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Application of Annual Ratchet Method and Black-Scholes in The Calculation of Single Net Premium of Unit-Linked Endowment Life Insurance

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Abstract

Given the dynamic market conditions, the calculation of a single net premium for unit-linked endowment life insurance becomes increasingly crucial to ensure a balance between life protection and potential investment returns. Insurance companies need to take into account market volatility and economic uncertainty in the premium setting process so that the products offered remain relevant and competitive in the eyes of the public. This research aims to calculate the net single premium value of unit-linked endowment life insurance using Annual Ratchet. It also aims to calculate the net single premium of unit-linked endowment life insurance using the Black Scholes model and aims to compare the calculation of net single premium of unit-linked endowment life insurance with the minimum benefit of the Annual Ratchet and Black Scholes methods using prospective calculations. There are two methods that will be used, namely the Annual Ratchet method and the Black-Scholes model. The results of the calculation of the net single premium of unit-linked endowment life insurance for the insured aged 40 years using the Annual Ratchet method for women amounted to Rp. 10,955,968 and men amounted to Rp. 13,725,243. While the results of the calculation of the single net premium of unit-linked endowment life insurance for the insured using the Black Scholes model for women amounted to Rp. 14,073,580 and men amounted to Rp. 17,672,045. The single net premium of unit-linked endowment life insurance for ages 45, 50, and 55 years shows an increase, both for women and men. This is due to the higher risk of death that makes the net single premium increase from year to year and the value of the investment plays a role.

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1. INTRODUCTION

In the era of globalization and ever-changing economic dynamics, financial markets are often the arena of significant price fluctuations. These fluctuations can be caused by various factors, including changes in economic and political conditions or even exogenous factors [1]. The impact of these conditions causes significant market volatility, affecting a variety of financial instruments, including investments linked to life insurance products.

Life insurance is a financial instrument designed to provide financial protection to the family or heirs of the policyholder in the event of the insured's death. In its development, life insurance not only functions as protection but also as a means of investment through investment-based life insurance products, one of which is unit-linked life insurance. This product combines life protection with investment benefits, where a portion of the premium paid is allocated for investment in financial instruments such as stocks, bonds, or mutual funds [2].

Unit-linked insurance has become popular in the insurance market because it offers more flexibility than traditional insurance. This product is considered attractive to policyholders as it provides an opportunity to gain investment growth that can be used as future funds [3]. However, given that most of the premiums paid by policyholders are invested in volatile financial market instruments, insurance companies are faced with the challenge of determining premiums that can reflect the risks and potential benefits to be obtained. This situation is a challenge for insurance companies in determining premiums that are fair and in accordance with the promised benefits. Premiums that are too low can result in risks for the company to fulfill obligations to policyholders, while premiums that are too high will reduce the attractiveness of the product in the eyes of consumers [4].

Insurance companies face great challenges in determining unit-linked endowment life insurance premiums, especially in maintaining a balance between sufficient protection value and the potential for competitive investment returns. Competitive insurance premiums and clear benefits in unit-linked products are important factors in influencing consumer interest in investment-based insurance. In the study, it was concluded that insurance companies must consider market conditions and consumer behavior to be able to determine reasonable premiums and offer attractive benefits [5].

Given the dynamic market conditions, the calculation of a single net premium for unit-linked endowment life insurance becomes increasingly crucial to ensure a balance between life protection and potential investment returns. Insurance companies need to take into account market volatility and economic uncertainty in the premium setting process so that the products offered remain relevant and competitive in the eyes of the public.

Default cases in the insurance industry in Indonesia have become a serious issue that affects public confidence in the sector. Several leading insurance companies experienced solvency issues, resulting in thousands of customers losing their rights to policy claims. Based on information from the Financial Services Authority (*OJK*) as of 2023, some companies that have experienced default cases include *PT Asuransi Jiwa Adisarana Wanaartha* (Wanaartha Life) amounting to Rp. 15 trillion in 2018, *Jiwasraya* amounting to Rp. 12.4 trillion in 2019 and *Bumiputera 1912* amounting to Rp. 20.72 trillion.

Therefore, to overcome the default problem, a premium calculation method is needed that considers market volatility and potential fluctuations in asset value so that the premium set is not only fair to policyholders but also ensures product sustainability in the midst of existing market challenges. The ratchet method guarantees that the unit-linked value (policy benefits) will not drop from the previous high-water mark, even if the market value drops [6]. Therefore, the Black Scholes model uses option pricing theory to value the minimum guaranteed benefit in unit-linked products [7].

A comparison between the annual ratchet method and the Black-Scholes model is important because they offer different approaches to valuing guaranteed benefits in unit-linked products-annual ratchet provides deterministic investment value protection based on an annual maximum value, while Black-Scholes uses a market-based stochastic approach to calculate the fair value of guarantees such as financial options. By comparing the two, insurance companies can evaluate the accuracy of premium setting, the effectiveness of risk management, and the balance between protection for policyholders and the financial sustainability of the company. This comparison also helps in designing products that are fair, competitive, and in accordance with modern actuarial principles.

In previous research conducted by [8], the application of the Black Scholes model was used to calculate unit-linked endowment life insurance premiums. Research conducted by [9] on determining the single premium of Endowment Unit Link Life insurance with Minimum Guarantee Using the Annual Ratchet Method and the Black Scholes. Previously, there was no research on the application of the Annual Ratchet and Black Scholes methods to the calculation of a single net premium for unit-linked endowment life insurance with several ages.

2. METHODS

The type of data used in this research is quantitative data using data on the closing price of *PT Bank Central Asia (Persero) Tbk* (BBCA.JK) for the period January 2, 2023 to December 29, 2023. Endowment unit-linked insurance products are characterized by a combination of protection and investment benefits. The selection of assets that provide value growth potential while maintaining stability is crucial. BBCA meets both criteria: fair value growth and manageable systematic risk. In addition, there are data on *Tabel Mortalita Penduduk Indonesia (TMPI)* 2023, Bank Indonesia interest rates, and policyholder profile simulation data. BBCA stock data is obtained from the investing.com website, 2023 *TMPI* data is obtained from the official website of the Indonesian Life Insurance Association (*AAJI*) and the constant interest rate value is obtained from the *Bank Indonesia* website.

In this research, there are two methods that will be used, namely the Annual Ratchet method and the Black-Scholes model.

2.1. Unit Link Life Insurance

Unit link life insurance is a combination of insurance and investment benefits. This product is unbundled, where protection coverage, funds, and investment components are determined separately, thus providing more clarity than ordinary life insurance products. In general, unit link products are categorized based on their portfolios, namely equity funds, fixed income funds, management funds, and cash funds [8]. In unit link life insurance, we need to calculate the discount factor, with the discount factor formula is

$$v = \frac{1}{1+r} \tag{1}$$

With r is insterest rate and v is discount factor.

One type of unit-linked life insurance is unit-linked endowment life insurance. Unit link endowment life insurance is a combination of endowment life insurance and unit link life insurance. The determination of the net single premium for this insurance is based on the existence of a minimum guarantee value. This minimum guarantee is required so that insurance companies can be involved in risk sharing from the investment of these insurance products [9].

2.2. Stock

Stock can be defined as proof of capital participation of a person or an entity (such as a business entity) in a company or limited liability company. As an investment instrument, stocks are chosen by many investors because of their attractive profit potential [10]. The higher the expected stock return, the greater the risk that must be faced [11].

2.2.1. Stock Return

Stock returns reflect the level of profit obtained by investors from stock investments that have been made [12]. The equation used in the calculation of stock returns is as follows.

$$R_t = \ln\left(\frac{S_t}{S_{t-1}}\right) ; t = 1,2,3,\dots,N \tag{2}$$

And to calculate the average stock return is as follows.

$$\overline{R_t} = \frac{1}{N}\sum_{t=1}^{N} R_t \tag{3}$$

And to calculate the estimated variance of annual stock returns is as follows.

$$var = \frac{1}{N-1}\sum_{t=1}^{N}(R_t - \overline{R_t})^2 \tag{4}$$

Where R_t is t-time stock return, $\overline{R_t}$ is average annual stock return, var is estimated variance of annual stock return, N is number of business days of stock data, S_t is t-time stock price, and S_{t-1} is stock price at time $t-1$.

2.2.2. Stock Return Volatility

Stock return volatility is a measurement tool that shows the extent to which the price of an asset fluctuates within a certain period. The higher the price volatility of an asset, the greater the price fluctuation [13]. The equation for calculating the stock volatility value is as follows.

$$\sigma = \frac{1}{\sqrt{\tau}}\sqrt{var} \tag{5}$$

$$\tau = \frac{1}{N} \tag{6}$$

Where τ is temporal frequency or time interval in the calculation and σ is stock return volatility.

2.3. Mortality Life Table

Mortality tables, often called life tables, are the primary tools used by actuaries to design premium and reserve structures for life insurance products, annuities, and pension plans [14]. These tables depict a schema that shows mortality data in probability form [15] and summarizes the basic idea that the impact of mortality that gradually reduces a population can be presented in tabular form [16].
In general, the notation used in mortality tables is [17] :
a. notation x stating the age or lifespan of each individua
b. notation l_x states the number of individuals who survive to the right x year;
c. notation d_x states the number of individuals who died after reaching their last birthday, with the equation to obtain the value d_x :

$$d_x = l_x - l_{x+1} \tag{7}$$

d. notation p_x states the probability of a person being the right age x will live and calculated by the equation$(x+1)$

$$p_x = \frac{l_{x+1}}{l_x} \tag{8}$$

e. notation q_x states the probability that a person of the right age will die before reaching the age of x years,

$$q_x = \frac{d_x}{l_x} = \frac{(l_x - l_{x+1})}{l_x} = 1 - \frac{l_{x+1}}{l_x} = 1 - p_x \tag{9}$$

2.4. Insurance Premiums

Insurance premium is the amount of money determined by the insurance or reinsurance company paid according to the insurance agreement or according to the law to obtain insurance benefits. There are two types of premiums, namely net premiums and gross premiums. Net premiums are calculated without considering additional costs, while gross premiums include calculations for these costs [18].

2.5. Single net premium for unit link dual purpose life insurance with Annual Ratchet method

Hardy in 2003 defined the Annual Ratchet method as an indexing method based on the participation rate evaluated annually. This method also considers the premium value and benefit value based on the minimum (floor) and maximum (cap) interest rates. The Annual Ratchet method is divided into two types, namely simple ratchet and compound ratchet. The benefit structure in investments using the Annual Ratchet method can be written mathematically as follows [19].

$$\begin{aligned} b(t) &= \max(\beta(1+g)^T, CR) \\ &= \max(CR + \beta(1+g)^T - CR, CR + CR - CR) \\ &= CR + \max(\beta(1+g)^T - CR, CR - CR) \\ &= CR + \max\,(\beta(1+g)^T - CR, 0) \end{aligned} \tag{10}$$

Where

$$CR = \prod_{T=1}^{n} \left(1 + (\min(\max(\alpha d), f), c)\right) \tag{11}$$

The expected value of insurance benefits is as follows.

$$E[b(t)] = \begin{cases} E[\beta(1+g)^T]\,; CR < \beta(1+g)^T \\ E[CR]\,; CR \geq \beta(1+g)^T \end{cases} \tag{12}$$

Thus, the expected value of insurance benefits is obtained [19] :

$$E[b(t)] = U(T) = \begin{cases} e^{-rT}\beta(1+g)^T\,; CR < \beta(1+g)^T \\ e^{-rt}\left((1+f)\phi(-d_{2a}) + (1-\alpha)\left(\phi(d_{2a}) - \phi(d_{4a})\right) + \alpha\left(\phi(d_{1a}) - \phi(d_{3a})\right) + (1+c)\phi(d_{4a})\right)^T; CR \geq \beta(1+g)^T \end{cases} \tag{13}$$

With,

$$d_{1a} = \frac{\ln\left(\frac{1}{1+\frac{f}{\alpha}}\right) + r + \frac{\sigma^2}{2}}{\sigma} \tag{14}$$

$$d_{2a} = d_{1a} - \sigma \tag{15}$$

$$d_{3a} = \frac{\ln\left(\frac{1}{1+\frac{c}{\alpha}}\right) + r + \frac{\sigma^2}{2}}{\sigma} \tag{16}$$

$$d_{4a} = d_{3a} - \sigma \tag{17}$$

and

$$\phi(z) = P(Z \leq z) = \int_{-\infty}^{z} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt \tag{18}$$

Where,
ϕ: standard normal cumulative distribution function
d_{1a}: the relative position of the floor to market conditions, taking into account the level of return and volatility
d_{2a}: a certain condition value that reflects a more conservative scenario.
d_{3a}: the relative position of the cap interest rate to the risk-free interest rate
d_{4a}: Correction taking volatility into account.d_{3a}
$b(t)$: benefits of investment
$U(T)$:expected insurance benefit value
g: guaranteed interest rate
β: premium return percentage
c: maximum interest rate (cap)
α: participation level
f: minimum interest rate (floor)
r : interest rate

The premium value of unit link dual purpose life insurance up to the 2nd year without the stock investment value for unit link dual purpose life insurance which provides benefits of $b(t)$ is

$$P_t = \sum_{t=1}^{T} \pi(t) U(T) = \sum_{t=1}^{T} P(T) \tag{19}$$

With

$$\pi(t) = \begin{cases} {}_{t-1}p_x q_{x+t-1} = {}_{t-1}q_x \;; t = 1,2,\ldots,T-1 \\ {}_{T-1}p_x q_{x+T-1} + {}_{T}p_x = {}_{T}p_x \;; t = T' \end{cases} \tag{20}$$

So the net single premium value for a share is

$$P_m = P_t \times S_0 \times u \tag{21}$$

Where P_m is the net single premium of unit link annual ratchet dual purpose life insurance, P_t is the premium of unit link dual purpose life insurance up to the t -th year without the stock investment value, $\pi(t)$ is the investment value.

2.6. Single net premium for unit link dual purpose life insurance with Black Scholes Models

The final payment for the call option is$(S_T - K)^+$ where K : strike price (execution price) is set and the (+) sign indicates that the value is positive. The equation for calculating the value of a call option is as follows.

$$C = e^{-rt}E[(S_T - K)^+] \tag{22}$$

Where

$$E[(S_T - K)^+] = E\left[S_T.1_{\{S_T>K\}}\right] - K.E[1_{\{S_T>K\}}] \tag{23}$$

Where $1_{\{S_T>K\}}$ the indicator that $S_T > K$, which has a value of 1 if the condition is met, and 0 otherwise

$$E\left[S_T.1_{\{S_T>K\}}\right] = S_0\phi(d_{1b}) \tag{24}$$

and

$$E\left[1_{\{S_T>K\}}\right] = \phi(d_{1b}) \tag{25}$$

Where C is the value of the call option,K is the exercise price value, and S_T is the stock price at time T. Substitute equations (27) and (28) into equation (26) and you will obtain the following call option pricing equation using the Black Scholes model.

$$\begin{aligned} C &= e^{-rt}E[(S_T - K)^+] \\ &= e^{-rt}[S_0\phi(d_{1b}) - K\phi(d_{1b})] \\ C &= S_0\phi(d_{1b}) - Ke^{-rt}\phi(d_{1b}) \end{aligned} \tag{26}$$

Where the value of $S_0\phi(d_{1b})$ does not require discounting because the asset is currently priced, whereas K needs to be discounted because it is a future payment.

$$d_{1b} = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{27}$$

$$d_{2b} = d_{1b} - \sigma\sqrt{T} \tag{28}$$

With,
d_{1b}: the current position of the asset price relative to the strike (execution) price, taking into account time to expiration and volatility
d_{2b}: the value of certain conditions related to the strike price

Unit link life insurance with a minimum guarantee provides benefits to the policy holder in the amount of the investment value at the time the claim occurs or at least the amount of the guarantee that has been agreed upon at the beginning. Assume that the amount of the guarantee at the time T denoted by K_T is formulated with

$$K_T = S_0e^{rT} \tag{29}$$

Where,
S_0: Initial Share Price
K_T: Initial investment value S_0 accumulated using the risk interest rate r

Equation (26) can be viewed as the payoff of a European call option with K_T as the strike price. Thus, by using risk-neutral valuation, the option price can be determined, which in this case is the benefit value at time 0. Based on the Black-Scholes theorem for a European call option, then :

$$e^{-r}\left(S_0e^{-rT} + S_0\phi(d_{1b}) - K_Te^{-rt}\phi(d_{2b})\right) = S_0 + S \tag{30}$$

So that it is obtained

$$\begin{aligned} U(T) &= E\left[v_T \max\left(S_{T,}K_T\right)\right] \\ &= e^{-rT}K_T + e^{-rT}\max{(S_T, K_T)]} \\ &= S_0 + S_0\phi(d_{1b}) - K_Te^{-rt}\phi(d_{2b}) \end{aligned} \tag{31}$$

With

$$d_{1b} = \frac{\ln\left(\frac{S_0}{G_T}\right)+\left(r+\frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} \tag{32}$$

And d_{2b} can be calculated with the same equation as equation (28). The net single premium equation for unit link dual purpose life insurance with a minimum Black Scholes guarantee can be obtained by substituting equation (29) into equation (18) to obtain:

$$P_n = \sum_{t=1}^{T} \pi(t)(S_0 + S_0\phi(d_{1b}) - K_T e^{-rt}\phi(d_{2b})) \tag{33}$$

Where,

d_{1b}: the current position of the asset price relative to the strike (execution) price, taking into account time to expiration and volatility

d_{2b}: the value of certain conditions related to the strike price

$\pi(t)$ the same equation as equation (19).

So the net single premium value for the Black-Scholes method for a share u of stock is:

$$P_n = P_t \times u \tag{34}$$

and the minimum benefit received is [9]

$$G_T = \beta \times P_n \tag{35}$$

Where

P_n : Black Scholes model unit link dual purpose life insurance net single premium

P_t: Unit link dual purpose life insurance premiums without involving share value

G_T: Minimum guarantee

β: Rate of return of premium

u: Number of shares outstanding

In the data analysis process, the author used Microsoft Excel software. The stages of data analysis contained in this study are as follows: (a) Determining the profile of prospective policyholders or insureds, namely variables such as customer age (x), gender, interest rate (r), number of premium payments in one period, and coverage value. (b) Conduct a literature study to solve the case. (c) Collecting historical stock data of *PT Bank Central Asia (Persero) Tbk* (BBCA.JK) for the period January 2 to December 29, 2023. (d) Calculating the daily stock price return value by using the equation of the estimated value of the mean daily stock price return, and the estimated value of annual volatility. (e) Calculating the single net premium value of unit-linked endowment life insurance with equation (24) using the Annual Ratchet method. (f) Calculating the single net premium value of unit-linked endowment life insurance with equation (37) using the Black Scholes model. (g) Calculating the single net premium value of endowment life insurance with equation (39) using the prospective method. (h) Simulating the premium calculation for ages 45, 50, and 55 for each method with a period of 10 years.

3. RESULT AND DISCUSSION

3.1 Data

Some assumptions used in calculating the net single premium value using the Annual Ratchet and Black-Scholes methods based on realistic actuarial and market considerations for the calculation of the net single premium of unit-linked life insurance using the annual ratchet method and the Black-Scholes model. The 10-year period reflects the common medium term in unit-linked products. The interest rate of 6% reflects the government bond interest rate and is used as the discount rate. The 30% participation, 30% cap, and 1% floor represent annual investment return limits to control risk and ensure minimum protection, while the 5% guarantee rate provides minimum return certainty. The 90% premium return reflects the life cover commitment, the initial share price of Rp8,600 and 5,000 shares reflect the market exposure, and the projected

share growth of 16% is based on historical JCI expectations. All of these values were chosen so that the model reasonably reflects market conditions while allowing for an accurate and fair valuation of the options.
The following data will be used in the calculation of the net single premium:

Table 1. Profile of Policyholder or Insured

Age ($\boldsymbol{x}$)	Women (a) and Men (b) for 40 age years
Insurance period ($\boldsymbol{n}$)	10 years
Risk-free interest rate ($\boldsymbol{r}$)	6%
Participation rate ($\boldsymbol{\alpha}$)	30%
Guaranteed interest rate ($\boldsymbol{g}$)	5%
Cap interest rate ($\boldsymbol{c}$)	30%
Floor interest rate (f)	1%
Rate of return of premium ($\boldsymbol{\beta}$)	90%
Initial share price ($\boldsymbol{S_0}$)	Rp. 8,600
Total number of shares to be purchased ($\boldsymbol{u}$)	5000 shares
Stock Growth in the Next 10 Years ($\boldsymbol{d}$)	16%

3.2 *Calculating daily stock price return values, estimating mean stock returns, and estimating annual volatility values.*

The stock return movement graph for time t from January 2, 2023 to December 29, 2023 is as follows.

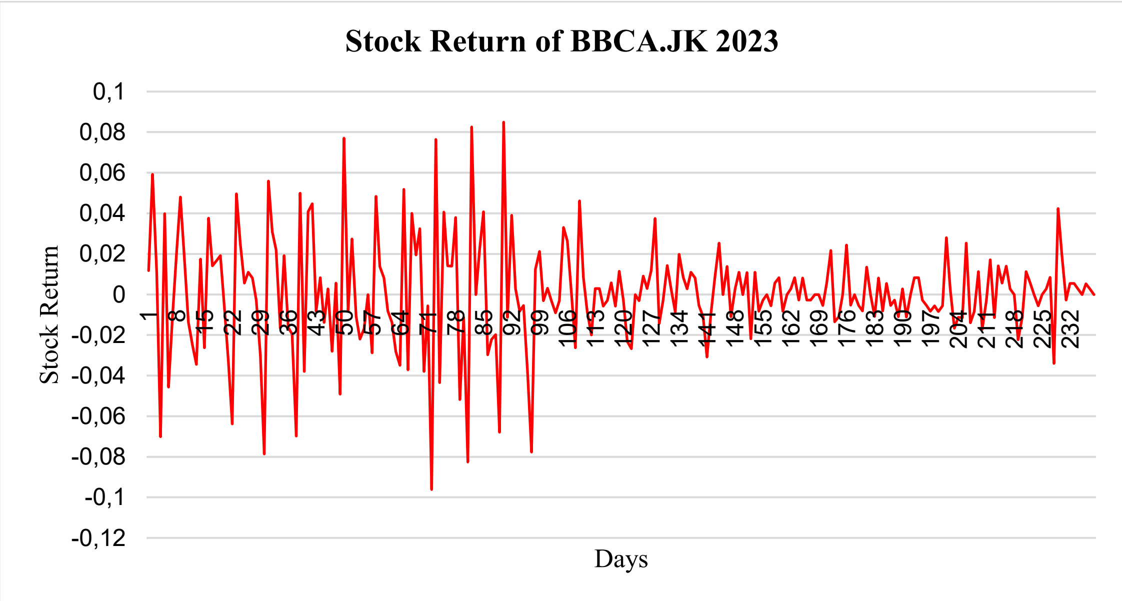

Figure 1. Stock Return of BBCA.JK 2023

In general, BBCA stock returns during 2023 are seen to fluctuate around the zero value, indicating that there is no consistent upward or downward trend in daily returns. This is common for blue-chip stocks with large capitalization and higher stability.

Next, to calculate the annual stock volatility, it is necessary to calculate the estimated value of the daily stock price return using equation (3) as follows.

$$\bar{R}_t = \frac{\sum_{t=1}^{N} R_t}{N} = \frac{\sum_{t=1}^{238} R_t}{238} = \frac{(0{,}01169603976319)+(0{,}05925569620909)+\cdots+(0{,}00266311741944)+0}{238} = 0{,}000422872$$

After obtaining the average value of daily stock returns, the estimated value of annual stock volatility can then be calculated using equation (4).

$$var = \frac{1}{238-1}(0{,}000127084 + \cdots + 1{,}78821\mathrm{e}^{-07}) = 0{,}000701957$$

And

$$\tau = \frac{1}{t} = \frac{1}{238} = 0{,}004202$$

Next, using equation (5), the annual stock volatility value is obtained as 0.408736898. The volatility value of 0.408736898 indicates that BBCA stock has a fairly significant level of daily fluctuations during 2023. The volatility value also shows that BBCA stock price fluctuates regularly, but not too extreme compared to highly volatile stocks and has quite dynamic movements in the past year, but still within the limits that can be considered stable for blue-chip stocks in the Indonesian market.

3.3 Calculating Single Premiums for Unit Link Dual Purpose Life Insurance Using the Annual Ratchet Method

By using the 2023 Indonesian population mortality table (TMPI) for women aged x, the value of $\pi(t)$ can be calculated as follows.

Table 2. Invest value for women

t	T	x	q_x	l_x	$\pi(t)$
1	0	40	0.002233	95615,18801	0
2	1	41	0.002418	95401,67929	0.00241
3	2	42	0.002631	95170,99803	0.00551
4	3	43	0.002881	94920,60314	0.00947
5	4	44	0.003161	94647,13688	0.01451
6	5	45	0.003458	94347,95728	0.02094
7	6	46	0.003791	94021,70204	0.02908
8	7	47	0.004176	93665,26577	0.03918
9	8	48	0.00461	93274,11962	0.05125
10	9	49	0.005079	92844,12593	0.06533
11	10	50	0.005598	92372,57061	0.08139

To calculate the compound ratchet, the assumptions in Table 1 are used using equation (11) to obtain the following.

Table 3. Ratchet Compound Value Calculation for Women

T	$\beta(1+g)^T$	d	$1+\alpha d$	CR
1	0.945	16%	1,048	1,048000
2	0.99225	16%	1,048	1.098304
3	1.0418625	16%	1,048	1.151023
4	1.093955625	16%	1,048	1,206272
5	1.148653406	16%	1,048	1,264173
6	1,206086077	16%	1,048	1.324853
7	1.26639038	16%	1,048	1.388446
8	1.329709899	16%	1,048	1.455091
9	1.396195394	16%	1,048	1.524936
10	1.466005164	16%	1,048	1,598133

After obtaining the compound ratchet, the expected value of investment benefits will be calculated using equation (13) with the value $CR > \beta(1+g)^T$:

Table 4. Calculation of Ratchet Compound Value and Women's Net Single Premium

T	CR	Women				Male			
		$e^{-rT}(m)$	$U_m(T)$	$\pi_m(t)$	$P_m(T)$	$e^{-rt}(n)$	$U_n(T)$	$\pi_n(t)$	$P_n(T)$
1	1,04800	0.9370675	1.223738	0.0024180	0.002958998	0.937067	1.223738	0.002911	0.003562
2	1.09831	0.8780954	1.146725	0.0055044	0.006312056	0.878095	1.146725	0.006635	0.007608
3	1.15102	0.8228347	1.074559	0.0094701	0.010176104	0.822835	1.074559	0.011429	0.012281
4	1,20627	0.7710516	1.006934	0.0145067	0.014607285	0.771052	1.006934	0.017536	0.017658
5	1,26417	0.7225274	0.943565	0.0209372	0.019755657	0.722527	0.943565	0.025409	0.023975
6	1.32485	0.6770569	0.884184	0.0290763	0.025708848	0.677057	0.884184	0.035616	0.031491
7	1.38845	0.634448	0.828540	0.0391789	0.032461284	0.634448	0.828540	0.048684	0.040336
8	1.45509	0.5945205	0.776398	0.0512462	0.039787465	0.594521	0.776398	0.064630	0.050179
9	1.52494	0.5571059	0.727537	0.0653321	0.047531504	0.557106	0.727537	0.083352	0.060642
10	1,59813	0.5220458	0.681752	0.0813944	0.055490759	0.522046	0.681752	0.104817	0.071459

So the amount of premium that must be paid by the insured with 5000 shares and the share price along with Rp. 8,600 per share is:

$$P_m(a) = P_{10} \times S_0 \times u = 0{,}254789962 \times 8.600 \times 5000 = 10.955.968$$

So, the net single premium of unit link dual purpose life insurance with a minimum guarantee of 90% of the premium that must be paid by the insured for 5000 shares is Rp. 10,955,968. With the minimum benefit value obtained is 90% of the premium:

$$G_T = 90\% \times 10.955.968 = 9.860.371{,}2$$

So the amount of premium that must be paid by the insured with 5000 shares and the share price along with Rp. 8,600 per share for a men is :

$$P_m(b) = P_{10} \times S_0 \times u = 0{,}319192 \times 8.600 \times 5000 = 13.725.243$$

So, the net single premium of unit link dual purpose life insurance with a minimum guarantee of 90% of the premium that must be paid by the insured for 5000 shares is Rp. 13,725,243. With the minimum benefit value obtained is 90% of the premium, namely:

$$G_T = 90\% \times 13.725.243 = 12.352.719$$

3.4 Calculating Single Premiums for Unit Link Dual Purpose Life Insurance Using the Black Scholes Model

The minimum Black-Scholes guarantee and the single premium value will be obtained as follows.

Table 5. Black Scholes Guarantee and net single premium value

T	K_T	$U(T)$	$\pi_a(t)$	$P_a(T)$	$\pi_b(t)$	$P_b(T)$
1	9,131.79	9992,636	0.002418	24,1621	0.002911	29,0886
2	9,696.47	10478,080	0.005504	57,6757	0.006635	69,5219
3	10,296.07	10470,880	0.009470	99.1595	0.011429	119.6749
4	10,932.74	9939,870	0.014507	144,1947	0.017536	174,3048
5	11,608.79	9236,718	0.020937	193,3915	0.025409	234,6963
6	12,326.63	8783,069	0.029076	255,3796	0.035616	312,8191
7	13,088.87	8628,839	0.039179	338,0683	0.048684	420,0821
8	13,898.24	8602,236	0.051246	440,8321	0.064630	555,9632
9	14,757.66	8600,076	0.065332	561,8606	0.083352	716,8347
10	-	8600,001	0.081394	699.9919	0.104817	901,4231

	Total	**2814,7160**		**3534,4090**

Based on the table above, the value of the unit link dual purpose life insurance premium for women is obtained, 2.814,716 and for men, 3.534,409. The amount of the net single premium for unit link endowment life insurance for women is as follows.

$$P_n\,(a) = P_{10(a)} \times u = 2.814{,}716 \times 5000 = 14.073.580$$

And for men as follows.

$$P_n(b) = P_{10(b)} \times u = 3.534{,}409 \times 5000 = 17.672{,}045$$

With a minimum benefit value obtained of 90% of the premium for women, namely:

$$G_{T(a)} = 90\% \times 14.073.580 = 12.666.222$$

And for men as follows.

$$G_{T(b)} = 90\% \times 17.672{,}045 = 15.904.840{,}5$$

3.5 Life insurance premium calculation simulation for several ages

The net single premium results for unit link dual purpose life insurance for ages 40, 45, 50, and 55 years with a term of 10 years are as follows.

Table 6. Single net premium dual purpose unit link life insurance with a term of 10 years with the annual ratchet method and black-scholes

Gender/Age	Annual Ratchet		Black-Scholes	
	Woman	Man	Woman	Man
40	10,955,968.36	13,725,243.06	14,073,581.13	17,672,043.21
45	14,480,068.69	21,213,951.21	18,149,762.15	27,176,126.17
50	20,455,879.03	30,667,423.74	25,524,188.59	39,051,497.36
55	26,899,331.43	41,599,567.36	33,423,586.07	52,703,560.28

Based on the application of the Annual Ratchet and Black Scholes methods in calculating the unit link dual purpose life insurance premium according to the case above and with a minimum guarantee, it is found that the single premium value of unit link life insurance with the Black Scholes method is greater than the single premium value of unit link life insurance with the Annual Ratchet method. In addition, the single premium value of women's unit link life insurance is smaller than the single premium value of men's unit link life insurance, both using the Annual Ratchet method and using Black Scholes.

The Black-Scholes premium is higher because it places greater value on unlimited potential returns and takes into account the full volatility of the asset price, without any annual adjustments or limits. The Annual Ratchet method, with its cap and floor, limits exposure to risk and returns, resulting in a lower premium.

4. CONCLUSIONS

The calculation result of single net premium of unit link dual purpose life insurance for insured aged 40 years using Annual Ratchet method for women is Rp. 10,955,968 and men is Rp. 13,725,243. While the calculation result of single net premium of unit link dual purpose life insurance for insured using Black Scholes model for women is Rp. 14,073,580 and men is Rp. 17,672,045. Women's net single premium is lower than men's because women's life expectancy is greater than men's life expectancy. This means that the greater a person's life expectancy, the smaller the premium that must be paid.

The net single premium value of unit link dual purpose life insurance for ages 45, 50, and 55 years showed an increase, both for women and men. This is due to the higher risk of death, which makes the net single premium increase from year to year. Therefore, the Black-Scholes premium is higher because this method places greater value on potentially unlimited gains and takes into account the full volatility of the asset price, without any annual adjustments or caps. The Annual Ratchet method, with a cap and floor, limits exposure to risk and return, resulting in a lower premium.

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6. REFERENCES

[1] M. Hisam, "Menavigasi Volatilitas Pasar: Wawasan Tentang Instrumen Keuangan dan Strategi Investasi," Currency: J. Ekon. dan Perbank. Syariah, vol. 2, no. 2, pp. 315–328, 2024, doi: 10.32806/ke534p70.

[2] X. Pan, "The impact of investment strategies on unit linked insurance product pricing," J. Risk Insur., vol. 86, no. 4, pp. 1003–1021, 2019.

[3] T. Wang, S. Liu, and H. Luo, "Exploring factors influencing the preference for unit linked insurance products," J. Financ. Serv. Mark., vol. 23, no. 4, pp. 240–253, 2018.

[4] S. Chong, R. Tan, and X. Zhou, "Investment-linked insurance products: A comparative analysis," Insur. Math. Econ., vol. 85, pp. 43–52, 2019.

[5] S. Kim and K. Park, "Understanding customer satisfaction in life insurance services: A case of unit-linked products," Asia Pac. J. Mark. Logist., vol. 30, no. 1, pp. 156–175, 2018.

[6] M. R. Hardy, Investment Guarantees: Modelling and Risk Management for Equity-Linked Life Insurance, USA: John Wiley and Sons, Inc., 2003.

[7] J. Stampfli and V. Goodman, The Mathematics of Finance: Modeling and Hedging, Indiana: Brooks/Cole, 2001.

[8] S. Seftiani, N. Satyahadewi, and N. M. Huda, "Penerapan Model Harga Opsi Black Scholes dalam Penentuan Premi Asuransi Jiwa Dwiguna Unit Link," Euler: J. Ilm. Matematika, Sains dan Teknol., vol. 11, no. 2, pp. 318–327, 2023, doi: 10.37905/euler.v11i2.23049.

[9] A. R. Shella and M. Subhan, "Penentuan Premi Tunggal Asuransi Jiwa Dwiguna Unit Link dengan Garansi Minimum Menggunakan Metode Annual Ratchet dan Model Black Scholes," J. Math. UNP, vol. 6, no. 3, pp. 59–65, 2021.

[10] I. Nurmasari, "Pengaruh rasio keuangan dan pertumbuhan pendapatan terhadap return saham pada perusahaan perkebunan di bursa efek indonesia 2010–2017," J. Sekuritas, vol. 2, no. 1, pp. 20–31, 2018.

[11] B. Balqis, "Determinasi Earning Per Share dan Return Saham: Analisis Return on Asset, Debt to Equity Ratio, dan Current Ratio," J. Ilmu Manaj. Terapan, vol. 2, no. 5, pp. 665–675, 2021, doi:

[12] D. S. Parawansa, M. Rahayu, and B. Sari, "Pengaruh ROA, DER dan SIZE Terhadap Return Saham," J. IKRA-ITH Ekonomika, vol. 4, no. 2, pp. 1–10, 2021.

[13] C. O. B. Putri and M. Syaichu, "Pengaruh Return On Asset, Risiko Sistematik, Volume Perdagangan Saham, Bid-Ask Spread, dan Volatilitas Saham Terhadap Return Saham (Studi Kasus Pada Perusahaan Jakarta Islamic Index Tahun 2015–2020)," Diponegoro J. Manaj., vol. 12, no. 1, pp. 1–15, 2023. [Online]. Available: https://ejournal3.undip.ac.id/index.php/djom/article/view/38689

[14] E. Pitacco, Health Insurance. Basic Actuarial Models, Cham, Switzerland: Springer Verlag, 2014.

[15] J. S. Smith et al., "Rates and causes of mortality associated with spine surgery based on 108,419 procedures: a review of the Scoliosis Research Society Morbidity and Mortality Database," Spine, vol. 37, no. 23, pp. 1975–1982, 2012.

[16] H. Utomo, "Perbandingan Tabel Mortalita Indonesia dan Tabel Mortalita CSO Menggunakan Uji Mann-Whitney dan Uji Kruskal-Wallis," Syntax Literate: J. Ilm. Indones., vol. 6, no. 3, p. 1210, 2021, doi: 10.36418/syntax-literate.v6i3.2364.

[17] A. Prabowo, "Konstruksi Tabel Mortalitas untuk Laki-Laki Menggunakan Hukum Makeham dengan Mengacu pada TMI 2019," Perwira J. Sci. Eng., vol. 2, no. 2, pp. 37–42, 2022, doi: 10.54199/pjse.v2i2.137.

[18] A. J. Fikri, A. A. Muhartini, O. Sharoni, T. Febrianti, and I. Mahuda, "Perbandingan Perhitungan Premi Asuransi Jiwa Berjangka, Seumur Hidup, dan Dwiguna Pada Kasus Laki-Laki dan Perempuan," J. Bayesian, vol. 2, no. 1, pp. 31–38, 2022, doi: 10.46306/bay.v2i1.26.

[19] Y. Saputra, "Penentuan Proporsi Keuntungan untuk Kontrak Asuransi Jiwa Dwiguna Unit Link dengan Menggunakan Metode Annual Ratchet," STATISTIKA: J. Theor. Stat. Its Appl., vol. 18, no. 1, pp. 31–37, 2018, doi: 10.29313/jstat.v18i1.3874.