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Comparison of Mack Chain-Ladder and Bootstrap Methods for Claim Reserve Estimation under IFRS 17 in Lampung General Insurance

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ABSTRACT

Claim reserves are funds set aside by insurance companies to pay for reported claims (RBNS) as well as claims that have not yet been reported (IBNR), and they are crucial because they directly affect the financial health of the company. In 2024, there were customer complaints in Lampung regarding delays in claim payments by general and life insurance companies. Therefore, this study uses claim data from general insurance companies in Lampung for the period 2013–2024. The novelty of this study lies in comparing the Mack Chain Ladder analytical method and the Bootstrap simulation method for estimating claim reserves within the IFRS 17 framework using regional insurance data from Lampung, which has not been widely explored in previous studies. This study aims to estimate claim reserves and estimate the Liability for Incurred Claims (LIC), Best Estimate Liability (BEL), and Risk Adjustment (RA) under IFRS 17. Accurate estimation of claim reserves and the implementation of IFRS 17 play a vital role in ensuring the sustainability of insurance companies. The Mack Chain-Ladder (MCL) method is used to obtain equations for the expected value and variance of future claims as well as the prediction error rate. Meanwhile, the Bootstrap method generates numerous simulated claim datasets that reflect various possible scenarios. The advantage of the simulation approach is its ability to provide a full predictive distribution, which can be used to estimate the risk adjustment under IFRS 17. The empirical results show that the estimated claim reserve using the Mack Chain-Ladder (MCL) method is 234,740,644, while the Bootstrap method with 5.000 simulations produces a reserve range of 233,158,004-236,320,156. These results provide empirical insights into claim reserve estimation and support the implementation of IFRS 17 in regional insurance companies by calculating the BEL, RA, and LIC values, whose results are based on the claim reserve calculation.

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A. INTRODUCTION

As time goes by, whether we realize it or not, everyone will inevitably face risks. Risk is the possibility of an event that can be measured and may result in a loss. Therefore, one way to deal with such risks is through risk transfer. One form of risk transfer available to individuals, institutions, and companies is through insurance institutions. Basically, insurance is a form of financial protection that aims to provide compensation or benefits when unexpected and undesirable events occur that cause loss to the insured (Jabbar et al., 2024). There are two types of insurance, these are life insurance and general insurance (Fang et al., 2020). Insurance companies must provide insurance reserve funds to fulfill their obligations to the insured or policyholders. These funds are called claim reserves (Cazzari & Moreira, 2022).

In 2024, several customers in the Lampung region submitted complaints regarding delays in claim payments by general and life insurance companies. These complaints have been addressed by the OJK Regional Office 7 for Southern Sumatra, which has authority over the area. The issue was caused by the lack of analysis and control in corporate governance, especially in claim reserve calculations, resulting in financial sector instability, delayed claim payments, claim defaults, and even bankruptcy. The urgency of this research is to calculate claim reserves, as accurate claim reserve calculation is crucial and impacts the financial health of the company (Yulita & Effendie, 2022). Poor reserve calculation can lead to bankruptcy, so claim reserves must be calculated accurately neither excessive nor insufficient (Badounas & Pitselis, 2020). The methods used in this study are the Mack CL and Bootstrap methods.

The Mack Chain-Ladder (MCL) method is the most popular method for calculating claim reserves due to its simplicity and distribution-free nature (Zohry & Ahmed, 2020). Many general and life insurance companies still use the Chain-Ladder (CL) method to calculate claim reserves. The CL method utilizes historical data to estimate future claims by using development patterns from one period to the next, processed in the form of a run-off triangle. This triangle contains the number or amount claims reported in each period and the development of claims in subsequent periods. The run-off triangle will eventually contain information on claim reserves, which can be calculated in both incremental and cumulative forms. The purpose of this method is to predict the future triangle using delay factors and the cumulative claim amounts located on the main diagonal of the run-off triangle (Julianty et al., 2025). The advantage of the CL method is that it provides formulas for both the expected value and variance based on cumulative values. However, claim reserve value calculated using the CL method is a fixed value, so a simulation-based method that provides a range of reserve values to reflect various possible scenarios is needed. One such simulation-based method is the Bootstrap method (Mack, 1993).

The Bootstrap technique is a method that essentially uses resampling techniques, where samples are repeatedly drawn N times to produce Bootstrap samples. The advantage of the Bootstrap method is that it provides a variety of possible reserve values to simulate different scenarios that may occur based on the available data. The Bootstrap method is used to estimate statistical parameters of an unknown underlying distribution, such as the mean and variance, by resampling the data. Bootstrap has practical advantages over the MCL method because it can explicitly measure uncertainty through the distribution of reserve results in the form of a range of claim amounts, rather than just a point estimate, thus providing upper and lower bounds for claim reserves. Although it requires repeated simulations (resampling), the computational burden is justified because Bootstrap produces risk metrics such as confidence intervals, Value at Risk (VaR), and Tail Value at Risk (TVaR), which are crucial for risk management and regulatory compliance (solvency). In addition, Bootstrap enables model validation and scenario analysis, and is more compatible with modern stochastic projection systems (Pinheiro et al., 2003).

Under the Solvency II regulations in Europe, a risk margin is required to account for reserve risk in internal capital models and to use international standard calculations. Therefore, the International Accounting Standards Board (IASB) requires a risk adjustment in liability estimations, as stipulated in IFRS 17 (IFRS Foundation, 2017). IFRS 17 is an international financial accounting standard that governs the accounting treatment of insurance contracts, developed by the International Accounting Standards Board (IASB) (Treasury, 2025). The calculation of IFRS 17 is essential to ensure that the financial reporting of insurance contracts is transparent, accurate, and consistent with global standards, thereby reflecting insurance profitability and liabilities more realistically (Vazov & Hristozov, 2025). IFRS 17 introduces several new concepts for measuring liabilities, including Liability for Incurred Claims (LIC), Best Estimate Liability (BEL), and Risk Adjustment (RA). BEL refers to the present value of the best estimate of insurance claim liabilities; RA is the compensation required by a company to bear the uncertainty regarding the amount and timing of cash flows arising from non-financial risks, calculated based on risk measures such as VaR. LIC represents the company's liability for claims that have already occurred. The LIC value is expected to provide an estimate of the amount of funds that must be set aside by the company to settle claims that have already occurred (Yousuf et al., 2021). The calculation of IFRS 17 is very important for the insurance industry and its implementation has been mandated globally by the IASB and by the Financial Services Authority (OJK) in Indonesia since 2021 (Sensi, 2022).

Although various studies have examined claim reserve estimation using either deterministic or stochastic approaches, research comparing the Mack Chain-Ladder method and the Bootstrap method within the IFRS 17 framework remains limited, particularly in the context of regional insurance data in Indonesia. Therefore, this study aims to compare claim reserve estimations using the MCL and Bootstrap methods and to evaluate their implementation in the calculation of BEL, RA, and LIC under IFRS 17 using the Value at Risk (VaR) risk measure. The novelty of this study lies in the quantitative comparison between the analytical Mack Chain-Ladder method and the stochastic Bootstrap simulation method for claim reserve estimation using regional insurance data from Lampung. Furthermore, this research integrates claim reserve estimation with the calculation of IFRS 17 components, namely BEL, RA, and LIC, based on risk measures derived from simulated claim distributions. By combining traditional reserving methods with stochastic risk measurement under the IFRS 17 framework, this study is expected to contribute to improving claim reserve estimation, financial reporting transparency, and risk management practices in the Indonesian insurance industry.

B. METHODS

The data used in this study are secondary data, namely insurance data from PT Asuransi Umum Jasa Raharja Putera Lampung for the period 2013–2024. This study used Microsoft Excel and Rstudio as the main software tools. Microsoft Excel was used for data processing and run-off triangle preparation, MCL method, while Rstuido was used for Bootstrap simulation and further analysis in estimating BEL, RA, and LIC under IFRS 17. The following are the steps to compare claim reserve estimates using the Mack Chain-Ladder (MCL) and Bootstrap methods as implemented in IFRS 17 calculations.

1. Organizing Claim Data in the Form of a Run-Off Triangle

Run-off triangle data contains a summary of all claims (in aggregate) and serves as a summary of individual claim data sets (Yulita et al., 2025). The data in the run-off triangle usually consists of one of the following, the amounts of claims or the number of claims, both of which are presented in incremental form (Julianty et al., 2025). Suppose $D_{i;j}$ represents the incremental claim that occurred in accident year (i) with $i \in \{1, \dots, n\}$ and were reported in development year (j), with $j \in \{0, \dots, J\}$, thus the incremental run-off triangle can be obtained in Table 1.

Table 1. Run-Off Incremental Triangle

Accident period (i)	Development period (j)					
	0	1	…	j	…	J
1	$D_{1;0}$	$D_{1;1}$	…	$D_{1;j}$	…	$D_{1;J}$
⋮	…	…	…	…	⋰	
i	$D_{i;0}$	$D_{i;1}$	…	$D_{i;j}$		
⋮	…	…	⋰			
$n-1$	D_{n-1}	$D_{n-1;1}$				
n	$D_{n;0}$					

The data in the run-off triangle in incremental form is shown in Table 1 can be converted into a cumulative run-off triangle using the following relationship (Kartikasari et al., 2017).

$$C_{i;j} = \sum_{j=0}^{J} D_{i;j} \quad (1)$$

2. Estimating Claim Reserves Using the Mack Chain-Ladder Method

The Mack Chain-Ladder (MCL) method is a technique for estimating future claim reserves based on data presented in the aggregate run-off triangle. The initial step in determining claim reserve estimates using the MCL method is to construct the run-off triangle using Equation (1). The next step in claim reserve estimation using the MCL method is the calculation of development factors. The development factor for j −period can be determined using the following equation.

$$\widehat{\lambda}_J = \frac{\sum_{i=1}^{n-j-1} C_{i;j+1}}{\sum_{i=1}^{n-j-1} C_{i;j}} \quad (2)$$

with $j \in \{1,2, \dots, n-1\}$. These development factors are then used to estimate the claims in the gray-shaded area of the cumulative run-off triangle up to development j −period, as follows

$$\hat{C}_{i;j} = C_{i;j-1}\hat{\lambda}_{i;j} \quad (3)$$

for $i \in \{2,3, \dots, n\}$ and $j \in \{n-i+2, \dots, n\}$. In addition, the total claims for accident i −period, $i \in \{2,3, \dots, n\}$ can also be obtained using the following equation.

$$\hat{R}_i = \hat{C}_{i;j} - \hat{C}_{i;j-1} \quad (4)$$

Thus, the total future claims can be obtained as follows (Tirta Julianty et al., 2025).

$$\hat{R} = \sum_{i=2}^{n} \hat{R}_i \quad (5)$$

The purpose of reserve calculation is to fill in the lower part of the triangle that is still empty and to perform extrapolation beyond the maximum development period if necessary. Mack proposed a stochastic version of the MCL technique, focusing on cumulative claims with mean and variance values for $0 \leq j \leq J$ (Bradlee, 2021). Thus, it can be concluded that the expected value and variance of the cumulative claims are proportional to the cumulative claims of the previous development period. According to Mack, MCL is a weighted normal regression method with the dependent variable Y being $C_{i;j+1}$, the independence variable X being $C_{i;j}$, and the weight being $\frac{1}{C_{i;j}}$ (Saragih et al., 2023). Based on the weighted least squares estimation method and the normal regression assumption, $\hat{\lambda}_j$ in Equation (2) can also be obtained from the following equation for $0 \leq j \leq J$ and it is found that MCL does not take into account any dependence between accident periods or $\{C_{i;1}, \dots, C_{i;J}\}, \{C_{k;1}, \dots, C_{k;J}\}, i \neq k$ (England et al., 2019).

$$\hat{\lambda}_j = \frac{\sum_{i=1}^{n-j-1} C_{i;j} f_{i;j}}{\sum_{i=1}^{n-j-1} C_{i;j}} \tag{6}$$

with the value of $f_{i;j}$ obtained from.

$$f_{i;j} = \frac{C_{i;j+1}}{C_{i;j}} \tag{7}$$

The estimate of $\hat{\lambda}_j$ is the weighted average of $C_{i;j}$. The parameter value σ_j^2 can be obtained, which is derived using the weighted sum of squared residuals method. Thus, the estimated value of the parameter σ_j^2 can be obtained using the following equation.

$$\hat{\sigma}_j^2 = \frac{1}{n-j-2} \sum_{i=1}^{n-j-1} C_{i;j} \left(f_{i;j} - \hat{\lambda}_j\right)^2 \tag{8}$$

for $0 \leq j \leq J-2$. If the value $\hat{\lambda}_{J-1} = 1$ it can be concluded that claims are completed in $J-1$ period and $\hat{\sigma}_J = 0$, conversely if the value $\hat{\lambda}_{J-1} \neq 1$, it can be assumed that the series $\hat{\sigma}_1, \dots., \hat{\sigma}_{J-3,} \hat{\sigma}_{J-2}$ decreases exponentially by one additional member, where $\frac{\hat{\sigma}_{J-3}}{\hat{\sigma}_{J-2}} = \frac{\hat{\sigma}_{J-2}}{\hat{\sigma}_{J-1}}$. The estimator for the final unknown variable $\hat{\sigma}_{J-1}$ is given by the following equation (Bradlee, 2021).

$$\hat{\sigma}_{J-1}^2 = min\left(\hat{\sigma}_{J-3}^2, \hat{\sigma}_{J-2}^2, \frac{\hat{\sigma}_{J-3}^4}{\hat{\sigma}_{J-2}^2}\right) \tag{9}$$

3. Simulating Claim Reserves Using Bootstrap Method

The Bootstrap technique is a resampling method with N replications, which produces a predictive distribution consisting of the mean, prediction error, and percentile values (Pinheiro et al., 2003). In claim reserves, the mean represents the claim amount, the prediction error indicates the accuracy of the reserve estimation, and the percentile values provide insight into the reserve amount that the company needs to prepare. The data for resampling must be independent and identically distributed; therefore, the Bootstrap technique is applied to the residual data (England et al., 2019). Residuals are determined based on the model used, after which new data are generated through residual resampling, and the process is repeated until a joint distribution of parameter estimates is obtained. The predictive distribution is then derived from simulations that incorporate both process and parameter uncertainty. The Bootstrap model in this study is MCL with a Generalized Linear Model (GLM) approach, assuming Normal distribution and an identity link function (McCullagh, 2019). Next, the Pearson residuals are derived based on the GLM approach with a normal distribution, and the procedure continues within the Bootstrap framework as follows (England & Verrall, 2006):

a. Calculate the residuals to be used in the Bootstrap method and the non-constant scale parameter, the residual values are obtained using the following equation.

$$r_{i;j} = r_p^{adj}\left(f_{i;j}, \hat{\lambda}_j, C_{i;j}, \hat{\sigma}_j\right) = \frac{\sqrt{\frac{n_j}{n_j-1}}\sqrt{C_{i;j}}(f_{i;j}-\hat{\lambda}_j)}{\hat{\sigma}_j} \tag{10}$$

b. The Bootstrap process is repeated N times with the following steps:
   1) Perform scaled residual resampling to form a new residual triangle.
   2) Each residual is recalculated using Equation (10), resulting in new data generated through the following equation.

$$f_{i;j}^{B;C} = r_{i,j}^{B;C}\frac{\hat{\sigma}_j}{\sqrt{C_{i;j}}} + \hat{\lambda}_j \tag{11}$$

   The index C indicates the total number of simulations, while B refers to the B^{th} simulation, where $B \in \{1,2,\dots,C\}$.

   3) The paid-to-date values (the diagonal of the cumulative triangle) are maintained to calculate claim payments for previous periods based on Equation (7), resulting in the following equation.

$$C_{i;j}^{B;C} = \frac{C_{i;j+1}^{B;C}}{f_{i;j}^{B;C}} \tag{12}$$

   4) Determine the new MCL development factors by applying Equation (6) to the resampled data, resulting in the following equation.

$$\tilde{\lambda}_{i;j}^{B;C} = \frac{\sum_{i=1}^{n-j+1} C_{i;j}^{B;C} f_{i;j}^{B;C}}{\sum_{i=1}^{n-j+1} C_{i;j}^{B;C}} \tag{13}$$

   5) Use a parametric approach to estimate future claim amounts, with the Gamma distribution as the process distribution. the values α and β can be calculated using the following equation.

$$\alpha_{i;j+1}^{B;C} = \frac{\tilde{\lambda}_j^{B;C^2} \tilde{C}_{i;j}^{B;C}}{\hat{\sigma}_j^2} \text{ and } \beta_{i;j+1}^{B;C} = \frac{\tilde{\lambda}_j^{B;C}}{\hat{\sigma}_j^2} \tag{14}$$

6) Calculate the Bootstrap claim reserve ($R_i^{B;C}$) using the following equation, based on the MCL method by applying Equation (4) and Equation (5) to the new dataset.

$$\begin{aligned} R_i^{B;C} &= \tilde{C}_{i;J}^{B;C} - C_{i;n-i}^{B;C} \\ R^{B;C} &= \textstyle\sum_{i=2}^{n} R_i^{B;C} \end{aligned} \tag{15}$$

7) The results are saved, and the process is repeated until N replication is generated. Each simulation result is stored to form a predictive distribution, and then the mean is compared with the MCL reserve estimate. The average reserve for accident i −period (R_i^C) and the average total claim reserve (R^C) are calculated using the following equations (England et al., 2019).

$$\begin{aligned} R_i^C &= \tfrac{1}{C} \textstyle\sum_{B=1}^{C} R_i^{B;C} \\ R^C &= \tfrac{1}{C} \textstyle\sum_{B=1}^{C} R^{B;C} \end{aligned} \tag{16}$$

4. Determining the Best Estimate of Claim Reserve

Prediction error is the difference between the predicted value and the actual value, one measure of which is the Mean Squared Error of Prediction (MSEP) (England et al., 2019). Process variance reflects the uncertainty related to the claim calculation process, while estimation variance represents the uncertainty in parameter estimation, both are calculated based on the model used. The model used in this study is the MCL model. The estimation variance and process variance are summed to obtain the MSEP equation for accident i −period. The MSEP equation is as follows.

$$MSEP\left[\hat{R}_i \middle| D\right] \approx C_{i;J}^2 \textstyle\sum_{j=n-i}^{J-1} \frac{\hat{\sigma}_j^2}{\hat{\lambda}_j^2} \left(\frac{1}{\hat{C}_{i;j}} + \frac{1}{\sum_{I=1}^{n-j-1} C_{I;j}} \right) \tag{17}$$

The calculation of the total claim reserve MSEP requires an adjustment for covariance between years using a correlation factor, which is done by multiplying the correlation between estimates for different years with the prediction variance. This adjustment aims to produce a more accurate variance that reflects the actual uncertainty. The equation used is as follows.

$$MSEP\left[\hat{R} \middle| D\right] \approx \textstyle\sum_{i=2}^{n} \left\{ MSEP\left[\hat{R}_i \middle| D\right] + 2C_{i;J} \left(\sum_{q=i+1}^{n} \hat{C}_{q;J} \right) \times \sum_{j=n-i}^{J-1} \frac{\hat{\sigma}_j^2}{\hat{\lambda}_j^2 \sum_{I=1}^{n-j-1} C_{I;j}} \right\} \tag{18}$$

In this study, the prediction error is measured using the Root Mean Squared Error of Prediction (RMSEP), which is the square root of the sum of the two previous components and can be considered as the standard deviation of the forecast that accounts for parameter uncertainty. RMSEP is calculated using the following.

$$RMSEP\left[\hat{R}_i\middle|D\right] \approx \sqrt{MSEP\left[\hat{R}_i\middle|D\right]} \text{ and } RMSEP\left[\hat{R}\middle|D\right] \approx \sqrt{MSEP\left[\hat{R}\middle|D\right]} \quad (19)$$

In the Bootstrap process, the prediction error Root Mean Squared Error of Prediction (RMSEP) is calculated using the standard deviation. The standard deviation of the claim reserve for accident i −period is calculated using the following equation.

$$\begin{aligned} RMSEP\left(R_i^C\right) &= \sqrt{\frac{1}{C}\sum_{B=1}^{C}\left(R_i^{B;C} - R_i^C\right)^2} \\ RMSEP(R^C) &= \sqrt{\frac{1}{C}\sum_{B=1}^{C}(R^{B;C} - R^C)^2} \end{aligned} \quad (20)$$

5. Calculating the International Financial Reporting Standard (IFRS 17) Components

IFRS 17 is an international accounting standard for insurance contracts issued by the IASB, replacing IFRS 4. This standard governs the recognition, measurement, and presentation of financial statements by distinguishing three main approaches: the General Measurement Model (GMM) as this research, which is used for long-term contracts; the simpler Premium Allocation Approach (PAA) for short-term contracts; and the Variable Fee Approach (VFA), which is applied to insurance products that depend on underlying items, such as unit-linked products (Padoan, 2023). In addition, IFRS 17 distinguishes between two types of liabilities, these are Liability for Remaining Coverage (LRC), which represents the risk of contracts still in force, and Liability for Incurred Claims (LIC), which includes claims that have already occurred both those not yet reported (IBNR) and those already reported but not yet settled (RBNS).

a. Calculating of Best Estimate Liability (BEL)

Best Estimate Liability (BEL) is the best estimate of expected future cash flows related to insurance liabilities, in accordance with IFRS 17 accounting standards. In this study, BEL will use the present value of claims from each accident period. The claim amount for each accident period can be calculated using the following equation.

$$D_{i;j}^B = \tilde{C}_{i;j}^B - \tilde{C}_{i;j-1}^B \quad (21)$$

This study will focus only on the calculation of claim reserves; therefore, the value of cash inflows is not considered, as premium payments occur mid-year and only claim reserve outflows are considered. The present value of claim reserves for accident i^{th} period and B^{th} simulation based on the present value of future claims, is calculated using the following.

$$PV(R_i^B) = PV(D_{i;J+1-i}^B) + \cdots + PV(D_{i;J}^B) \quad (22)$$

The total claim reserve value in the B^{th} simulation, based on future claim values discounted to the last accident period, will be used as the BEL value for B^{th} simulation because the present value of the total claim reserve represents the present value of cash outflows. The BEL value in simulation B^{th} simulations is calculated using the following equation.

$$BEL^B = \sum_i^n PV(R_i^B) \tag{23}$$

The BEL value to be used is the average BEL from all B simulations, as using the mean is expected to represent the entire BEL data set, including values in the tail. It is calculated using.

$$BEL = \frac{1}{B}\sum_{B=1}^{B} BEL^B \tag{24}$$

with $i + j \geq J + 1, i \in \{2, \dots, n\}$ and $j \in \{1, \dots, J\}$ during the B^{th} simulation, with $B \in \{1, \dots, 10.000\}$ at the MCL method $B = 1$, also t represents the difference between the settlement period and the current period ($t = i + j - (J + 1)$).

b. Calculating of Value at Risk (VaR)

Value at Risk (VaR) is a method used to measure the maximum potential loss at a certain confidence level. VaR indicates the minimum reserve required for a company to avoid bankruptcy with a high probability (Klugman et al., 2019). VaR for discrete data distributed i.i.d. $x_1, x_2, \dots, x_n$ VaR can be estimated as follows.

1) Sorting the data from largest to smallest $x_{(1)}, x_{(2)}, \dots, x_{(n)}$.
2) Determining the percentile p position from the sorted data using the equation $k = \big((n-1)p + 1\big)$, where $\tilde{k}$ is the floor (rounded down) value of k.
3) VaR value at position k is (Jorion, 2016).

$$VaR_p(X) \approx x_{\tilde{k}} + (k - \tilde{k})(x_{\tilde{k}+1} - x_{\tilde{k}}) \tag{25}$$

VaR assumes the data are normally distributed, so a normality test is required. One method used is the Kolmogorov-Smirnov test, which is simple and flexible for various distributions. Hypothesis testing in Kolmogorov-Smirnov testing is as follows.

H_0: the data are normally distributed

H_1: the data are not normally distributed

The Kolmogorov-Smirnov test statistic (D_{max}) is compared with the critical value from the Kolmogorov-Smirnov table (D_{tabel}) which depends on the sample size (n) and the significance level (α) using the equation (Klugman et al., 2019).

$$\begin{gathered} D_{max} = max|F_s(x_i) - F_t(x_i)| \\ D_{table} = \sqrt{\frac{-\ln(\frac{\alpha}{2})}{2n}} \end{gathered} \tag{26}$$

The decision rule is if $p - value < \alpha$ or if $D_{max} > D_{tabel}$ then H_0 rejected

c. Calculating of Risk Adjustment (RA)

Risk Adjustment (RA) is the compensation required by an insurance company for bearing the uncertainty of cash flows arising from non-financial risks. RA can be calculated using various methods, however, in this study, a risk measure approach based on a confidence level, namely Value at Risk (VaR), is used, with the confidence level determined according to the company's policy (Julianty et al., 2025). The RA value is calculated as the difference between the risk measure and the Best Estimate Liability (BEL), as follows.

$$RA_{VaRp} = VaR_p - BEL \tag{27}$$

d. Calculating of Liability for Incurred Claims (LIC)
Liability for Incurred Claims (LIC) is the company's obligation to pay claims that have already occurred but have not yet been settled. LIC consists of BEL and RA, so its value is determined by adding these two components. The equation is as follows.

$$LIC_{VaRp} = RA_{VaRp} + BEL \tag{28}$$

Thus, the value of LIC will be aligned with the RA calculation method used, as both reflect the estimated liability while taking risk at a certain confidence level into account.

C. RESULTS AND DISCUSSION

1. Organizing Claim Data in the Form of a Run-Off Triangle

The claim amount data in this study will be presented in two types of run-off triangles, incremental and cumulative, as shown in Table 2.

Table 2. Run-Off Incremental Triangle

Accident period (i)	Development period (j)											
	0	1	2	3	4	5	6	7	8	9	10	11
2013	15,769,865	13,612,669	13,125,941	13,514,443	9,613,903	7,149,602	5,192,397	3,544,559	2,015,477	872,640	406,087	129,162
2014	15,631,782	13,915,669	13,356,986	13,292,663	9,410,345	6,993,769	5,124,768	3,527,311	2,168,234	996,475	457,441	
2015	15,732,025	13,662,692	13,268,126	13,303,964	9,425,834	6,834,782	4,943,520	3,400,145	2,060,594	876,087		
2016	16,419,582	13,857,784	13,370,404	13,439,949	9,506,550	7,011,825	5,060,268	3,430,817	2,023,272			
2017	16,015,570	13,487,368	13,348,196	13,214,893	9,554,587	7,064,060	5,073,351	3,428,920				
2018	16,392,254	13,679,144	13,010,970	13,283,552	9,394,250	6,808,423	4,821,429					
2019	16,221,255	13,762,777	13,205,531	13,496,065	9,543,657	7,012,777						
2020	15,945,949	13,471,488	12,600,193	12,805,433	9,266,417							
2021	15,983,906	13,448,777	13,167,069	13,100,399								
2022	15,553,069	13,092,127	13,022,130									
2023	16,565,092	13,584,335										
2024	15,657,777											

The value of $D_{1;1}$ shows that the claim amount that occurred in 2013 and was reported in 2014 is 13,612,669, while the value of $D_{2;2}$ indicates that the claim amount that occurred in 2014 and was reported in 2016 is 13,356,986. The incremental run-off triangle in Table 2 is converted into a cumulative run-off triangle using Equation (1) and can be seen in Table 3.

Table 3. Run-Off Cumulative Triangle

Accident period (i)	Development period (j)											
	0	1	2	3	4	5	6	7	8	9	10	11
2013	15,769,865	29,382,534	42,508,475	56,022,918	65,636,821	72,786,423	77,978,820	81,523,379	83,538,856	84,411,496	84,817,583	84,946,745
2014	15,631,782	29,547,451	42,904,437	56,197,100	65,607,445	72,601,214	77,725,982	81,253,293	83,421,527	84,418,002	84,875,443	
2015	15,732,025	29,394,717	42,662,843	55,966,807	65,392,641	72,227,423	77,170,943	80,571,088	82,631,682	83,507,769		
2016	16,419,582	30,277,366	43,647,770	57,087,719	66,594,269	73,606,094	78,666,362	82,097,179	84,120,451			
2017	16,015,570	29,502,938	42,851,134	56,066,027	65,620,614	72,684,674	77,758,025	81,186,945				
2018	16,392,254	30,071,398	43,082,368	56,365,920	65,760,170	72,568,593	77,390,022					
2019	16,221,255	29,984,032	43,189,563	56,685,628	66,229,285	73,242,062						
2020	15,945,949	29,417,437	42,017,630	54,823,063	64,089,480							
2021	15,983,906	29,432,683	42,599,752	55,700,151								
2022	15,553,069	28,645,196	41,667,326									
2023	16,565,092	30,149,427										
2024	15,657,777											

The value $C_{1;1}$ shows that the cumulative claim amount that occurred in 2013 and had been reported up to 2014 is 29,382,534, the value $C_{2;2}$ shows that the claim amount that occurred in 2014 and had been reported up to 2016 is 42,904,437.

2. Estimating Claim Reserves Using the Mack Chain-Ladder Method

The calculation of claim reserves using the MCL method, after obtaining the cumulative run-off triangle data in

Table 3 involves calculating the development factor using Equation (2), and the results are shown in Table 4 below.

Table 4. Chain-Ladder Development Factor

j	0	1	2	3	4	5	6	7	8	9	10
$\hat{\lambda}_j$	1.8487	1.4447	1.3099	1.1686	1.1061	1.0692	1.0445	1.0254	1.0110	1.0051	1.0015

The value of the development factor for 0 −period ($\hat{\lambda}_0$) is 1.8487, this value indicates that the number of claims reported in period 1 is about 1.8 times the amount reported in 0 −period. Based on the cumulative claims ($C_{i;j}$) in Table 3 and the development factor ($\hat{\lambda}_j$) in Table 4 above can be used to predict the number of claims that happen in the future ($\hat{C}_{i;j}$) using Equation (3). The complete values of $\hat{C}_{i;j}$ are presented in the following Table 5.

Table 5. Chain-Ladder Claim Prediction

Accident period (i)	Development period (j)											
	0	1	2	3	4	5	6	7	8	9	10	11
2013	15,769,865	29,382,534	42,508,475	56,022,918	65,636,821	72,786,423	77,978,820	81,523,379	83,538,856	84,411,496	84,817,583	84,946,745
2014	15,631,782	29,547,451	42,904,437	56,197,100	65,607,445	72,601,214	77,725,982	81,253,293	83,421,527	84,418,002	84,875,443	85,004,693
2015	15,732,025	29,394,717	42,662,843	55,966,807	65,392,641	72,227,423	77,170,943	80,571,088	82,631,682	83,507,769	83,934,894	84,062,712
2016	16,419,582	30,277,366	43,647,770	57,087,719	66,594,269	73,606,094	78,666,362	82,097,179	84,120,451	85,045,671	85,480,662	85,610,834
2017	16,015,570	29,502,938	42,851,134	56,066,027	65,620,614	72,684,674	77,758,025	81,186,945	83,249,412	84,165,051	84,595,538	84,724,362
2018	16,392,254	30,071,398	43,082,368	56,365,920	65,760,170	72,568,593	77,390,022	80,835,448	82,888,985	83,800,661	84,229,284	84,357,550
2019	16,221,255	29,984,032	43,189,563	56,685,628	66,229,285	73,242,062	78,312,377	81,798,866	83,876,877	84,799,419	85,233,150	85,362,945
2020	15,945,949	29,417,437	42,017,630	54,823,063	64,089,480	70,886,590	75,793,843	79,168,206	81,179,389	82,072,261	82,492,043	82,617,664
2021	15,983,906	29,432,683	42,599,752	55,700,151	65,088,452	71,991,509	76,975,252	80,402,212	82,444,743	83,351,533	83,777,858	83,905,437

Accident period (i)	Development period (j)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
2022	15,553,069	28,645,196	41,667,326	54,579,606	63,779,038	70,543,224	75,426,706	78,784,724	80,786,165	81,674,713	82,092,462	82,217,474
2023	16,565,092	30,149,427	43,556,615	57,054,367	66,670,922	73,741,811	78,846,721	82,356,999	84,449,190	85,378,026	85,814,717	85,945,397
2024	15,657,777	28,947,255	41,819,848	54,779,393	64,012,499	70,801,445	75,702,803	79,073,113	81,081,880	81,973,680	82,392,959	82,518,428

The predicted claim amount value $\hat{C}_{12;1}$ for accident 12^{th} period and development period 1 is 28,947,255. The predicted claim reserve for i^{th} accident period $\left(\hat{R}_i\right)$ is calculated using Equation (4), while the predicted total claim reserve $(\hat{R})$ is calculated using Equation (5), and value of $\hat{C}_{i;j}$ in Table 5 with the following results, as shown in Table 6.

Table 6. Claim Reserve Using Chain-Ladder Method

i	1	2	3	4	5	6	7	8	9	10	11	12	Total $(\hat{R})$
$\hat{R}_i$	0	129,250	554,942	1,490,383	3,537,417	6,967,527	12,120,883	18,528,184	28,205,286	40,550,147	55,795,970	66,860,651	234,740,644

The predicted total claim reserve is 234,740,644, this value represents the amount of claim reserves that the company must prepare for all future claims. The calculated claim reserve will then be evaluated for prediction error using the Root Mean Squared Error of Prediction (RMSEP). To calculate RMSEP, the variance parameter for j −period $(\hat{\sigma}_j^2)$ and $f_{i;j}$. The value $f_{i;j}$ values are calculated using Equation (7) from value of $C_{i;j}$ in

Table 3 and are presented in Table 7.

Table 7. $f_{i;j}$

Accident period (i)	Development period (j)										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2013	1.8632	1.4467	1.3179	1.1716	1.1089	1.0713	1.0455	1.0247	1.0104	1.0048	1.0015
2014	1.8902	1.4521	1.3098	1.1675	1.1066	1.0706	1.0454	1.0267	1.0119	1.0054	
2015	1.8685	1.4514	1.3118	1.1684	1.1045	1.0684	1.0441	1.0256	1.0106		
2016	1.8440	1.4416	1.3079	1.1665	1.1053	1.0687	1.0436	1.0246			
2017	1.8421	1.4524	1.3084	1.1704	1.1077	1.0698	1.0441				
2018	1.8345	1.4327	1.3083	1.1667	1.1035	1.0664					
2019	1.8484	1.4404	1.3125	1.1684	1.1059						
2020	1.8448	1.4283	1.3048	1.1690							
2021	1.8414	1.4474	1.3075								
2022	1.8418	1.4546									
2023	1.8201										

The variance parameter values $\hat{\sigma}_j^2$ are calculated using Equation (8) and Equation (9) and value of $C_{i;j}$ in Table 3, $\hat{\lambda}_j$ in Table 4, and $f_{i;j}$ in Table 7. The complete variance parameter values are presented in Table 8.

Table 8. Value of the Variance Parameter

j	0	1	2	3	4	5	6	7	8	9	10
$\hat{\sigma}_j^2$	5,620.3	2,321.5	613.8	176.6	223.4	221.5	55.2	73.6	56.6	15.6	4.3

The calculation of RMSEP requires the value of MSEP first. The prediction error of claim reserves in the i^{th} accident period ($MSEP\left[\hat{R}_i\middle|D\right]$) is calculated using Equation (17) and the total prediction error of claim reserves ($MSEP\left[\hat{R}\middle|D\right]$) is calculated using Equation (18), as presented in the following Table 9.

Table 9. Chain-Ladder MSEP Value

i	1	2	3	4	5	6	7	8	9	10	11	12	Total ($MSEP\left[\hat{R}\middle|D\right]$)
$MSEP\left[\hat{R}_i\middle|D\right]$	0	$7.3 \cdot 10^8$	$2.7 \cdot 10^9$	$9.2 \cdot 10^9$	$1.7 \cdot 10^{10}$	$2.2 \cdot 10^{10}$	$4.5 \cdot 10^{10}$	$6.6 \cdot 10^{10}$	$8.5 \cdot 10^{10}$	$1.5 \cdot 10^{11}$	$4.6 \cdot 10^{11}$	$1.2 \cdot 10^{12}$	$2.7 \cdot 10^{12}$

The total prediction error of claim reserves $MSEP\left[\hat{R}\middle|D\right]$ is $2.663420 \cdot 10^{12}$, This value represents the expected squared difference between the actual value and the predicted value of the total claim reserves, along with the addition of the covariance adjustment. The MSEP value will be converted into RMSEP using Equation (19) with the MSEP value in Table 9, resulting in the following outcome, as shown in Table 10.

Table 10. Chain-Ladder RMSEP Value

i	1	2	3	4	5	6	7	8	9	10	11	12	Total ($RMSEP\left[\hat{R}\middle|D\right]$)
$RMSEP\left[\hat{R}_i\middle|D\right]$	0	27,019	51,682	95,870	129,623	149,306	212,436	256,070	291,773	384,022	674,792	1,101,812	1,631,999

The prediction error for the total claim reserve $RMSEP\left[\hat{R}\middle|D\right]$ is 1,631,999. A smaller RMSEP value indicates that the prediction is closer to the actual value. The RMSEP value will be compared with the standard deviation of claim reserves calculated using the Bootstrap method to determine the best reserve estimate.

3. Simulating Claim Reserve Using the Bootstrap Method

The calculation of claim reserves using the Bootstrap method begins by determining the Pearson residuals ($r_{i;j}$) of the MCL method using the cumulative claim values $C_{i;j}$ in Table 3, $\hat{\lambda}_j$ in Table 4, $f_{i;j}$ in Table 7 and σ_j^2 in Table 8. The residual values are calculated using Equation (10) and the results can be obtained as shown in Table 11.

Table 11. Residual $r_{i;j}$

Accident period (i)	Development period (j)										
	0	1	2	3	4	5	6	7	8	9	10
2013	0.803	0.241	2.242	1.840	1.680	1.325	1.242	-0.828	-0.823	-0.707	0.000
2014	2.294	0.875	-0.020	-0.662	0.318	0.854	1.142	1.554	1.407	0.707	
2015	1.094	0.793	0.545	-0.080	-0.898	-0.490	-0.608	0.207	-0.587		
2016	-0.270	-0.372	-0.558	-1.231	-0.451	-0.302	-1.212	-0.926			
2017	-0.370	0.920	-0.420	1.124	0.933	0.359	-0.561				
2018	-0.808	-1.442	-0.439	-1.139	-1.478	-1.748					
2019	-0.017	-0.512	0.730	-0.115	-0.100						
2020	-0.219	-1.942	-1.423	0.282							
2021	-0.411	0.317	-0.661								

Accident period (i)	Development period (j)										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
2022	-0.385	1.160									
2023	-1.633										

a. The residual resampling process to obtain the Bootstrap residuals ($r_{i;j}^{B;C}$) is carried out using R Studio software, based on the residual data $r_{i;j}$ in Table 11. The result of the first simulation from a total of 5,000 simulations is presented in Table 12 below.

Table 12. Bootstrap Residual

Accident period (i)	Development period (j)										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1^{st} simulation out of 5,000 simulations										
2013	-0,302	0,317	-0,828	-0,823	0,282	-0,115	-0,661	-1,442	1,554	0,920	0,000
2014	-0,115	-0,608	1,840	-0,561	0,793	-1,942	-1,212	0,207	0,359	-0,587	
2015	-0,808	0,875	-0,302	-0,808	-1,478	-0,661	1,407	2,242	0,875		
2016	0,707	0,207	0,318	-0,587	-0,370	-1,478	-0,490	0,854			
2017	-1,139	-0,823	-0,115	0,803	2,294	-1,423	0,359				
2018	1,407	-0,451	-0,558	0,318	0,920	0,207					
2019	0,318	1,160	0,241	0,854	-0,608						
2020	0,359	0,241	0,933	-0,370							
2021	1,680	-0,100	0,545								
2022	-1,478	0,793									
2023	0,207										

The residual value $r_{1;0}^{1;5,000}$ for accident period 1, development period 0, and the first simulation out of 5,000 simulations is -0.302, this value indicates that the actual claim amount is about 30% of a standard deviation below the MCL model's predicted value in the first simulation (out of 5,000) for accident period 1^{st} and development period 1^{st}.

b. Calculate the Bootstrap ratio value f which is determined using Equation (11). Based on the values of $C_{i;j}$ in Table 3, $\hat{\lambda}_j$ in Table 4, σ_j^2 in Table 8, and value of $r_{i;j}^{B;C}$ in Table 12, can be calculated the Bootstrap ratio value for accident i −period, development j −period, and the first simulation out of 5,000 simulations can be calculated as shown in Table 13.

Table 13. Bootstrap Ratio

Accident period (i)	Development period (j)										
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1^{st} simulation out of 5,000 simulations										
2013	1.8430	1.4475	1.3067	1.1671	1.1066	1.0690	1.0440	1.0240	1.0123	1.0055	1.0015
2014	1.8466	1.4393	1.3169	1.1676	1.1075	1.0658	1.0435	1.0256	1.0113	1.0049	
2015	1.8335	1.4525	1.3087	1.1671	1.1033	1.0681	1.0457	1.0275	1.0117		
2016	1.8618	1.4465	1.3111	1.1675	1.1054	1.0667	1.0441	1.0262			
2017	1.8274	1.4374	1.3095	1.1700	1.1103	1.0667	1.0448				
2018	1.8748	1.4407	1.3078	1.1691	1.1078	1.0696					
2019	1.8547	1.4549	1.3108	1.1701	1.1049						
2020	1.8555	1.4468	1.3135	1.1679							
2021	1.8803	1.4438	1.3120								
2022	1.8206	1.4518									
2023	1.8526										

The ratio value $f_{1;0}^{1;5,000}$ for accident 1^{st} period, development 0 period, and the first simulation out of 5,000 simulations is 1.8430, this value indicates that, in the first simulation, the amount claims reported in accident period 1 and development period 1 is approximately 1.84 times the amount reported in accident period 1 and development period 0.

c. Construct the Bootstrap run-off triangle using Equation (12). Based on the values of $C_{i;j}$ in Table 3 and the Bootstrap ratio $f_{i;j}^{B;C}$ in Table 13 the simulated Bootstrap claim values are obtained as shown in Table 14.

Table 14. Bootstrap Claim Simulation

Accident period (i)	Development period (j)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	1st simulation out of 5,000 simulations											
2013	16,194,943	29,847,886	43,205,086	56,457,988	65,891,583	72,914,095	77,947,100	81,373,938	83,329,635	84,352,762	84,817,583	84,946,745
2014	16,179,139	29,875,893	43,000,335	56,624,991	66,112,858	73,221,324	78,041,817	81,436,554	83,521,368	84,464,723	84,875,443	
2015	16,024,968	29,381,487	42,675,739	55,851,567	65,185,272	71,920,501	76,816,030	80,327,335	82,540,128	83,507,769		
2016	16,152,052	30,072,345	43,499,635	57,031,638	66,585,524	73,602,254	78,508,780	81,971,791	84,120,451			
2017	16,302,957	29,792,255	42,823,247	56,075,123	65,606,577	72,842,270	77,704,006	81,186,945				
2018	15,815,978	29,651,750	42,720,122	55,868,738	65,316,920	72,355,010	77,390,022					
2019	16,016,916	29,706,083	43,219,410	56,651,977	66,286,059	73,242,062						
2020	15,562,975	28,876,983	41,780,223	54,876,437	64,089,480							
2021	15,639,098	29,405,478	42,455,697	55,700,151								
2022	15,763,530	28,699,841	41,667,326									
2023	16,274,555	30,149,427										
2024	15,657,777											

The simulated claim value $C_{1;10}^{1;5,000}$ for 1^{st} accident period, 10^{th} development period, and the first simulation out of 5,000 simulations is 84,817,583, this value represents the claim amount for 1^{st} accident period and 10^{th} development period in the first simulation out of 5,000.

d. Calculate the Bootstrap development factor using Equation (13). Based on the Bootstrap ratio values $f_{i;j}^{B;C}$ in Table 13 the simulated claim values $C_{i;j}^{B;C}$ in Table 14 can be computed the values $\tilde{\lambda}_j^{B;C}$ in Table 15.

Table 15. Bootstrap Development Factor

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	1^{st} simulation out of 5,000 simulations										
$\tilde{\lambda}_j^{1;5,000}$	1.8500	1.4461	1.3108	1.1683	1.1065	1.0676	1.0444	1.0258	1.0118	1.0052	1.0015
	⋮										
	$5,000^{th}$ out of 5,000 simulations										
$\tilde{\lambda}_j^{5,000;5,000}$	1.8526	1.4429	1.3105	1.1681	1.1060	1.0706	1.0448	1.0260	1.0100	1.0047	1.0015

In Table 15 shows the Bootstrap development factor values for the first simulation and the C^{th} simulation, illustrating a decreasing pattern across each development j^{th} period. The Bootstrap development factor for development period 0 in the first simulation out of 5,000 simulations ($\tilde{\lambda}_0^{1;5,000}$) is 1.8500, this value indicates that the estimated claims reported in development period 1 are approximately 1.8 times the amount reported in development period 0 in the first simulation out of 5,000 simulations.

e. The future claim values are estimated using a parametric approach, starting by calculating the values of $\alpha_{i;j+1}^{B;C}$ and $\beta_{i;j+1}^{B;C}$ using Equation (14). Based on value of σ_j^2 in Table 8, $C_{i;j}^{B;C}$ in Table 14, $\tilde{\lambda}_j^{B;C}$ in Table 15, the calculation results for $\alpha_{i;j+1}^{B;C}$ are as shown in Table 16.

Table 16. Bootstrap Parameter $\boldsymbol{\alpha_{i;j+1}^{B;C}}$

Accident period (i)	Development period (j) 0	1	2	3	4	5	6	7	8	9	10	11
						1st simulation out of 5,000 simulations						
2013												
2014												19,802,950
2015											5,408,574	19,580,819
2016										1,521,109	5,512,534	19,960,990
2017									1,160,751	1,502,576	5,439,163	19,686,027
2018								1,528,272	1,157,639	1,499,728	5,425,529	19,651,561
2019							376,918	1,543,094	1,166,649	1,513,548	5,475,094	19,838,013
2020						351,227	365,443	1,495,619	1,130,579	1,466,769	5,312,077	19,235,349
2021					430,564	357,086	371,447	1,520,644	1,149,225	1,492,103	5,411,020	19,611,956
2022				116,630	423,039	351,566	365,252	1,492,547	1,128,250	1,462,661	5,300,542	19,204,907
2023			27,159	122,200	443,090	367,241	381,951	1,563,610	1,182,055	1,530,245	5,545,298	20,090,469
2024		9,535	26,431	117,645	426,280	353,081	367,540	1,503,192	1,137,035	1,476,318	5,356,015	19,377,804

Meanwhile, the value of $\beta_{i;j}^{B;C}$ for accident i^{th} period, development j^{th} period, at the $5{,}000^{th}$ simulation.

Table 17. Bootstrap Parameter $\boldsymbol{\beta_{i;j+1}^{B;C}}$

Accident period (i)	Development period (j) 0	1	2	3	4	5	6	7	8	9	10	11
						1st simulation out of 5,000 simulations						
2013												
2014												0.232963
2015											0.0644331	0.232963
2016										0.0178722	0.0644331	0.232963
2017									0.0139371	0.0178722	0.0644331	0.232963
2018								0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2019							0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2020						0.0049526	0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2021					0.0066165	0.0049526	0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2022				0.0021355	0.0066165	0.0049526	0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2023			0.0006229	0.0021355	0.0066165	0.0049526	0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963
2024		0.0003292	0.0006229	0.0021355	0.0066165	0.0049526	0.0048201	0.0189078	0.0139371	0.0178722	0.0644331	0.232963

f. The distribution parameter values $\alpha_{12;1}^{1;5{,}000}$ and $\beta_{12;1}^{1;5{,}000}$ for 12^{th} accident period, 1^{st} development period, and the first simulation out of 5,000 simulations are 9,535 and 0.0003292, respectively. These values are used to calculate the estimated claim amount for 12^{th} accident period and 1^{st} development period in the first simulation from 5,000 simulations. Next, the predicted future claim amount is calculated based on the alpha parameter $(\alpha_{i;j}^{B;C})$ in Table 16 and $\beta_{i;j}^{B;C}$ in Table 17 the predicted future claim amount can be calculated as shown in Table 18.

Table 18. Bootstrap Claim Prediction

Accident period (i)	Development period (j) 0	1	2	3	4	5	6	7	8	9	10	11
						1st simulation out of 5,000 simulations						
2013	16,194,943	29,847,886	43,205,086	56,457,988	65,891,583	72,914,095	77,947,100	81,373,938	83,329,635	84,352,762	84,817,583	84,946,745
2014	16,179,139	29,875,893	43,000,335	56,624,991	66,112,858	73,221,324	78,041,817	81,436,554	83,521,368	84,464,723	84,875,443	84,995,493
2015	16,024,968	29,381,487	42,675,739	55,851,567	65,185,272	71,920,501	76,816,030	80,327,335	82,540,128	83,507,769	83,923,387	84,094,366
2016	16,152,052	30,072,345	43,499,635	57,031,638	66,585,524	73,602,254	78,508,780	81,971,791	84,120,451	85,112,890	85,552,801	85,684,698
2017	16,302,957	29,792,255	42,823,247	56,075,123	65,606,577	72,842,270	77,704,006	81,186,945	83,095,509	83,980,049	84,374,311	84,495,486
2018	15,815,978	29,651,750	42,720,122	55,868,738	65,316,920	72,355,010	77,390,022	80,969,280	82,938,014	83,769,544	84,226,590	84,333,007
2019	16,016,916	29,706,083	43,219,410	56,651,977	66,286,059	73,242,062	78,140,634	81,599,450	83,702,283	84,534,826	85,025,722	85,112,504
2020	15,562,975	28,876,983	41,780,223	54,876,437	64,089,480	71,012,312	75,736,556	79,076,578	81,115,293	82,017,853	82,442,704	82,565,800

Accident period (i)	Development period (j)											
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
	1st simulation out of 5,000 simulations											
2021	15,639,098	29,405,478	42,455,697	55,700,151	65,158,632	72,178,971	77,003,796	80,380,759	82,516,335	83,545,523	84,056,840	84,175,444
2022	15,763,530	28,699,841	41,667,326	54,726,577	64,151,309	70,975,108	75,580,970	78,913,700	80,888,140	81,839,762	82,312,232	82,428,232
2023	16,274,555	30,149,427	43,657,218	57,320,461	67,011,712	74,220,077	79,179,506	82,677,029	84,625,685	85,618,768	86,107,747	86,266,154
2024	15,657,777	29,342,028	42,029,987	55,145,838	64,427,869	71,419,828	76,120,031	79,528,146	81,643,371	82,696,263	83,053,267	83,171,852

The simulated claim value $\tilde{C}_{12;1}^{1;5,000}$, for 12^{th} accident period, 1^{st} development period, and the first simulation out of 5,000 simulations is 29,342,028. This indicates that the claim amount for12^{th} accident period, 1^{st} development period in the first simulation increased by 13,684,251 compared to period 0.

g. Next, the Bootstrap claim reserve is calculated. The Bootstrap claim reserve value is determined using Equations (15). Based on the simulated Bootstrap claim values ($\tilde{C}_{i;j}^{B;C}$) in Table 18 the Bootstrap claim reserve for i^{th} accident period from 5,000 simulations can be calculated as Table 19.

Table 19. Bootstrap Claim Reserve per Simulation

i	1	2	3	4	5	6	7	8	9	10	11	12	Total ($R^{B;C}$)
$R_i^{1;5,000}$	0	120,050	586,597	1,564,247	3,308,541	6,942,985	11,870,442	18,476,320	28,475,293	40,760,906	56,116,727	67,514,075	235,736,184
⋮	…	…	…	…	…	…	…	…	…	…	…	…	…
$R_i^{5,000;5,000}$	0	128,844	495,362	1,327,995	3,255,124	6,789,090	12,082,508	18,361,270	28,361,192	40,604,908	55,743,754	68,868,299	236,018,345

The predicted claim reserve value $R_3^{1;5,000}$ for 3^{th} accident period in the first simulation out of 5,000 simulations is 586,597. This indicates the amount of claim reserve that the company must set aside to pay for future claims occurring in 3^{th} accident period during the first simulation. Additionally, the predicted total Bootstrap claim reserve for the first simulation out of 5,000 is 235,736,184, this value represents the amount of claim reserves that the company must prepare for all future claims in the 1st simulation out of 5,000 simulations. The overall average value of Bootstrap claim reserves per accident period i^{th} and the total value is calculated using Equation (16). Based on the values of $R_i^{B;C}$and $R^{B;C}$ in Table 19, the values of $R_i^{5,000}$ and $R^{5,000}$ can be calculated as shown in Table 20.

Table 20. Total Bootstrap Claim Reserve

i	1	2	3	4	5	6	7	8	9	10	11	12	Total (R^C)
$R_i^{5,000}$	0	129,158	554,735	1,489,414	3,538,974	6,966,056	12,124,510	18,530,503	28,200,435	40,554,616	55,795,699	66,854,980	234,739,080

The predicted total claim reserve value based on 5,000 simulations is 234,739,080, this value indicates the amount of claim reserves the company should prepare for all future claims, according to the results of 5,000 simulations. Based on Table 20 the overall values of the Bootstrap claim reserve $R_i^{5,000}$ and $R^{5,000}$ illustrate the distribution of Bootstrap reserve values from the 5,000 simulations. For example, for 3^{rd} accident period, the distribution is shown as shown in Figure 1.

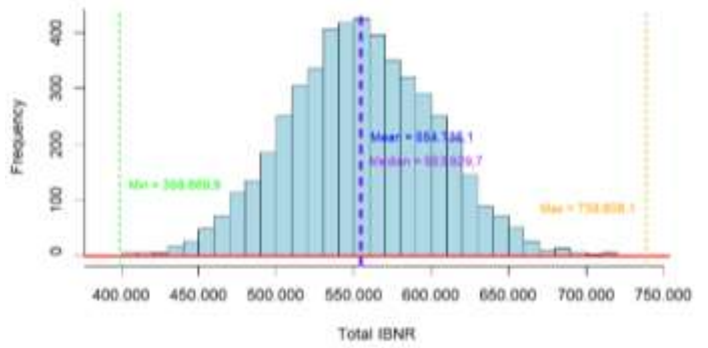

Figure 1. Bootstrap claim reserve value for $\boldsymbol{N = 5,000}$ in $\boldsymbol{3^{rd}}$ accident period

The Bootstrap claim reserve distribution for the 3^{rd} accident period is symmetrical, as the mean value is close to the median. The characteristics of the Bootstrap claim reserve data for the 3^{rd} accident period are as follows: the minimum value is 398,670, the maximum value is 738,606, the mean is 554,735, and the median is 553,929. The range of the Bootstrap claim reserve for the 3^{rd} accident period is 339,936, This range increases due to the addition of reserve predictions in the 10^{th} development period compared to the Bootstrap reserve for the 2^{nd} accident period. This pattern will continue in subsequent accident periods, where the range will consistently increase because of adding future claim predictions for each accident period.

h. Calculating the Bootstrap prediction error value (RMSEP). The claim reserve prediction error value, RMSEP, is calculated using Equation (20). Based on Table 19 and Table 20, the overall RMSEP prediction error values for all i^{th} accident periods as well as the total claim reserve are presented in the following Table 21.

Table 21. Bootstrap RMSEP Value

i	1	2	3	4	5	6	7	8	9	10	11	12	Total ($\boldsymbol{RMSEP(R^C)}$)
$RMSEP(R_i^{5,000})$	0	18,779	47,899	91,903	127,883	148,025	210,490	256,692	288,614	378,603	672,805	1,071,405	1,581,076

The prediction error value for the total claim reserve $RMSEP(R^{5,000})$ from 5,000 simulations is 1,581,076, This value indicates that, based on 5,000 simulations, the average spread of the simulated total claim reserve data relative to the total claim reserve amount results in the total claim reserve value falling within the range of 233,158,004 to 236,320,156.

4. Determining the Best Estimate of Claim Reserve

A comparison of the claim reserve prediction error values using the MCL method and the Bootstrap method is shown in the following Table 22.

Table 22. Chain-Ladder and Bootstrap RMSEP Value

i	1	2	3	4	5	6	7	8	9	10	11	12	Total
$RMSEP[\hat{R}_i\|D]$	0	27,019	51,682	95,870	129,623	149,306	212,436	256,070	291,773	384,022	674,792	1,101,812	1,631,999
$RMSEP(R_i^{5,000})$	0	18,779	47,899	91,903	127,883	148,025	210,490	256,692	288,614	378,603	672,805	1,071,405	1,581,076

The prediction error value for the MCL method appears to be higher than that of the Bootstrap method, indicating that the claim reserve predictions using the Bootstrap method are closer to the actual outcomes compared to those using the MCL method. Therefore, the Bootstrap method provides a better claim reserve estimate than the MCL method.

5. Calculating of International Financial Reporting Standard (IFRS 17) Components

a. Calculating of Best Estimate Liability (BEL)

The initial step in calculating the BEL value is to reconstruct the cumulative run-off triangle of the best estimate claim reserve into an incremental run-off triangle, representing claims that occurred in the i^{th} accident period and were reported in the j^{th} development period, for the first simulation through 5,000 simulations use Equation (21). Subsequently, the present value of claim reserves is calculated for accident period i and reported in development period j with simulations up to 5,000 using Equation (22) and an interest rate of 6%, yielding the following, as shown in Table 23.

Table 23. Present Value of Claim

Accident period (i)	Development period (j)											
	0	1	2	3	4	5	6	7	8	9	10	11
	1^{st} simulation out of 5,000 simulations											
2013												
2014												113,255
2015											392,093	152,170
2016										936,263	391,519	110,743
2017									1,800,532	787,237	331,031	95,982
2018								3,376,658	1,752,167	698,169	362,023	79,521
2019							4,621,294	3,078,334	1,765,579	659,452	366,826	61,178
2020						6,530,974	4,204,561	2,804,347	1,614,853	674,446	299,503	81,866
2021					8,923,095	6,248,076	4,051,016	2,674,871	1,595,827	725,538	340,055	74,413
2022				12,320,048	8,387,978	5,729,393	3,648,274	2,490,410	1,391,902	632,883	296,433	68,661
2023			12,743,200	12,160,237	8,136,961	5,709,701	3,705,973	2,465,616	1,295,967	623,073	289,426	88,454
2024		12,909,671	11,292,238	11,012,321	7,352,239	5,224,799	3,313,458	2,266,591	1,327,118	623,205	199,349	62,469

The BEL value in the B^{th} iteration simulation is calculated using Equation (23) and Table 23 with the results obtained as follows.

Table 24. Present Value of Claim Per Simulation

i	1	2	3	4	5	6	7	8	9	10	11	12	Total
$R_i^{1;5,000}$	0	113,255	544,263	1,438,526	3,014,781	6,268,537	10,552,663	16,210,548	24,632,891	34,965,982	47,218,607	55,583,457	200,543,513
⋮	…	…	…	…	…	…	…	…	…	…	…	…	…
$R_i^{5,000;5,000}$	0	121,551	460,956	1,221,817	2,970,598	6,130,328	10,776,117	16,133,588	24,576,661	34,891,824	46,850,567	56,701,360	200,835,373

The present value of the claim reserve$PV(R_2^1)$ for the 2^{nd} accident period from the 1^{st} simulation is 113,255. This value represents the present value of the claim reserve that the company must set aside to pay future claims arising from the 2^{nd} accident period. Meanwhile, the Best Estimate Liability (BEL), which represents the amount of funds the company needs to prepare to meet its financial obligations or liabilities, is calculated using Equation (24) resulting in a value of 199,711,615. The distribution of BEL values based on 5,000 simulations can be illustrated as shown on Figure 2.

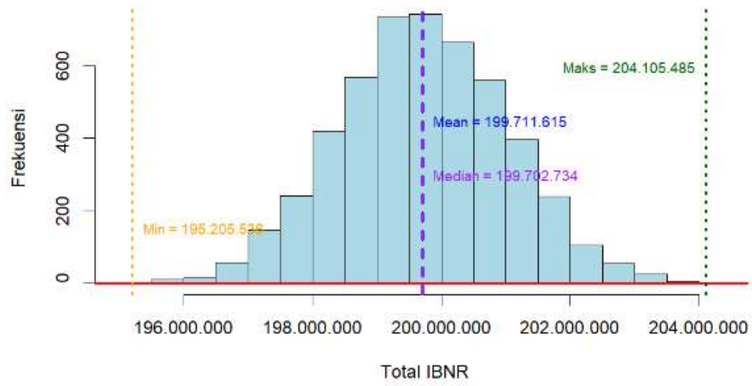

Figure 2. BEL

The BEL value is symmetrically distributed, as the mean is close to the median. The characteristics of the BEL data are as follows: the minimum value is 195,205,536, the maximum value is 204,105,485, the mean is 199,711,615, the median is 199,702,734, and the range is 8,899,949.

b. Calculating of Value at Risk (VaR)
The assumption that must be met to use the VaR risk measure is that the data to be used is normally distributed; therefore, the Kolmogorov-Smirnov test is applied. The value of α used is 5% or 0,05 (OJK, 2017). The D_{table} value is resulting in a value of 0.0192. The $p-value$ and D_{max} were computed with the assistance of R Studio software, and the results are presented as Table 25.

Table 25. Normality Test

D_{max}	D_{tabel}	$p-value$	α	Decision	Conclusion
0.00756	0.0192	0.9375	0.05	Accept H_0	Data are normally ditributed

Based on Table 25 all critical values where the $p-value$ (0.9375) > α (0.05) and D_{max} (0.00756) < D_{table} (0.0192) the result is to accept H_0 meaning the data are normally distributed. The calculation of the VaR risk measure for the distribution of BEL values begins by sorting the BEL data from each simulation from smallest to largest. Based on Table 24 the BEL value distribution data can be ordered as Table 26.

Table 26. Ordered BEL Value

Order	1	2	3	...	4,998	4,999	5,000
BEL Value	195,205,536	195,333,853	195,404,248	...	203,846,630	204,046,690	204,105,485

The second step in calculating the VaR risk measure is to determine the index k. Based on the formula $k = \big((n-1)p + 1\big)$ with a confidence level of p =95% the result is 4,750. Therefore, the calculation of the VaR value at a 95% confidence level is as follows.

$$VaR_{0,95}(X) \approx 201{,}828{,}878 + 0.05 \cdot 1{,}705 = 201{,}828{,}963.$$

This means that the VaR risk measure at the 95% confidence level is a BEL value of 201,828,963, indicating that the company can handle 95% of possible claims, with only a 5% chance of incurring a loss.

c. Calculating of Risk Adjustment (RA)
The RA value using the VaR risk measure is calculated based on Equation (27) using the previously calculated Best Estimate Liability (BEL) and VaR values, thus the RA value at a confidence level of $p = 95\%$ is calculated as follows.

$$RA_{VaR_{0.95}} = 201{,}828{,}963 - 199{,}711{,}615 = 2{,}117{,}349$$

This value represents the amount by which the BEL is increased as a risk adjustment above the initial estimate, used to address potential losses according to the VaR risk measure at a 95% confidence level which is approximately 1,06 % of the initial BEL estimate.

d. Calculating of Liability for Incurred Claims
The LIC value using the VaR risk measure is calculated based on Equation (28) using the previously calculated Best Estimate Liability (BEL) and Risk Adjustment (RA) values. Thus, the LIC value at a confidence level of $p = 95\%$ is calculated as follows.

$$LIC_{VaR_{0.95}} = 2{,}117{,}349 + 199{,}711{,}615 = 201{,}828{,}963$$

The LIC value based on the VaR risk measure at a 95% confidence level is 201,828,963, this value represents the total amount of funds the company must set aside to pay claim obligations that have occurred, including an additional risk adjustment based on the VaR risk measure at a 95% confidence level. Overall, the findings of this study are consistent with previous research indicating that the Mack Chain Ladder (MCL) method is capable of estimating the expected value and variance based on cumulative claim amounts, as well as deriving claim reserve estimates from the lower section of the cumulative run-off triangle. However, the reserve estimate produced by the MCL method is deterministic in nature, meaning that it yields a fixed estimate without explicitly capturing uncertainty. By contrast, the Bootstrap method applied in this study is in line with the work of England, showing that repeated resampling N times can generate a distribution of possible reserve values in the form of a claim range, thereby reflecting various plausible scenarios based on the observed data. Furthermore, the Bootstrap approach provides additional risk information, such as Value at Risk (VaR), which is particularly useful for the estimation of IFRS 17 components in the insurance industry. The resulting BEL, RA, and LIC values are also consistent with the conceptual framework established by the IASB, whereby the BEL represents the present value of future claim payments after discounting, the RA captures the level of non-financial risk adjustment at a specified confidence level based on VaR, and the LIC reflects the amount of funds that the insurer needs to set aside to settle incurred claims.

D. CONCLUSION

That both methods produce consistent estimates but Bootstrap provides a more comprehensive measure of uncertainty in the context of IFRS17. The estimated claim reserve value using the Mack Chain-Ladder (MCL) method is 234,740,644. The estimated claim reserve value using the Bootstrap method with $N = 5.000$ simulations are 234,739,080. The close similarity between these values indicates that the Bootstrap method is able to produce reserve estimates that are consistent with the traditional MCL approach. However, the main advantage of the Bootstrap method lies in its ability to generate a full predictive distribution of reserve estimates, providing additional information on uncertainty such as variance, confidence intervals, and Value at Risk. In this study, the simulated reserve distribution ranges from 233,158,004-236,320,156, offering a more comprehensive view of the uncertainty surrounding claim reserve estimation. From a predictive accuracy perspective, the Bootstrap method also performs slightly better. The Root Mean Squared Error of Prediction (RMSEP) for the MCL method is 1,631,999. While the Bootstrap method with $N = 5.000$ produces a lower prediction error of 1,581,076. This result indicates that the Bootstrap approach can better capture the variability in claim development data through repeated resampling of residuals, allowing it to account for uncertainty and complex variations in the data more effectively than the deterministic MCL method.

Within the IFRS 17 framework, the estimated, Best Estimate Liability (BEL) value is 199,711,615, which is lower than the previously calculated claim reserve by approximately 35,027,465. This difference arises because the BEL represents the present value of future claim payments, meaning that future cash flows are discounted using the applicable interest rate. The positive BEL value indicates that the present value of claim obligations exceeds the present value of expected inflows, reflecting the insurer's liability for incurred claims. The Risk Adjustment (RA) value at a 95% confidence level for the Value at Risk (VaR) risk measure is 2,117,349 or about 1,06 % of the BEL value. The Liability for Incurred Claims (LIC) at a 95% confidence level for the VaR risk measure is 201,828,963. The RA and LIC values are always directly proportional to the confidence level; thus, as the confidence level increases, the risk adjustment value also increases, and vice versa. The RA is expected to provide an overview of the magnitude of risk adjustments based on various risk measures and confidence levels for the company, which should assist in determining the funds allocated for the company's risk adjustment. The LIC is expected to provide an estimate of the funds the company needs to prepare to settle incurred claims, based on various risk measures and confidence levels, which should help in determining the funds allocated by the company for settling incurred claims.

Overall, this study shows that the Bootstrap method not only provides reserve estimates comparable to the Mack Chain-Ladder method but also offers additional insights into the uncertainty of claim reserves. These findings provide methodological and practical insights for insurance companies in implementing IFRS 17, particularly in estimating BEL, RA, and LIC based on stochastic claim reserve modeling. However, several 17 components have not yet been incorporate in this study, particularly the Liability for Remaining Coverage (LRC) and Contractual Service Margin (CSM). Moreover, this research is limited to general insurance products and does not consider investment components. Therefore, future studies are recommended to extend the IFRS 17 measurement framework to other insurance products, such as Unit Link, as well as approaches including PAA and VFA.

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