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Comparison of Historical Simulation and Variance-Covariance Methods for Value at Risk Estimation of BBRI Stock

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ABSTRACT

Stock investment is exposed to market risk arising from fluctuations in stock prices. Therefore, accurate risk measurement is essential for investors and risk managers. Among the various tools available for quantifying investment risk, Value at Risk (VaR) has gained widespread adoption as a method for determining the worst expected loss under a given probability threshold. This study compares the Historical Simulation and Variance-Covariance methods in estimating the Value at Risk of PT Bank Rakyat Indonesia (Persero) Tbk (BBRI) stock using daily closing price data from January 2, 2024, to December 31, 2025. The Jarque-Bera normality test indicated that the return data were not normally distributed, suggesting the presence of non-normal characteristics in the return distribution. Based on an assumed investment value of IDR 10,000,000, the VaR estimates at the 95% confidence level were IDR 334,739 and IDR 356,444 using Historical Simulation and Variance-Covariance, respectively. At the 99% confidence level, the estimated VaR values were IDR 534,695 and IDR 500,158, respectively. Kupiec Proportion of Failures (POF) backtesting showed that both methods produced statistically valid VaR estimates. However, Historical Simulation generated a more conservative risk estimate at the 99% confidence level, indicating a greater ability to capture extreme losses under non-normal return distributions. Therefore, Historical Simulation is recommended as the preferred method for measuring the market risk of BBRI stock.

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1. INTRODUCTION

The capital market is a crucial pillar of the financial system, serving as a means of investment and fundraising for both the public and companies. Stocks are one of the most popular investment instruments in the capital market due to their ability to provide relatively high returns. However, stock investments also carry unavoidable risks due to price fluctuations influenced by various factors, such as macroeconomic conditions, interest rate changes, monetary policy, company conditions, and global market sentiment [1]. Therefore, risk measurement is a crucial aspect in supporting rational and measured investment decision-making.

One widely used method for measuring market risk is Value at Risk (VaR). VaR serves as a quantitative tool that approximates the largest potential financial loss an asset or portfolio might incur within a defined time horizon under a specified probability level [1]. This method has become a standard in risk management because it presents risk information in an easily understood format. In practice, there are various approaches to calculating VaR, including Historical Simulation and Variance-Covariance. The Historical Simulation method uses historical return data without assuming a specific distribution, while the Variance-Covariance method assumes that asset returns follow a normal distribution and utilizes statistical parameters such as the mean and standard deviation in its calculations [2]. These differences in assumptions can result in different risk estimates, necessitating an evaluation of the performance of each method. Various studies have been conducted to compare the two methods on various financial instruments. Wicaksono, Wilandari, and Rusgiyono [3] showed that both the Historical Simulation and Variance-Covariance methods can be used to measure mutual fund investment risk, but produce different risk estimates depending on the characteristics of the data used. Research by Irsan, Priscilla, and Siswanto [4] on banking stock portfolios found that the Variance-Covariance method performed better at the 99% confidence level, while the Historical Simulation method performed better at the 95% confidence level based on backtesting results. Furthermore, Bukit [5] emphasized that backtesting is a crucial step in evaluating the reliability of the VaR model used. Mauren's [6] research, which compared the Variance-Covariance, Historical Simulation, and Monte Carlo methods, showed that the different assumptions in each method resulted in different risk estimates. Furthermore, Saniah [7] found that the Historical Simulation method tended to provide better results on data that did not meet the normal distribution assumption. Meanwhile, Nurhaliza, Saputra, and Mirtawati [8] showed that the Historical Simulation method produced consistent VaR estimates based on Kupiec backtesting results.

However, there are still research gaps that require further study. Most previous studies focused on stock portfolios or used observation periods different from current market conditions [3]–[8]. Furthermore, previous research results indicate that there has been no consistent conclusion regarding the VaR method that provides the best performance for banking sector stocks [4], [7], [8]. To date, research specifically comparing the Historical Simulation and Variance-Covariance methods on PT Bank Rakyat Indonesia (Persero) Tbk (BBRI) shares using data from the 2024–2025 period is still limited. This period is interesting to study because it is characterized by various economic dynamics that have the potential to influence the characteristics of banking stock returns, thus resulting in different risk estimates compared to previous periods.

Based on this description, this study aims to compare the results of Value at Risk measurements using the Historical Simulation and Variance-Covariance methods on BBRI shares for the 2024–2025 period and evaluate the performance of both methods using Kupiec's backtesting test [2]. The novelty of this study lies in the use of BBRI stock data for the 2024–2025 period, which represents current market conditions, and the application of backtesting as the basis for objective evaluation in comparing the performance of the two VaR methods. The research results are expected to provide useful information for investors and risk managers in selecting appropriate risk measurement methods for banking sector stocks in Indonesia.

2. METHOD

2.1 Data Collection

This study employed a quantitative research design using secondary data in the form of daily closing prices of PT Bank Rakyat Indonesia (Persero) Tbk (BBRI). The data were obtained from Yahoo Finance and covered the period from January 2, 2024, to December 31, 2025. An initial investment value of IDR 10,000,000 was assumed for Value at Risk (VaR) estimation.

2.2 Research Procedure

The research procedure consisted of several stages. First, daily closing price data of BBRI stock were collected and transformed into logarithmic returns. Subsequently, descriptive statistical analysis and the Jarque-Bera normality test were conducted to examine the distributional characteristics of the return data. VaR was then estimated using the Historical Simulation and Variance-Covariance methods at confidence levels of 95% and 99%. Finally, the performance of both methods was evaluated using Kupiec Proportion of Failures (POF) backtesting to determine the accuracy of risk estimation. The overall research workflow is presented in Figure 1.

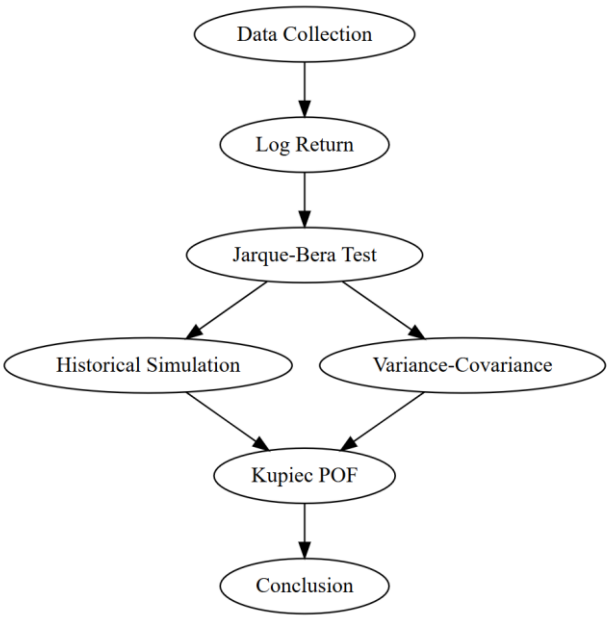


Figure 1. Research Flowchart

2.3 Logarithmic Return

Daily stock returns were calculated using logarithmic returns as follows [1]:

$$R_t = \ln\left(\frac{P_t}{P_{t-1}}\right) \quad (1)$$

where R_t denotes the return at time t, P_t represents the closing price at time t, and P_{t-1} represents the closing price at time t−1. Logarithmic returns were selected because they are time-additive and commonly used in financial risk analysis [1].

2.4 Jarque-Bera Normality Test

The Jarque-Bera test was applied to assess whether the return data followed a normal distribution, which is an underlying assumption of the Variance-Covariance method [10]. The Jarque-Bera statistic is defined as follows [10]:

$$JB = n\left(\frac{S^2}{6} + \frac{(K-3)^2}{24}\right) \quad (2)$$

where JB denotes the Jarque-Bera statistic, n is the number of observations, S represents the skewness coefficient, and K represents the kurtosis coefficient [10]. The null hypothesis is rejected when the calculated Jarque-Bera statistic exceeds the critical value of $\chi^2(2)$ = 5.991 at the 5% significance level [10].

2.5 Historical Simulation Method

Historical Simulation (HS) is a non-parametric approach that estimates VaR directly from historical return observations without assuming any specific probability distribution [1], [4]. The procedure involves sorting historical returns from the smallest to the largest value and determining the empirical quantile corresponding to the selected confidence level. This approach is particularly advantageous when return data exhibit skewness and fat tails, as the empirical distribution inherently captures these characteristics without imposing restrictive parametric assumptions [11]. VaR is calculated as follows [1]:

$$VaR_{HS} = -Q_{\alpha}(R) \times W \tag{3}$$

where VaR_{HS} denotes the Value at Risk estimated using the Historical Simulation method, $Q_{\alpha}(R)$ represents the empirical quantile of historical returns at significance level α, and W denotes the investment value [1]. An exception occurs when the actual return is lower than the estimated VaR threshold.

2.6 Variance-Covariance Method

The Variance-Covariance (VC) method is a parametric approach that assumes stock returns follow a normal distribution. VaR is estimated using the mean return, standard deviation, and the corresponding z-score of the standard normal distribution [1], [4].

$$VaR_{VC} = W(z_{\alpha}\sigma - \mu) \tag{4}$$

where VaR_{VC} denotes the Value at Risk estimated using the Variance-Covariance method, z_{α} is the critical value of the standard normal distribution, σ represents the standard deviation of returns, μ denotes the mean return, and W is the investment value [1].

2.7 Kupiec Proportion of Failures Backtesting

The accuracy of VaR estimates was evaluated using the Kupiec Proportion of Failures (POF) test [2]. An exception occurs when the actual return is lower than the estimated VaR value. The likelihood ratio statistic is given by [2]:

$$LR_{POF} = -2\ln\left[\frac{(1-p)^{T-N}p^{N}}{\left(1-\frac{N}{T}\right)^{-N}\left(\frac{N}{T}\right)^{N}}\right] \tag{5}$$

where LR_{POF} denotes the likelihood ratio statistic of the Kupiec Proportion of Failures test, T represents the total number of observations, N denotes the number of exceptions, and p represents the expected exception probability. In this study, p = 0.05 for the 95% confidence level and p = 0.01 for the 99% confidence level [2]. The VaR model is considered valid when the calculated LRPOF value is smaller than the critical value of $\chi^2(1)$ = 3.841 at the 5% significance level [2].

2.8 Software

All statistical analyses and VaR computations were performed using R software. The analysis included return calculation, normality testing, VaR estimation, and Kupiec backtesting for model validation.

3 RESULTS AND DISCUSSION

3.1 Descriptive Statistics

Descriptive statistical analysis was conducted to provide an overview of the characteristics of BBRI stock return data during the observation period. The results are presented in Table 1.

Table 1. Descriptive Statistics of BBRI Stock Returns

Statistic	Value
Minimum	-0.1067
1st Quartile	-0.0131
Median	0.0000
Mean	-0.0009
3rd Quartile	0.0095
Maximum	0.0883
Standard Deviation	0.0211

Table 1 shows that the average daily return of BBRI stock was −0.0009, indicating a slight average decline during the observation period. The standard deviation of 0.0211 reflects the volatility of daily stock returns. Furthermore, the minimum and maximum returns were −0.1067 and 0.0883, respectively, indicating considerable fluctuations in stock performance throughout the study period. The relatively large difference between the minimum and maximum return values suggests substantial market movements during the observation period. Such fluctuations emphasize the importance of measuring market risk accurately. Therefore, Value at Risk (VaR) analysis is required to estimate the maximum potential loss that may occur within a specified confidence level.

3.2 Normality Test

The Jarque-Bera test was employed to determine whether the return data followed a normal distribution. This test is particularly important because the Variance-Covariance method assumes normally distributed returns.

Table 2. Jarque-Bera Normality Test Results

Statistic	Value
Jarque-Bera Statistic	108.60
p-value	< 0.0001

As shown in Table 2, the obtained p-value falls below the 0.05 threshold, providing sufficient evidence to reject the normality assumption. Consequently, the return data cannot be considered to conform to a normal distribution. The rejection of normality suggests that the return data exhibit non-normal characteristics commonly found in financial time series. Financial return distributions often deviate from normality due to extreme market movements and volatility clustering [10]. This pattern is well-documented across various equity markets, where empirical return distributions typically display excess kurtosis and asymmetry relative to the normal distribution [12]. In circumstances where normality cannot be assumed, distribution-free methods like Historical Simulation offer greater adaptability, as they make no prior assumptions about the shape of the return distribution. Nevertheless, the Variance-Covariance method was retained in this study to provide a comparison between parametric and non-parametric VaR approaches.

3.3 Value at Risk Estimation

The Value at Risk (VaR) of BBRI stock was estimated using Historical Simulation and Variance-Covariance methods with an assumed investment value of IDR 10,000,000. The calculations were performed at confidence levels of 95% and 99%.

Table 3. Value at Risk Estimation Results

Method	VaR 95%(IDR)	VaR 99%(IDR)
Historical Simulation	334,739	534,695
Variance-Covariance	356,444	500,158

Table 3 indicates that at the 95% confidence level, the Variance-Covariance method produced a VaR estimate of IDR 356,444, which is higher than the Historical Simulation estimate of IDR 334,739. This result suggests that under moderate market conditions, the parametric approach provides a slightly more conservative risk estimate.

However, at the 99% confidence level, Historical Simulation generated a larger VaR value of IDR 534,695 compared with IDR 500,158 obtained from the Variance-Covariance method. This finding indicates that Historical Simulation captures extreme losses more effectively because it relies directly on the empirical distribution of historical returns rather than assuming normality.

From an investment perspective, the results imply that with an investment value of IDR 10,000,000, the maximum expected daily loss at the 95% confidence level is approximately IDR 334,739 using Historical Simulation and IDR 356,444 using Variance-Covariance. Meanwhile, at the 99% confidence level, the maximum expected daily loss increases to IDR 534,695 and IDR 500,158, respectively.

Similar findings have been reported in previous studies, where Historical Simulation tends to produce higher risk estimates at extreme confidence levels because it is more responsive to tail events observed in historical data [3], [4]. This result is consistent with the Jarque-Bera test presented in Table 2, which indicated that the return data were not normally distributed. Under non-normal conditions, the empirical quantile used in Historical Simulation is able to capture extreme losses more effectively than the Variance-Covariance approach, which relies on the assumption of normality [2]. Consequently, the Variance-Covariance method may underestimate tail risk when extreme observations are present in the return distribution. This limitation has been documented in the broader literature on non-normally distributed returns, where normality-based VaR models have been shown to systematically understate downside risk when returns exhibit heavy tails and skewness [13].

3.4 Kupiec Proportion of Failures (POF) Backtesting

To evaluate the accuracy of the VaR estimates, Kupiec Proportion of Failures (POF) backtesting was performed. This procedure examines whether the observed frequency of VaR violations is consistent with the expected frequency implied by the selected confidence level [2]. The likelihood ratio (LR) statistic obtained from the Kupiec test was compared with the critical Chi-Square value of 3.8415 at a significance level of 5%.

Table 4. Kupiec POF Backtesting Results

Method	Confidence Level	LR Statistic	Decision
Historical Simulation	95%	0.0071	Accepted
Historical Simulation	99%	0.0165	Accepted
Variance-Covariance	95%	0.1167	Accepted
Variance-Covariance	99%	0.9686	Accepted

As shown in Table 4, all LR statistics are substantially lower than the critical Chi-Square value of 3.8415. Therefore, the null hypothesis cannot be rejected for any model-confidence level combination. This result indicates that the observed violation rates are statistically consistent with the expected violation rates. The Historical Simulation method produced LR statistics of 0.0071 and 0.0165 at the 95% and 99% confidence levels, respectively. Meanwhile, the Variance-Covariance method produced LR statistics of 0.1167 and 0.9686. Although all models were accepted, the relatively higher LR statistic obtained by the Variance-Covariance method at the 99% confidence level suggests that its performance is closer to the rejection boundary compared with Historical Simulation.

These findings indicate that both Historical Simulation and Variance-Covariance methods are statistically valid for estimating the market risk of BBRI stock. Similar

conclusions have been reported in previous studies emphasizing the importance of backtesting procedures in validating VaR models and assessing their predictive accuracy [2]. Overall, the backtesting results confirm that both methods provide reliable VaR estimates. However, Historical Simulation demonstrates greater sensitivity to extreme losses and provides a more conservative estimate of tail risk at the 99% confidence level. Therefore, Historical Simulation may be more appropriate for investors and risk managers who prioritize protection against extreme market fluctuations.

4 CONCLUSION

This study compared the Historical Simulation and Variance-Covariance methods in estimating the Value at Risk (VaR) of BBRI stock using daily closing price data. Results from the Jarque-Bera test revealed that the return data deviated significantly from a normal distribution, reflecting distributional characteristics atypical of the standard bell curve. The VaR estimation results showed that at the 95% confidence level, the Variance-Covariance method produced a slightly higher VaR value than Historical Simulation. However, at the 99% confidence level, Historical Simulation generated a larger VaR estimate, indicating a greater ability to capture extreme losses under non-normal return distributions. These findings suggest that Historical Simulation provides a more conservative risk estimate for BBRI stock, particularly at higher confidence levels. The Kupiec Proportion of Failures (POF) backtesting results demonstrated that all VaR models were acceptable, as the likelihood ratio (LR) statistics were lower than the critical chi-square value. Therefore, both Historical Simulation and Variance-Covariance methods can be considered valid for estimating the market risk of BBRI stock. Overall, Given its capacity to more accurately reflect extreme loss scenarios without requiring normally distributed returns, Historical Simulation stands out as the more suitable approach for assessing the market risk of BBRI shares. Future studies are recommended to compare VaR with other risk measurement approaches, such as Monte Carlo Simulation, GARCH-based VaR, and Expected Shortfall (ES), using longer observation periods and a broader range of financial assets.

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