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Value-at-Risk Estimation with Normal Distribution Approach on Stock Return of BBNI and BBRI

Dwi Susanti[1*], Maria JatuVerrany[2]

[1]*Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran,Sumedang, Indonesia*
[2]*Bachelor of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Sumedang, Indonesia*

**Corresponding author email: dwi.susanti@unpad.ac.id*

Abstract

This paper discusses risk analysis on a single stock return. Stock data analyzed are shares of BBNI and BBRI. The method used is Value-at-Risk with a normal distribution approach. The steps are, after obtaining stock returns, then the value-at-risk (VaR) is estimated using a normal distribution approach. Then a back-test is carried out to measure the performance of risk measures. The results of the analysis show that VaR for BBNI and BBRI produces a small Quadratic Probability Score (QPS) close to zero. This shows that VaR with the normal distribution approach is more consistent and can be used to measure risk for BBNI and BBRI.

Keywords: stock return, risk, normal distribution, Value-at-Risk, back-test.

1. Introduction

Every company, especially those engaged in finance, is very vulnerable to risk, and their financial activities are very unstable. In the financial world, if there is a crisis that destroys the economic sector so that it can result in losses, then one of the losers is the investor. So, investors should be able to face all the risks that may occur to obtain the expected results and also be able to calculate these risks properly to avoid losses (Selmier et al., 2014; Wamalwa & Mukanzi, 2018; Onsongo et al., 2020).

Therefore, a risk measurement method is needed that can translate the risk in a quantitative form so that it can be widely used and serves as an early warning in the financial sector that can be immediately addressed. Quantitative risk measurement can use Value-at-Risk (VaR) which has been widely used in the financial sector and has become a general standard in risk calculation because it can be applied to all types of risk (Pasaribu, 2019; Juniar et al., 2020; Indarwati and Kusumawati, 2021). Danielsson and Devries (2000) proposed the Value-at-Risk (VaR) method and its evaluation requirements. The greatest risk is modeled parametrically with a normal distribution approach, while the small risk is carried out using a non-parametric empirical distribution function. Nainggolan et al. (2020) said that for consideration for investors in investing a risk calculation is needed. To avoid this, investors must be able to anticipate the level of risk with a high return, through a risk measurement called Value-at-Risk (VaR).

The purpose of this paper is to estimate VaR on the stock returns of BBNI and BBRI. The method used is the normal distribution approach, because the stock returns of BBNI and BBRI are thought to follow a normal distribution pattern. The implications of the results of this VaR calculation are expected to be a consideration for investors in making decisions, especially on BBNI and BBRI shares.

2. Materials and Methods

2.1. Materials

To find out the daily stock VaR of a company, the company's own daily closing price is needed. In this paper, we will observe the daily share prices of BNI and BRI for a year, starting from January 1, 2019 to December 30, 2019. The daily share data of BBNI is taken from http://finance.yahoo.com/q/hp?s= BBNI.JK, and for daily BBRI shares taken through http://finance.yahoo.com/q/hp?s=BBRI.JK.

2.2. Methods

2.2.1. Single and Portfolio Investment Return

Suppose the stock price for stock k on day i and $i-1$ is P_i and P_{i-1}. So that in a time horizon of 1 day (24 hours), the return obtained on day i is

$$r_{ki} = \ln\left(\frac{P_i}{P_{i-1}}\right). \tag{1}$$

The calculation of portfolio returns on day i which is denoted by r_{pi} with N number of shares is

$$r_{pi} = \sum_{k=1}^{N} \omega_k r_{ki}, \tag{2}$$

where ω_k is the weight of k shares with the total weight of the formed shares must be 1 and r_{ki} is the return of k shares at time i.

2.2.2. Normal Distribution and Its Parameters

The general form of the normal distribution model is as follows.

A random variable X that has a μ mean and a $\sigma^2 < \infty$ variance is said to be normally distributed if the probability density function is

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}, -\infty < x < \infty. \tag{3}$$

The following is an estimate of the $\hat{\mu}$ mean and $\hat{\sigma}^2$ variance,

$$\hat{\mu} = \frac{1}{n-1}\sum_{i=1}^{n} x_i\,, \hat{\sigma}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \mu)^2. \tag{4}$$

2.2.3. VaR Estimation with Normal Distribution Approach

VaR estimation with a normal distribution approach is a parametric VaR estimate by assuming that returns are normally distributed and VaR is estimated using parameters such as mean and variance (Rupert, 2004).

VaR estimation for k stocks (single investment) with a confidence coefficient $(1-\alpha)100\%$ is

$$VaR_k(\alpha) = -S_0(\hat{\mu}_k + \Phi^{-1}(\alpha)\hat{\sigma}_k), \tag{5}$$

where S_0 is the initial investment, $\hat{\mu}_k$ and $\hat{\sigma}_k$ are the mean and standard deviation of the stock return k, and $\Phi^{-1}(\alpha)$ indicates the inverse of the standard normal Z value which can be seen in the normal distribution table.

2.2.4. Back-test

After getting the VaR estimation results, a validity test (back-test) was carried out on the VaR model used. In this paper, a back-test is carried out to test the consistency of the VaR method against the actual loss that occurs, and in its calculation, the Lopez II approach is used which suggests the size of the loss function as follows

$$C_i = \begin{cases} 1 + (L_i - VaR)^2, & L_i > VaR, \\ 0, & L_i \le VaR, \end{cases} \tag{6}$$

where L_i is the daily return. After getting the loss function, then the Quadratic Probability Score (QPS) is calculated as follows

$$QPS = \frac{2}{n}\sum_{i=1}^{n}(C_i - p)^2, \tag{7}$$

where p is the α value of the confidence coefficient $(1-\alpha)100\%$. The smaller the QPS value, the better the VaR model.

3. Results and Discussion

In this section, VaR estimation is carried out using the normal distribution approach, both for single investments and for portfolio investments. In addition, back-test is also discussed to measure VaR performance.

3.1. Data Characteristics

To determine the daily stock VaR of a company, this paper uses the daily closing price of the company's own shares, namely BBNI and BBRI shares. The two patterns of changes in closing price data can be seen in Figures 1 and 2.

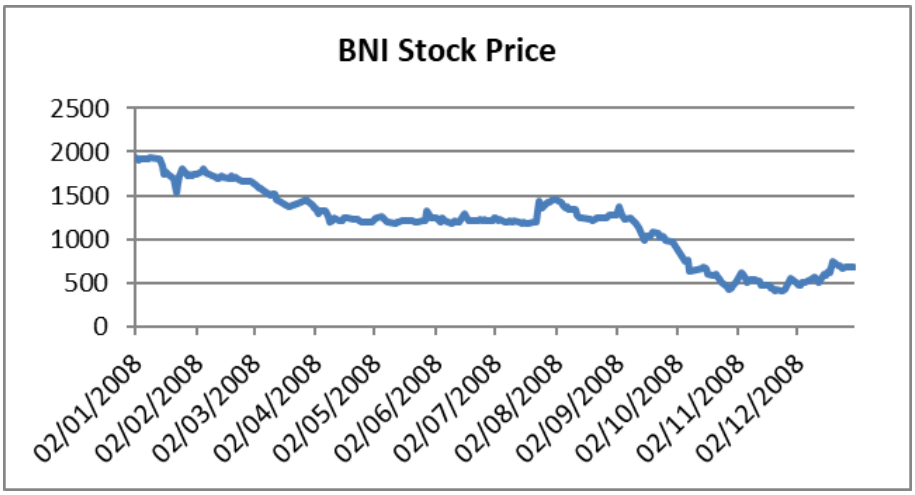

Figure 1: BBNI Stock Closing Price Chart

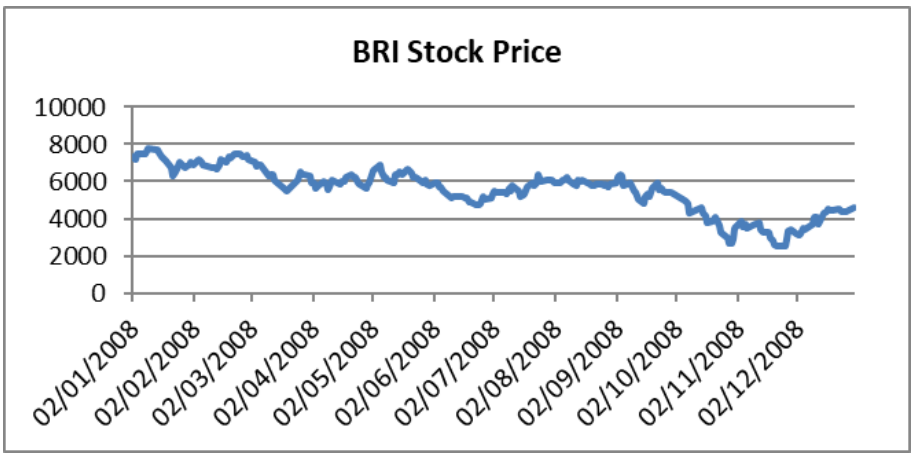

Figure 2: BBRI Stock Closing Price Chart

3.2. VaR Estimation Stages for Single Investment

This section discusses the stages of estimating VaR for a single investment using the normal distribution approach.

3.2.1. Return Calculation for Single Investment

In this section, the return calculation for each BBNI and BBRI share is carried out. From the stock price data of BBNI and BBRI for a year which consists of 236 shares, 235 daily returns will be obtained. The return is calculated using equation (1). For example, the stock price of BBNI on the first day of observation is IDR 1,940.00, and the stock price of BBNI on the second day of observation is IDR 1,910.00. So that in a one-day time horizon (24 hours) the 1st-day return for BBNI is

$$r_{11} = \ln\left(\frac{1910}{1940}\right) = -0.0067684.$$

For example, the share price of BBRI on the first day is IDR 7,350.00 and the share price of BBRI on the second day is IDR 7,200.00. In a one-day time horizon (24 hours) the 1st-day return for BBRI is

$$r_{21} = \ln\left(\frac{7200}{7350}\right) = -0.0089548.$$

To calculate the return on the 2nd-day to the 235th-day of return for each bank, the same method is used as above. The complete calculation results can be seen in Figures 3 and 4.

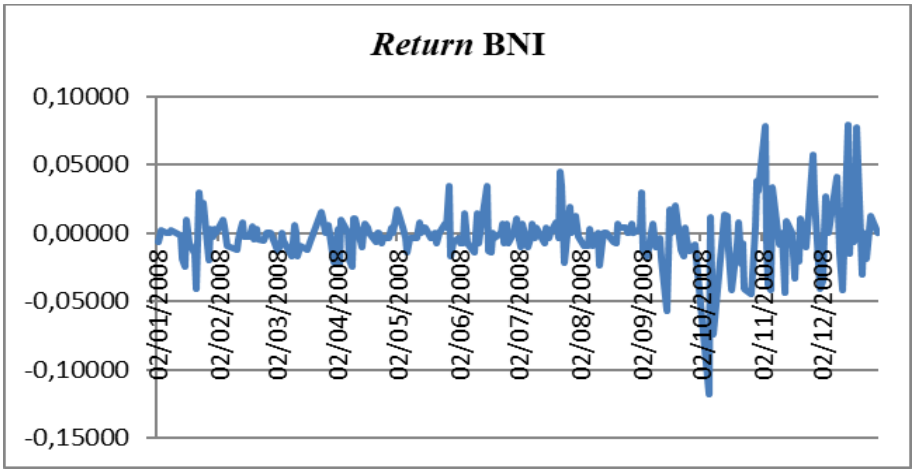

Figure 3: BBNI Stock Return Graph

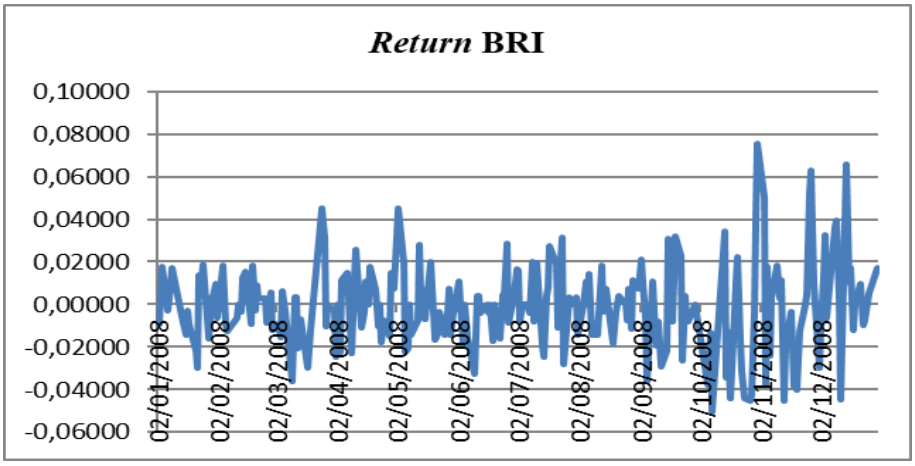

Figure 4: BBRI Stock Return Graph

3.2.2. VaR Estimation Stages with Normal Distribution Approach for Single Investment

The stages of VaR estimation with a normal distribution approach for BBNI and BBRI shares are as follows.

1) The return data of BBNI and BBRI, for a year consisting of 235 data, were processed using SPSS 13.0 software to test whether the returns were normally distributed and to find the mean and standard deviation values. Based on these tests, it was found that the returns of BBNI and BBRI were normally distributed. The mean and standard deviation values are as follows.

Estimated Distribution Parameters

		BBNI
Normal Distribution	Location	-.0019
	Scale	.02054

Estimated Distribution Parameters

		BBRI
Normal Distribution	Location	-.0009
	Scale	.02015

For a normal distribution, the mean and standard deviation are the same as the location and scale parameters. So, from the Estimated Distribution Parameters above, the mean and standard deviation for BBNI returns are -0.0019 and 0.02054. Meanwhile, the mean and standard deviation for BBRI returns are -0.0009 and 0.02015.

2) For example, an investor will invest in one of the banks, namely BNI and BRI, assuming an initial investment of IDR 1.00 and 95% confidence coefficient. Then the VaR of each bank will be calculated using the three methods that have been studied previously with a confidence coefficient of 90%, 92.5%, 95%, 97.5%, and 99.9% for comparison.
3) For example, for a 95% confidence coefficient, $\alpha = 0.05$ so that $\Phi^{-1}(0.05) = -1.645$. The value of $\Phi^{-1}(0.05)$ can be seen in normal distribution table, the negative sign indicates that the probability area is under the left-hand curve.
4) If it is assumed that the initial investment (S_0) is IDR1.00 and based on equation (5), the VaR for BBNI and BBRI shares is obtained, namely
   a. $VaR_1(0.05) = -1[-0.0019 + (-1.645 \cdot 0.02054)] = 0.0356883$,
   b. $VaR_2(0.05) = -1[-0.0009 + (-1.645 \cdot 0.02015)] = 0.0340468$.

In Table 1, below are shown some VaR estimation results with other confidence coefficients.

Table 1: VaR Estimation Results for BBNI and BBRI Shares with Normal Distribution Approach

Confidence Coefficient	BNI VaR in IDR	BRI VaR in IDR
90.0%	0.0281912	0.0266920
92.5%	0.0314776	0.0299160
95.0%	0.0356883	0.0340468
97.5%	0.0421584	0.0403940
99.9%	0.0653686	0.0631635

3.2.3. Back-test Stage

The stages of the back-test on the normal distribution approach are as follows.

1) The return data of BBNI and BBRI are sorted from the largest to the smallest.
2) Calculate the C_i indicator function using equation (6), where L_i is daily return (r_i) and $VaR_1 = 0.0356883$ for BBNI returns and $VaR_2 = 0.0340468$ for BBRI returns. Because the 1st order returns of BBNI and BBRI are 0.0791812 and 0.0754211, it means that for BNI returns, we get $L_i > VaR_1$, and $L_i > VaR_2$ for BBRI returns. Therefore, the indicator function on the 1st order return for BBNI and BBRI with a 95% confidence coefficient (α=0.05) is
   $C_i = 1 + (0.0791812 - 0.0356883)^2 = 1.0018916$, for BBNI.
   $C_i = 1 + (0.0754211 - 0.0340468)^2 = 1.0017118$, for BBRI.
   To calculate the indicator function on the 2nd to 235th sequence returns, it can be done in the same way as above.
3) Furthermore, the results of the calculation of the indicator function are used to calculate QPS using equation (7). Using probability $p = 0.05$ (95% confidence coefficient). Examples of calculations like the following
   $\sum_{i=1}^{n}(C_i - p)^2 = 7.7988199$ for BBNI,
   $\sum_{i=1}^{n}(C_i - p)^2 = 10.4959855$ for BBRI.
   Thus, the magnitude of the QPS value is
   $QPS = \frac{2}{235}(7.7988199) = 0.0663729$ for BBNI,
   $QPS = \frac{2}{235}(10{,}4959855) = 0.0893275$ for BBRI.

In Table 2, below are shown some back-test results with other confidence coefficients.

Table 2: VaR Back-test Results on BBNI and BBRI Stock Returns

Confidence Coefficient	BBNI QPS	BBRI QPS
90.0%	0.1290751	0.1494801
92.5%	0.0981771	0.1270906
95.0%	0.0663729	0.0893275
97.5%	0.0417433	0.0578900
99.9%	0.0254909	0.0169919

3.2.4. VaR Analysis and Back-test for Single Investment

Based on the back-test results that have been obtained, for the greater confidence coefficient, it appears that the QPS is getting smaller. Therefore, for the largest confidence coefficient, which is 99.9%, on BBNI shares, the smallest QPS is obtained at 0.0254909. While in BBRI shares, the smallest QPS was obtained at 0.0169919. This

shows that the confidence is 99.9%, the most consistent or best method used to estimate VaR on BBRI shares, compared to BBNI shares.

Then based on the results of the analysis applied to the following example. Suppose an investor wants to invest in BBNI and BBRI with an initial investment of IDR 10,000,000.00 and a confidence coefficient of 99.9%, based on the results of the VaR estimation, the VaR obtained by the best method is

$$\text{VaR(BBNI)} = 10{,}000{,}000 \times \text{IDR } 0.1175400 = \text{IDR } 1{,}175{,}400.00,$$
$$\text{VaR(BBRI)} = 10{,}000{,}000 \times \text{IDR } 0.0631635 = \text{IDR } 631{,}635.00.$$

From these results, it can be seen that the VaR of BBRI produces a smaller value than the VaR of BBNI. In other words, investing in BBRI shares will have a smaller risk of loss than investing in BBNI shares. So, with an investment of IDR 10,000,000.00 in BBRI shares and a confidence coefficient of 99.9%, the investor will be at risk of loss of IDR 631,635.00, while in BBNI shares will be at risk of IDR 1,175,400.00.

4. Conclussion

In this paper, the risk of BBNI and BBRI stock returns has been measured using the normal distribution approach. The back-test results show that for the 99.9% confidence coefficient, a more consistent method is VaR for BBRI shares, compared to BBNI shares. Based on the results of the VaR estimation with the best method, the risk of loss on investment in BBRI shares is smaller than investment in BBNI shares. Thus, investing in BBRI is more profitable, compared to investing in BBNI.

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