser test was employed to detect heteroskedasticity. The null hypothesis states that the residuals have constant variance. If the $p - value$ of the Glejser test are greater than 0.05, the null hypothesis is not rejected, indicating that heteroskedasticity is not present[8]. Conversely, if the the $p - value$ is less than or equal to 0.05, the null hypothesis is rejected, indicating the presence of heteroskedasticity.

2.3 Extended Vasicek

The Extended Vasicek one-factor model is a short-term interest rate model that follows *a mean-reverting* process, in which interest rates tend to return to their average value in the long term [12]. Vasicek Extended Model assumes that changes in interest rates are influenced by three parameters, namely constant parameters that indicate the rate return to its average (a), long-term average $(\theta(t))$, and volatility (σ). The variable $r(t)$ is a short-term interest rate, and $W(t)$ is a Wiener process or Brown's motion. The stochastic differential Equation of the Extended Vasicek model is as follows:

$$dr(t) = [\theta(t) - a\, r(t)]dt + \sigma\, dW(t)$$

The solution of the Extended Vasicek interest rate model is as follows [13]:

$$r(t) = r(0)e^{-at} + e^{-at}\int_0^t \theta(t)\, e^{au}du + \sigma e^{-at}\int_0^t e^{au}\,\sigma dW(u) \tag{1}$$

The Extended Vasicek interest rate model that has been obtained is then expressed in discrete form using the Euler method as follows:

$$r(t_{i+1}) = r(t_i)(1 - a\Delta t) + \theta\Delta t + \sigma\Delta W_i \tag{2}$$

2.4 Ordinary Least Squares

The Ordinary Least Squares (OLS) method minimizes the sum of squared errors of the model. In this study, the OLS method is used to estimate the parameters of the Extended Vasicek model based on the discretised from of the model. The discretized Extended Vasicek model can be expressed as follows:

$$r_{t+1} = \beta_0 + \beta_1 r_t + \varepsilon_t$$

where r_{t+1} represents the dependent variable, namely the BI rate at period $t+1$, while r_t represents the independent variable, namely the BI rate at period t. The parameter β_0 is the intercept, β_1 is the regression coefficient, and ε_t is the error term.

If Y is the $n\ x$ 1 - dimensional observation vector, X is the n x k data matrix of the regressor, beta is the k x 1 regression coefficient vector, and ε is the n x 1 error vector, the multiple linear regression model can be expressed as follows [14]:

$$Y = X\beta + \varepsilon \tag{3}$$

The usual smallest square estimator for parameter β is

$$\hat{\beta} = (X^T X)^{-1} X^T Y \tag{4}$$

With a covariance matrix of $\hat{\beta}$ as $cov(\hat{\beta}) = \sigma^2 (X^T X)^{-1}$ with σ^2expressing the variance of the error [15].

2.5 Commutation Symbol

Commutation symbols are notations used to simplify calculations in mortality tables, such as premium, reserve, and other insurance value calculations. The commutation symbols used in this study are as follows **[16]**:

1. Symbol D_x is the present value of the number of people alive at age x.
$$D_x = v^x l_x$$
With l_x expressing the number of people who are x years old and $v = \frac{1}{1+i}$ expressing the discount factor.
2. Symbol N_x is the sum of the present value of all people living from age x to the highest age w.
$$N_x = D_x + D_{x+1} + \cdots + D_{\omega-1}$$
With w being the highest age in a cohort.
3. The symbol C_x represents the present value of the benefit of death at age x.
$$C_x = v^{x+1} d_x$$
With v^{x+1} expressing the discount factor to be paid at the end of the year to $x+1$ and $d_x = l_x - l_{x+1}$ expressing the number of people who died at the age of x years, before reaching the age of $x+1$ years.
4. The symbol M_x is the sum of the present value of all death events from age x to the highest age w.
$$M_x = C_x + C_{x+1} + \cdots + C_{\omega-1}$$
With ω being the highest age in a cohort.

2.6 Life Annuity

A term life annuity is a living annuity whose payments are made over a specified period. According to **[16]**, the cash value of the initial term annuity of a life insurance participant who is x years old with a period of n years, in the commutation symbol, is expressed by

$$\ddot{a}_{x:\overline{n}|} = \frac{N_x - N_{x+n}}{D_x} \tag{5}$$

2.7 Term Life Insurance Premiums

In participating in life insurance, policyholders must make a number of payments called premiums. The amount of premiums paid by policyholders is greatly influenced by the type of life insurance and annuity [17]. The term life insurance single premium for a person aged x with a coverage period of n years and the sum insured 1 paid at the end of the policy year is notated with $A^1_{x:\overline{n|}}$. The term life insurance single premium is stated as follows :

$$A^1_{x:\overline{n|}} = \frac{M_x - M_{x+n}}{D_x} \tag{6}$$

Annual premiums are earned by dividing a single premium by a term life annuity. The annual premium of term insurance for n years for a person aged x, sum insured 1, and paid at the end of the policy year is

$$P^1_{x:\overline{n|}} = \frac{M_x - M_{x+n}}{N_x - N_{x+n}} \tag{7}$$

If the premium payment is for m years, the premium is as follows:

$${}_mP^1_{x:\overline{n|}} = \frac{M_x - M_{x+n}}{N_x - N_{x+m}} \tag{8}$$

2.8 Full Preliminary Term Method

Full Preliminary Term is an actuarial approach to calculating premium reserves that aims to modify the premium structure in the first year to be as low as possible without causing negative reserves. In this method, the net premium for the first year is used only to cover claims for deaths that occurred during the first year, so the reserve at the end of the first year is set to zero. For subsequent years, the reserve calculation is carried out assuming that the new policy is issued one year after the original policy, to the insured who is one year older, with a reduced premium payment period of one year, but with the policy maturity date remaining the same as the original policy. Therefore, the net premium from the second year onwards is equivalent to that for new policies issued at one year older, and the duration of premium payments is shorter.

In general, the reserves in the t year of term life insurance with the FPT method, with premium payments for m years with a coverage period of n years, namely [18].

$${}^m_tV^F_{x:\overline{n|}} = A^1_{x+t:\overline{n-t|}} - {}_{m-1}P^1_{x+1:\overline{n-1|}}\, \ddot{a}_{x+t:\overline{m-t|}} \tag{9}$$

2.9 Fackler Method

The Fackler method was first developed by David Parks Fackler, who is an actuary from the United States [19]. The Fackler method is one of the methods of calculating premium reserves with a retrospective approach [20]. The premium reserve with the Fackler method at the end of year t is the large difference between the premium per period multiplied by the present value of the annuity of the premium payments still to be paid after time t and the present value of the insurance benefit. The premium reserve with the Fackler method at the end of the year can be stated as follows:

$${}_tV = P\ {}_tU_x - \ {}_tk_x \tag{10}$$

With

$_tV$: Fackler method premium reserve at the end of the year t

P : Annual net premium

$_tU_x$: The present value of the premium payment annuity that will still be paid after time t by someone who is $x + t$ years old

$_tk_x$: The present value of the insurance benefits that will still be paid after time t by a person who is of the year $x + t$

3. RESULTS AND DISCUSSION

3.1 Descriptive Statistical Analysis

The data used in this study is the average BI Rate data in 2010-2025 [21] and uses the 2019 Indonesian Mortality Table (TMI) [22]. The BI Rate data used in this study is presented in **Table 1**.

Table 1. BI Rate Interest Rate Average

Years	BI Rate Average (%)
2010	6.50
2011	6.58
2012	5.77
2013	6.48
2014	7.54
2015	7.52
2016	6.00
2017	4.56
2018	5.10
2019	5.63
2020	4.25
2021	3.52
2022	4.00
2023	5.81
2024	6.10
2025	5.27

From the data in **Table 1**, a descriptive statistical analysis was carried out, which is presented in **Table 2** as follows:

Table 2. Descriptive Statistical Analysis

BI Rate	N	Maximum	Minimum	Mean	Std. Deviation
	16	7.54	3.52	5.76	1.17

Based on descriptive statistical analysis of average BI Rate data from 2010 to 2025, totaling 16 years, the average BI rate is 5.76%. The maximum value of the BI Rate occurred in 2014, at 7.54%, while the minimum occurred in 2021, at 3.52%. The standard deviation of 1.17 for the BI Rate data indicates a moderate degree of year-to-year variation.

3.2 Classical Assumption Tests

Classical assumption tests are used to assess whether the regression model satisfies the fundamental assumptions required for further statistical analysis.

1. Normality Test
   The normality test produced a p-value of $0.812 > 0.05$, indicating that the regression residuals were normally distributed.
2. Autocorrelation Test
   The Breusch-Godfrey autocorrelation test produced a $p - value$ of $0.1025 > 0.05$, indicating that there was no significant autocorrelation in the regression residuals.
3. Heteroscedasticity Test
   The heteroscedasticity test produced a significance value of $0.215 > 0.05$, indicating that there was no significant heteroscedasticity in the regression residuals.

3.3 Estimation of Ordinary Least Squares Parameters for the Extended Vasicek Interest Rate

The Extended Vasicek interest rate is a stochastic model with parameters a, θ, and σ, estimated by OLS. The Python estimation results yielded $a = 0.3540$, $\theta = 1.9327$, and $\sigma = 0.8406$. Based on **Equation (2)** and an initial interest rate of 6.5%, the Extended Vasicek interest rate model is obtained as follows:

$$r(t_{i+1}) = r(t_i)(1 - 0.3540\Delta t) + 1.9327\Delta t + 0.8406\Delta W_i \tag{11}$$

The model is estimated using annual BI Rate observations from 2010 to 2025. The annual frequency is selected to maintain consistency with the annual time horizon of the term life insurance reserve calculations. Accordingly, each annual observation represents the interest-rate condition for the corresponding year and provides the interest-rate assumption required for the subsequent reserve calculations. The 2010–2025 observation period is maintained consistently throughout the estimation and reserve calculation process. The following is a comparison of the BI Rate interest rate with the Extended Vasicek rate:

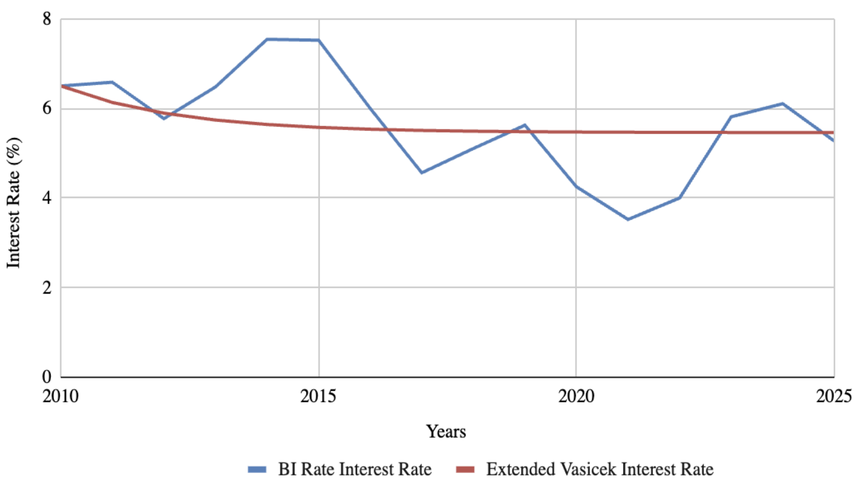

Figure 1. Comparison of BI Rate and Extended Vasicek Interest Rates

Case 1

The calculation of term life insurance premiums in case 1 uses the Full Preliminary Term method with a premium payment period of 15 years, a coverage period of 15 years and an insured amount of IDR 300,000,000. It is assumed that the age used is 45 years and the interest rate (i) uses OLS estimates from the annual average BI Rate data for 2010-2025 that has been obtained previously.

The completion of case 1 begins with determining the value of v and commutation value using TMI 2019 as follows:

Table 3. Commutation Value

Year	x	Interest Rate (%)	v	D_x	C_x
1	45	6.5000	0.9390	5,730.78	10.06
2	46	6.1315	0.9422	6,299.34	12.41
3	47	5.8934	0.9443	6,582.43	14.30
4	48	5.7396	0.9457	6,649.92	15.91
5	49	5.6403	0.9466	6,568.59	17.22
6	50	5.5761	0.9472	6,392.03	18.47
7	51	5.5347	0.9476	6,157.91	19.55
8	52	5.5079	0.9478	5,892.73	20.55
9	53	5.4906	0.9480	5,613.13	21.44
10	54	5.4794	0.9481	5,330.00	22.33
11	55	5.4722	0.9481	5,049.71	23.12
12	56	5.4676	0.9482	4,776.24	23.73
13	57	5.4645	0.9482	4,512.46	24.09
14	58	5.4626	0.9482	4,259.01	24.27
15	59	5.4613	0.9482	4,017.06	24.23
16	60	5.4605	0.9482	3,786.53	24.09

Furthermore, the insurance reserve is calculated using the FPT Method using **Table 3**, and the following results are obtained:

Table 4. Insurance Reserves with FPT Method

t	${}^{15}_{t}V^{FPT}_{45:\overline{15}\rvert}$
1	Rp0
2	Rp469,871
3	Rp890,901
4	Rp1,270,400
5	Rp1,608,777
6	Rp1,893,207
7	Rp2,113,701
8	Rp2,256,149
9	Rp2,308,267
10	Rp2,251,304
11	Rp2,071,424
12	Rp1,759,877
13	Rp1,313,953
14	Rp727,431
15	Rp0

Table 4 can be visualized as follows :

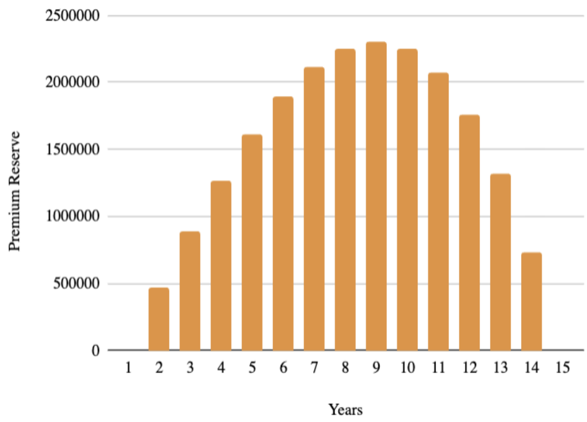

Figure 2. Full Preliminary Term Insurance Reserve

Case 2

The calculation of term life insurance premiums in case 2 uses the Fackler method with an insured period of 15 years, , a premium payment period of 15 years, and an insured amount of IDR 300,000,000. It is assumed that the age is 45 years, and the interest rate (i) is based on OLS estimates from the previously obtained annual average BI Rate data for 2010-2025.

The completion of case 2 begins with determining the value of v and the commutation value as shown in **Table 2**. Furthermore, the insurance reserve is calculated using the Fackler Method, and the following results are obtained:

Table 5. Insurance Reserves with Fackler Method

t	${}_tV^F_{45:\overline{15}\rceil}$
1	Rp470,394
2	Rp883,726
3	Rp1,263,001
4	Rp1,608,696
5	Rp1,917,429
6	Rp2,174,211
7	Rp2,367,703
8	Rp2,482,973
9	Rp2,507,184
10	Rp2,421,215
11	Rp2,210,951
12	Rp1,867,402
13	Rp1,387,679
14	Rp765,371
15	Rp0

Table 5 can be visualized as follows:

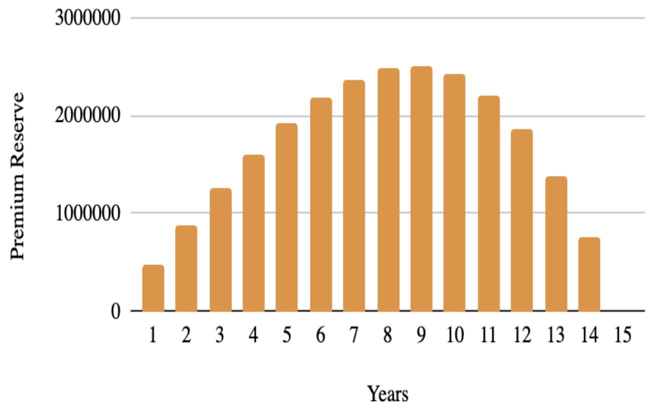

Figure 3. Fackler Insurance Reserve

To quantitatively compare the reserve values obtained using the FPT and Fackler methods, the reserve difference and percentage difference were calculated for each policy year. The difference was calculated as the Fackler reserve minus the FPT reserve, while the percentage difference was measured relative to the Fackler reserve. The results are presented in Table 6.

Table 6. Quantitative Comparison of Insurance Reserves Using FPT and Fackler Methods

t	${}_{t}^{15}V_{45:\overline{15}|}^{FPT}$	${}_{t}V_{45:\overline{15}|}^{F}$	Difference
1	Rp0	Rp470,394	Rp470,394
2	Rp469,871	Rp883,726	Rp413,855
3	Rp890,901	Rp1,263,001	Rp372,100
4	Rp1,270,400	Rp1,608,696	Rp338,296
5	Rp1,608,777	Rp1,917,429	Rp308,652
6	Rp1,893,207	Rp2,174,211	Rp281,004
7	Rp2,113,701	Rp2,367,703	Rp254,002
8	Rp2,256,149	Rp2,482,973	Rp226,824
9	Rp2,308,267	Rp2,507,184	Rp198,917
10	Rp2,251,304	Rp2,421,215	Rp169,911
11	Rp2,071,424	Rp2,210,951	Rp139,527
12	Rp1,759,877	Rp1,867,402	Rp107,525
13	Rp1,313,953	Rp1,387,679	Rp73,725
14	Rp727,431	Rp765,371	Rp37,940
15	Rp0	Rp0	Rp0

The reserve values obtained using the Fackler and Full Preliminary Term (FPT) methods show different patterns throughout the 15-year coverage period. As presented in Table X, the Fackler method produces higher reserve values than the FPT method during policy years 1 to 14. In the first year, the Fackler reserve is Rp470,394, whereas the FPT method produces a reserve of Rp0. The difference between the two methods then decreases as the policy progresses. For example, in the third year, the reserves are Rp1,263,001 for Fackler and Rp890,901 for FPT, resulting in an absolute difference of approximately Rp372,100. The decreasing difference becomes more apparent in the later policy years. In year 9, the Fackler reserve reaches its highest value of Rp2,507,184, compared with Rp2,308,267 under the FPT method, giving an absolute difference of

Rp198,917. Subsequently, the difference continues to decline, reaching Rp107,525 in year 12 and Rp37,940 in year 14. Although the reserve values under both methods decrease after reaching their respective maximum levels, the Fackler reserve remains higher than the FPT reserve until the end of year 14. In year 15, both methods produce a reserve of Rp0, and therefore no difference remains. Overall, the results indicate that the Fackler method produces a higher reserve in the earlier and middle stages of the policy, while the difference between the two methods gradually diminishes as the policy approaches maturity. The pattern suggests that the effect of the valuation method on the resulting reserve is more pronounced during the earlier policy years and becomes less significant toward the end of the coverage period.

4. CONCLUSION

The comparison demonstrates that the Fackler and FPT methods produce different reserve levels throughout the policy term, with the Fackler method consistently yielding higher reserves during the first 14 years. The maximum reserve reaches IDR 2,507,184 under the Fackler method and IDR 2,308,267 under the FPT method, both occurring in the 9th year. However, the difference between the methods gradually decreases as the policy approaches maturity. By the end of the 15-year coverage period, both methods produce a reserve of IDR 0. These findings indicate that the choice of valuation method has a greater effect on reserve determination during the earlier stages of the policy, whereas the results of the two methods become increasingly similar toward maturity.

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Second Author : Data curation, methodology refinement, data validation, analytical

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Authors state no conflict of interest.

Informed Consent
Not applicable.

Ethical Approval
Not applicable.

Data Availability
The data that support the findings of this study are available from the corresponding author, [ANIBR], upon reasonable request.

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