

Unit Link Single Life Premium Calculation for Unit Link Lifetime Insurance Using the Ratchet Compound Method

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Abstract

Unit link insurance contains investments where the value varies according to the value of the investment asset. This can be overcome by limiting the minimum (floor) and maximum (cap) benefit that the insured will get. This research was conducted to calculate single net premium of unit link whole life insurance by limiting the benefits that will be accepted by insured. The method used is the Compound Ratchet method. Data used in this research is stock closing prices for case study at PT Astra Internasional Tbk. in 2016. Based on the research result, obtained the amount of premium that must be paid by prospective policy holders in four different cases of floor and cap values. The higher of the top value and the floor value, the higher of the premium value to be paid.

Keywords:

Whole Life Insurance, Unit Link Insurance, Compound Ratchet Method, Cap, Floor.

1. Introduction

Some people now prefer to invest their money because it is considered more profitable than joining traditional life insurance. Therefore, unit link life insurance was developed to increase public interest in following insurance. Unit link life insurance is life insurance where policyholders will get two benefits at once, namely protection and investment benefits. This insurance product gives the policy holder the freedom to choose the desired investment. Usually, policyholders choose to invest in stocks because they do not have a minimum capital limit and the highest return compared to other investments.

Unit link insurance contains investments where the value varies at any time according to the value of the investment asset. When stock prices fall then the benefits also drastically come down. The way to overcome this is that the insurance company provides a minimum (floor) benefit and the insured will get the benefit of the price of the agreement on the contract. Conversely, if the stock price rises sharply, then the benefits also rose. This can be overcome by giving the maximum benefit limit (stamp) that the insured will get. The Insured or heir will receive the maximum benefit in the amount of the current stamp value and the minimum benefit in the amount of the agreed floor value, Hardy, M.R. 2003.

There are three indexing methods that can be used to calculate unit link insurance benefits, namely point to point, annual ratchet, and high water mark Hardy, M.R. 2004. The Annual Ratchet method consists of 2 types, namely the Simple Ratchet Method and Compound Ratchet Method. The Simple Ratchet method is suitable for customers with stable income, while the Compound Ratchet method is suitable for high-income customers. The Annual Ratchet method calculates the benefits to be obtained by the insured by giving a minimum (floor) and maximum value (cap) limit by paying attention to the stock price for one year so that it can be used to overcome existing problems.

Research on the calculation of the whole-life insurance premiums of unit links using the Compound Ratchet method has not been done so the authors will conduct the research. The stock data used is the daily stock data of PT

Astra International Tbk in 2016, the bank interest rate used is the interest rate of Bank of Indonesia in January 2017, and policyholder data as an illustration are simulation data determined by researchers based on the possibility that can occur. The mortality table used is the Indonesian Mortality Table in 2011.

Whole life insurance, also known as cash value insurance or permanent value, offers protection during the life of the insured, Futami, T.1993. This insurance is considered as term insurance that is due when the policy holder's age reaches 111 years. According to Bowers et al. (1997), the present value of the actuarial of life insurance at the end of the policy death year can be calculated using the formula

$$A_x = \sum_{k=0}^{\infty} k p_x q_{x+k} v^{k+1} \quad (1)$$

so that the value single net premium whole life insurance is

$$P(A_x) = \text{benefit} \times \sum_{k=0}^{\infty} k p_x q_{x+k} v^{k+1} \quad (2)$$

Unit link life insurance is modern life insurance with benefit payments made at the end of the policy contract, Tsai, M. S., Lee, S. C., Chen, J. L., and Wu, S. L. 2014. According to Tsai, M. S., Lee, S. C., Chen, J. L., and Wu, S. L. 2014, unit link life insurance has the following characteristics:

- 1) Unit link insurance can be used as a savings and protection tool. Protection can take the form of death protection, total permanent disability, and death by accident.
- 2) In general, unit link insurance has a choice of investment types that range from conservative, moderate and aggressive.
- 3) The cost of protection is generally fulfilled by charging the fee in accordance with the age and the amount of protection. This fee is charged by reducing the number of units of available funds except for a single premium.
- 4) Unit link insurance is transparent so that policyholders can freely monitor the development of stock prices at any time through print media or website links from insurance companies that are followed.
- 5) Each policy holder gets a report on the amount of premium that must be paid in the first year and the investment proceeds obtained during the current year.
- 6) Unit link insurance is flexible. Some characteristics of unit link insurance flexibility are as follows:
 - a. Premiums can be reduced or abandoned as long as the cash value of the investment followed is still sufficient to pay the premium. The level of protection can also be changed in accordance with the wishes of the policyholder, must be in accordance with the applicable requirements.
 - b. Taking cash value from investments that can be done at any time. Adding premiums to increase the amount of investment placed can also be done from time to time.

In unit link life insurance the calculation of benefits must be done by observing changes in assets every time t . The function of the benefits of unit link life insurance is

$$b_t = \max[S_t, g_t] \quad (3)$$

with S_t is the stock price at t and g_t is the guarantee at t .

One suitable investment for unit link life insurance is stock investment. Shares are units of value or bookkeeping in various financial instruments that refer to the ownership of a company [3]. The stock price model at time t is

$$S_t = S_0 \exp \left[\sigma \sqrt{t} z + \left(r - \frac{\sigma^2}{2} \right) t \right] \quad (4)$$

Stock return can be interpreted as the rate of return (profit rate) obtained as a result of investment, Carriere, J. F. 1992. The condition of investment assets allows stock return values to be positive or negative. Stock return is denoted by R_t . According to Carriere, J. F. 1992, for risk-neutral shareholders, $R_t = \frac{S_t}{S_{t-1}}$ is lognormal distribution.

$$R_t = \frac{S_t}{S_{t-1}} \quad (5)$$

Stock return volatility is the standard deviation of annual period stock returns, Hogg, R.V. Mckean, J.W. Craig, A.T. 2013. One way to estimate the volatility of stock returns is to calculate based on past prices, this method is called the historical volatility method. Calculations use the following formula:

$$\sigma = \sqrt{\text{number of trading days} \times \left(\frac{\sum_{i=1}^j (R_t - \bar{R}_t)^2}{j-1} \right)} \quad (6)$$

The Anderson Darling method is used to test whether data samples come from populations with certain distributions, Capinski, M., and Zastawniak, T. 2003.

Suppose x_1, x_2, \dots, x_n is the data that will be tested for its lognormal distribution with a significance level α , then the Anderson Darling test can be obtained using the following formula:

$$A = -n - S \quad (7)$$

with

$$S = \frac{1}{n} \sum_{i=1}^n [2i - 1] [\ln(F(Z_i)) + \ln(1 - F(Z_{n+1-i}))] \quad (8)$$

$$Z_i = \frac{(\ln x_i) - \bar{x}}{s} \quad (9)$$

Modification of Anderson Darling's method uses the following formula:

$$A^* = A \left(1 + \frac{0.75}{n} + \frac{2.25}{n^2} \right) \quad (10)$$

The critical value obtained is by counting:

$$c_\alpha = a_\alpha \left(1 + \frac{b_\alpha}{n} + \frac{d_\alpha}{n^2} \right) \quad (11)$$

with a_α, b_α , and d_α value can be seen in Table 1.

Table 1. Value of a_α, b_α , and d_α for Anderson Darling Test

α	0.0500	0.01	0.025	0.0500	0.1000	0.2000
a_α	1.1578	1.0348	0.8728	0.7514	0.6305	0.5091
b_α	1.0630	1.0130	0.8810	0.79500	0.7500	0.7560
d_α	1.3400	0.9300	0.9400	0.8900	0.8000	0.3900

The test using the Anderson Darling Method was carried out as follows:

H_0 : data is lognormally distributed

H_1 : data is not lognormally distributed

If $A^* < c_\alpha$ then H_0 received or lognormal distributed data.

2. Methodology

This section will describe how to calculate whole-life unit-linked insurance premiums using the Compound Ratchet method.

According to Hardy (2003), the structure of benefits from an investment at time t with the Compound Ratchet method can be written

$$b_t = \prod_{t=1}^n (1 + \min(\max(\alpha^*(R_t - 1), f), c)) \quad (12)$$

Benefit coefficient value on Compound Ratchet methods is,

$$(1 + \min(\max(\alpha^*(R_t - 1), f), c)) = \begin{cases} 1 + f & , R_t < 1 + \frac{f}{\alpha^*} \\ 1 + \alpha^* R_t - \alpha^* & , 1 + \frac{f}{\alpha^*} < R_t \leq 1 + \frac{c}{\alpha^*} \\ 1 + c & , R_t > 1 + \frac{c}{\alpha^*} \end{cases} \quad (13)$$

Expectation value b_t obtained from the substitution of equation (5) is

$$E[1 + \min(\max(\alpha^*(R_t - 1), f), c)] = E \left[1 + \min \left(\max \left(\alpha^* \left(\frac{S_t}{S_{t-1}} - 1 \right), f \right), c \right) \right] \quad (14)$$

According to Hardy (2003), value of $\frac{S_t}{S_{t-1}}$ has same distribution with $\frac{S_1}{S_0}$. For $t = 1$ obtained

$$R_1 = \frac{S_1}{S_0} \quad (15)$$

Assume that $S_0 = 1$ without removing the general situation because $t = 0$ is an index, obtained

$$R_1 = S_1 \quad (16)$$

so that

$$R_t = S_t \quad (17)$$

Assume R_t has same distribution with S_t i.e. lognormal distribution. Actuarial present value on Compound Ratchet method obtained through expectations of the value of benefits and interest on insurance, i.e.

$$U_t = E[v_t b_t] = E[v_t (1 + \min(\max(\alpha^*(R_t - 1), f), c))](18)$$

Substitution Equation (17) obtained the contract value at the present time with the Compound Ratchet method

$$\begin{aligned} U_t &= E[v_t (1 + \min(\max(\alpha^*(S_t - 1), f), c))] \\ &= v_t E[1 + \min(\max(\alpha^*(S_t - 1), f), c)] \\ &= e^{-r} E[1 + \min(\max(\alpha^*(S_t - 1), f), c)] \\ &= e^{-r} \left[\int_{-\infty}^{\infty} (1 + \min(\max(\alpha^*(S_t - 1), f), c)) f(S_t) dS_t \right] \\ &= e^{-r} \left[\int_{-\infty}^{1+\frac{f}{\alpha^*}} (1+f)f(S_t) dS_t + \int_{1+\frac{f}{\alpha^*}}^{1+\frac{c}{\alpha^*}} (1+\alpha^*R_t - \alpha^*)f(S_t) dS_t + \int_{1+\frac{c}{\alpha^*}}^{\infty} (1+c)f(S_t) dS_t \right] \\ &= e^{-r} [(1+f)\Phi(-d_2) + (1-\alpha^*)(\Phi(d_2) - \Phi(d_4)) + \alpha^*e^{-d}(\Phi(d_1) - \Phi(d_3)) + (1+c)\Phi(d_4)] \\ &= e^{-r}(1+f)\Phi(-d_2) + e^{-r}(1-\alpha^*)(\Phi(d_2) - \Phi(d_4)) + \alpha^*e^{-d-r}(\Phi(d_1) - \Phi(d_3)) + e^{-r}(1+c)\Phi(d_4) \end{aligned} \quad (19)$$

Φ is a standard normal cumulative distribution function, Chriss, N. A. 1997, with

$$\begin{aligned} d_1 &= \frac{\ln \frac{1}{K_1} + r - d + \frac{\sigma^2}{2}}{\sigma} \\ d_2 &= \frac{\ln \frac{1}{K_1} + r - d - \frac{\sigma^2}{2}}{\sigma} = d_1 - \sigma \\ d_3 &= \frac{\ln \frac{1}{K_2} + r - d + \frac{\sigma^2}{2}}{\sigma} \\ d_4 &= \frac{\ln \frac{1}{K_2} + r - d - \frac{\sigma^2}{2}}{\sigma} = d_3 - \sigma \end{aligned}$$

Based on the Compound Ratchet method, it can be obtained the equation for a single net premium unit-linked whole-life insurance with the Compound Ratchet method, i.e.

$$P(A_x)_{CR} = S_0 \times u \times \left(\sum_{t=0}^{\infty} k p_x q_{x+k} \left[e^{-r}(1+f)\Phi(-d_2) + e^{-r}(1-\alpha)(\Phi(d_2) - \Phi(d_4)) \right]^{k+1} \right) \quad (20)$$

This research was conducted in several steps. Data needed in determining premiums is stock data and policy holder simulation data. The steps in determining a single net premium whole-life unit link insurance with the Compound Ratchet method, that is:

- 1) Input daily stock price data.
- 2) Determine the return value of daily stock prices.
- 3) Test the lognormal return value of daily stock data.
- 4) Determine the estimated value of return volatility of daily stock data.
- 5) Determine the profile of prospective policyholders.
- 6) Determine the contract value at the present time with the minimum (floor) and maximum (cap) warranty limits.
- 7) Determine the value of a single net premium whole-life unit link insurance with the Compound Ratchet method.

The object of this research is the prospective policy holder whose profile must be determined by making simulation data. Profile of prospective policyholders, i.e.

Table 2. *Cap* value and *floor* value

	Case 1	Case 2	Case 3	Case 4
<i>Cap</i> value	30%	30%	25%	25%
<i>Floor</i> value	6%	1%	6%	1%

- Age (x) : 50 years
- Gender : Male
- Initial stock price (S_0) : IDR5.900,00
- Number of shares to be purchased (u) : 1.000 sheets
- Risk-free interest rates (r) : 4.75%
- Level of participation(α) : 75%
- Dividend (d) : 2%

The initial stock price (S_0) was obtained from the share price of PT Astra International Tbk in the beginning of the insurance contract, which is equal to IDR5.900,00. The interest rate used is the interest rate of the Central Bank of the Republic of Indonesia in January 2017.

3. Illustration Analysis

3.1 Return Value of Daily Stock Prices PT Astra International Tbk in 2016

Based on data on the closing price of shares of PT Astra International Tbk in the period of January 4 2016 to December 30, 2016, the daily stock price return value can be calculated using Equation (5).

$$\begin{aligned}
 R_1 &= 1.03814 \\
 R_2 &= 0.99184 \\
 R_3 &= 0.98354 \\
 &\vdots \\
 R_{238} &= 1.01846
 \end{aligned}$$

3.2 Anderson Darling Lognormal Test Return Value of Daily Stock Prices PT Astra International Tbk on 2016

Compound Ratchet method can be used if stock return data is lognormal distribution. The lognormal test used is the Anderson Darling Test. The following is Anderson Darling's lognormal test results from the return data of the daily stock price of PT Astra International Tbk in 2016 using Minitab 16 software.

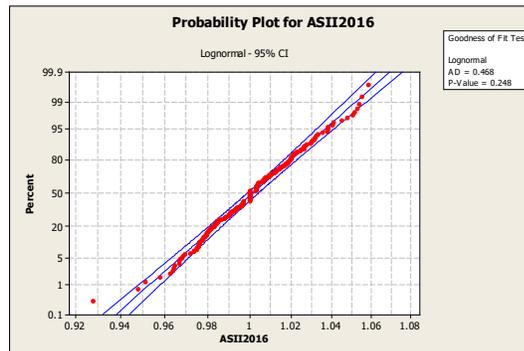


Figure 1. Anderson Darling's lognormal test results return data for the daily stock price of PT Astra International Tbk in 2016

$P\text{-value} = 0.248 > \alpha = 0.05$ so that H_0 received or lognormal distributed data. Calculating volatility can use equation (6), obtained by the value of volatility is $\sigma = 0.32733$

3.3 Single Net Premium Value of Whole-life Unit Link Insurance using Compound Ratchet Method

The first step is calculate the value of $d_1, d_2, d_3,$ and d_4 .

1) Case 1

Value of $f_1 = 6\% = 0.06$

Value of $c_1 = 30\% = 0.3$

so that

$$\begin{aligned}d_{1_1} &= 0.0125605 \\d_{2_1} &= -0.3147695 \\d_{3_1} &= -0.7802516 \\d_{4_1} &= -1.1075816\end{aligned}$$

2) Case 2

Value of $f_2 = 1\% = 0.01$

Value of $c_2 = 30\% = 0.3$

so that

$$\begin{aligned}d_{1_2} &= 0.2072136 \\d_{2_2} &= -0.1201164 \\d_{3_2} &= -0.7802516 \\d_{4_2} &= -1.1075816\end{aligned}$$

3) Case 3

Value of $f_3 = 6\% = 0.06$

Value of $c_3 = 25\% = 0.25$

so that

$$\begin{aligned}d_{1_3} &= 0.0125605 \\d_{2_3} &= -0.3147695 \\d_{3_3} &= -0.6311967 \\d_{4_3} &= -0.9585267\end{aligned}$$

4) Case 4

Value of $f_4 = 1\% = 0.01$

Value of $c_4 = 25\% = 0.25$

so that

$$\begin{aligned}d_{1_4} &= 0.2072136 \\d_{2_4} &= -0.1201164 \\d_{3_4} &= -0.6311967 \\d_{4_4} &= -0.9585267\end{aligned}$$

The second step is determine $\Phi(d_1), \Phi(d_2), \Phi(-d_2), \Phi(d_3),$ and $\Phi(d_4)$ for each case. The calculation results of $\Phi(d_1), \Phi(d_2), \Phi(-d_2), \Phi(d_3),$ and $\Phi(d_4)$ for each case can be seen in Table 3.1.

Table 3. The Calculation Result of $\Phi(d_1), \Phi(d_2), \Phi(-d_2), \Phi(d_3),$ and $\Phi(d_4)$ For Each Case

Case i	$\Phi(d_{1_i})$	$\Phi(d_{2_i})$	$\Phi(-d_{2_i})$	$\Phi(d_{3_i})$	$\Phi(d_{4_i})$
Case 1	0.505011	0.376468	0.623532	0.217621	0.134021
Case 2	0.582078	0.452195	0.547805	0.217621	0.134021
Case 3	0.505011	0.376468	0.623532	0.263956	0.168899
Case 4	0.582078	0.452195	0.547805	0.263956	0.168899

The third step is determine the current time contract value (U_t) with the Compound Ratchet method using Equation (19) for each case.

1) Case 1

$$U_{t_1} = 1.05570116$$

2) Case 2

$$U_{t_2} = 1.02511604$$

3) Case 3

$$U_{t_3} = 1.0500877$$

4) Case 4

$$U_{t_4} = 1.01950258$$

The fourth step is determine the value of ${}_k p_x q_{x+k}$ for each k . Based on the Indonesian Male Mortality Table in 2011, a person's age limit is 111 years. In this study, prospective policyholders are 50 years old. The age difference between prospective policyholders and the age limit on the mortality table is the period of the insured contract (k), which is 61 years.

For $k = 0$, obtained

$${}_0 p_{50} q_{50+0} = \frac{l_{50+0}}{l_{50}} q_{50} = 0.00538$$

For $k = 1$, obtained

$${}_1 p_{50} q_{50+1} = \frac{l_{50+1}}{l_{50}} q_{51} = 0.00612$$

For $k = 2$, obtained

$${}_2 p_{50} q_{50+2} = \frac{l_{50+2}}{l_{50}} q_{52} = 0.00691$$

$$\vdots$$

For $k = 61$, obtained

$${}_{61} p_{50} q_{50+61} = \frac{l_{50+61}}{l_{50}} q_{111} = (1.7878 \times 10^{-7})$$

The fifth step is calculates the present value of a whole-life unit link insurance (A_{50}) for each case.

1) Case 1

$$A_{50_1} = \sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_1})^{k+1} = 5.1326511$$

2) Case 2

$$A_{50_2} = \sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_2})^{k+1} = 2.0370861$$

3) Case 3

$$A_{50_3} = \sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_3})^{k+1} = 4.315207$$

4) Case 4

$$A_{50_4} = \sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_4})^{k+1} = 1.730273$$

The final step is calculate a single net premium for whole-life unit link insurance with the Compound Ratchet method for each case. Calculations using Equations (20).

1) Case 1

$$P(A_{50})_{CR_1} = S_0 \times u \times \left(\sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_1})^{k+1} \right) = \text{IDR}30,282,642.00$$

2) Case 2

$$P(A_{50})_{CR_2} = S_0 \times u \times \left(\sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_2})^{k+1} \right) = \text{IDR}12,018,808.00$$

3) Case 3

$$P(A_{50})_{CR_3} = S_0 \times u \times \left(\sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_3})^{k+1} \right) = \text{IDR}25,459,720.00$$

4) Case 4

$$P(A_{50})_{CR_4} = S_0 \times u \times \left(\sum_{k=0}^{\infty} {}_k p_{50} q_{50+k} (U_{t_4})^{k+1} \right) = \text{IDR}10,208,611.00$$

Amount of single net premium for whole-life unit link insurance with the Compound Ratchet method for four different cases of floor values and cap values can be seen in Table 4.

Table 4. The Calculation Results of Cap Value, Floor Value, and Premium

	Case 1	Case 2	Case 3	Case 4
Cap Value	30%	30%	25%	25%
Floor Value	6%	1%	6%	1%
Premium	IDR30,282,642.00	IDR12,018,808.00	IDR25,459,720.00	IDR10,208,611.00

4. Conclusion

Based on the research that has been done, it can be concluded that: Determining the amount of a single net premium for whole-life unit link insurance with the Compound Ratchet method can be done using the formula in Equation (20). Based on this equation, the results of the calculation of the single net premium unit unit lifetime insurance for a man aged 50 years with the initial share price (S_0) of IDR. 5,900.00 and the number of shares (u) as many as 1,000 in four different cases cap values and floor values are in Table 3.1. The higher of the value of the cap and the floor, the higher the value of the premium that must be paid because the policy holder has a greater opportunity to get more profits from the investment in shares.

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