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Geometric Brownian Motion and Value at Risk For Analysis Stock Price Of Bumi Serpong Damai Ltd

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Abstract: Investment is one of the activities that last actually attractive to the people of Indonesia. One of the most widely traded financial assets in the capital market is stocks. Stock prices frequently experience challenges to predict changes, so they can increase or decrease at any time. One method that can be applied to predict stock prices is GBM. Then, the risk can be measured using the VaR risk measure. The GBM model is determined to be accurate in predicting the stock price of BSDE.JK, with a MAPE value of 5.17%. By using VaR-HS and VaR CFE, the prediction of risk of loss at the 95% confidence level for the period 06/07/21 is -0.0597 and -0.0623.

Keywords: Investment; Risk; GBM; VaR-HS; VaR-CFE

1. Introduction

Investment is one of the activities that are actually attractive to the people of Indonesia. According to Kuchancur [9], investment can also be interpreted as a positive net additional capital activity. In common, investment is categorized into two types, namely real investment, and financial investment. Real investment is an investment in durable goods, such as buildings, housing, and so on. While financial investment is a form of investment in securities. One of the investments that attract many investors, mainly in the financial sector, is an investment in the capital market. Mihajlovic (2016) defines the capital market as a market for various long-term financial instruments that can be traded, both in the form of debt and equity, whether issued by the government or private businesses.

Stocks are one of the most extensively used types of securities in the capital market. Over more extra companies listing their shares on the stock exchange, stock trading is getting more further popular and attracts investors to buy and sell stocks [Badruzaman 1]. Essentially, an investor of owned funds can buy stocks based on the desire to make a profit. One approach that can be done to find out how much profit is obtained from stock trading activities is by looking at stock returns. According to Mis-kolczi [14], return is the top rate of return obtained from investing. Based on Zamfir, Manea, and Ionescu (2016) - 5, by looking at the return value, investors can find out changes in the price of a stock, how much profit or loss will be received, so that it can be used as a guideline to decide whether to invest with the stock or not.

Stock prices often experience problems to forecast changes, therefore they can increase or decrease at any time. Changes in stock prices that can increase and decrease at any time result in the uncertainty of the return value that will be received, so that investors cannot obtain certainty whether they will gain or lose. Concerning uncertainty about changes in stock prices, a mathematical model is necessitated to predict future stock prices based on existing stock price data. The state of stock prices in the past is very influential in predicting stock prices in the future. Elapsed stock price data can be used to calculate the value of stock returns. The general model of stock return consists of two parts, particularly the size of the average growth in stock prices and the size of changes in stock prices (volatility). According to Parungroat and Kidsom [15], the whole of the mathematical models that can be used to model and predict stock prices with a normal distribution of stock returns is the Geometric Brownian Motion (GBM) model.

Stock investment in addition to providing benefits also contains an element of risk. Anastassia and Firnanti [2] mention that in addition to profit factors, other factors that influence investors in carrying out their investment activities are risk factors. Therefore, we need a mechanism that can improve direct investors to a stock investment with a level of risk as an indicator. Value at Risk (VaR) is a form of risk measurement that is quite popular and popularly used because of its simple concept and ease of application to any investment data. VaR is established as the estimated maximum loss that will be obtained during a certain time period under normal market conditions at a certain confidence interval [11].

The property sector as one of the investment media is currently enduring quite active growth. One method of investment in the property sector is by buying a stock of companies engaged in a property. The increasing development of investment in the property sector can likewise be seen from the SEKI data (Indonesian Economic and Financial Statistics) issued by Bank Indonesia. It was recorded that in 2020, the economic value of the property sector reached Rp. 324.3 trillion or 3.02% of the total national GDP. This percentage increased by 0.25% compared to 2019 when property contributed 2.77% of the total national GDP [4].

One of the foremost property companies in Indonesia is PT. Bumi Serpong Damai Tbk (BSDE.JK) was founded in 1984. The core business of this company is a real estate developer based in Indonesia. In addition, the company is also engaged in planning and developing new cities, which are planned and integrated outlining areas with environmental and park facilities, which are designed to enhance independent cities called BSD City. In 2020, PT. Bumi Serpong Damai Tbk received four awards at the Indonesia Property Awards 2020 for the categories of Best Developer, Best High-End Housing Development, Best Housing Development (Indonesia), and Best Millennial Housing Development [5].

Based on this description, this study will conduct a study on forecasts and predictions of BSDE.JK losses as a reference for investors before deciding to stock the funds both have in this company. Price modeling will be carried out applying the GBM model and loss risk prediction will be carried out applying VaR with parametric and nonparametric approaches.

2. Related Works

In investing against financial assets, particularly, predicting future price conditions is an important duty to accomplish. This is because stock prices serve to fluctuate in a short time. Data about the price picture in the future can be a reference for investors to determine whether to buy or sell their stock so that they can get maximum profit. Suganthi and Jayalalitha [17] used the GBM model to predict the state of stock prices on the Indian stock market for the period 2013-2014. The results of the analysis show that the GBM model is accurate satisfactorily to forecast price movements in the next period.

Guloksuz [8] stated that GBM is the precise model to use when price conditions are stable without extreme price jumps. Therefore, GBM is used to model the stock of the Walmart company from March 16, 2019, to March 13, 2020. During that period, it was noted that the company's stock price was stable with evidence that prices followed the Normal distribution. The conclusion obtained is that the GBM model is able to accurately predict the stock price of the Walmart company, with a predictive accuracy value of 7%.

In addition to price prediction, loss prediction is an important point to recognize. Through understanding the possibility of loss, it will help us to prepare appropriate risk management steps so that the investment does not go bankrupt. Trimono, Maruddani, and Ispriyanti [18] combined the GBM model with Value at Risk to estimate losses on the stock of Ciputra Development Ltd. By using the Monte Carlo Simulation method which is a nonparametric approach, the results present that the risk is very accurate with the ratio value is 5%.

This investigation focuses on the application of the GBM method for price predictions in the future by utilizing historical returns. Then, the prediction results will be used to measure the risk of loss using the VaR approach through nonparametric and parametric methods. The purpose of using these two approaches is to compare the accuracy of predictions so that they can be used as a reference for investors regarding which approach is more desirable to apply.

3. Experiment and Analysis

3.1. Stock Return

Based on Aliu, Pavelkova, and Dehning [1], return is the rate of return on the results obtained as a result of investing. Security analysis generally uses log return. The log return method is formulated as follows:

$$R_t = \ln\left(\frac{S(t_i)}{S(t_{i-1})}\right) \tag{1}$$

where R_t represents stock returns, $S(t_i)$ represents stock prices in period t, and $S(t_{i-1})$ represents stock prices in period t_{i-1}.

3.2. Normal and Lognormal Distribution

A random variable X is said to follow a Normal Distribution with mean μ and variance σ^2 if it has the probability density function [11]:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2\right] \tag{2}$$

for $-\infty < x < \infty$, $-\infty < \mu < \infty$ and $0 < \sigma < \infty$. Then, for random variable *Y*, the probability density function for this lognormal distribution can be expressed as follows:

$$f(y) = \frac{1}{\sqrt{(2\pi\sigma^2)}\ y} \exp\left[-\frac{(\ln(y)-\mu)^2}{2\sigma^2}\right] \tag{3}$$

for $y > 0$, $-\infty < \mu < \infty$ and $0 < \sigma < \infty$.

3.3. Volatility

Volatility is the amount of fluctuation in the price of an asset. If there are n (number of observations) returns, then the expected return value can be estimated by the sample mean (sample mean) return [10]:

$$\overline{R} = \frac{1}{n}\sum_{t=1}^{n} R_t \tag{4}$$

The average return is then used to estimate the variance for each period, namely:

$$s^2 = \hat{\sigma}^2 = \frac{1}{n-1}\sum_{t=1}^{n}\left(R_t - \overline{R}\right)^2 \tag{5}$$

The root of variance (standard deviation) is the estimated value of stock price volatility.

3.4. Stochastic Processes

According to Evans, Majumdar, and Schehr [7], a stochastic process is a set of random variables {X(t), $t \in T$} where *t* represents time and *X(t)* represents a process at time *t*. The set *T* is called the index set of a stochastic process. If the set *T* is a time interval $t \in [0, \infty)$, then the stochastic process is said to be a continuous time stochastic process and is expressed in the form {X(t), $t \in 0$}.

3.5. Brownian Motion

A stochastic process a is called Brownian motion if it fulfill the following criteria [6]:

1. W(0) = 0 (with probability 1).
2. For $0 \le s < t \le T$, the random variable given by the change in *W(t)-W(s)* is normally distributed with mean 0 and variance $\sigma^2(t-s)$.
3. For $0 \le s < t < u < v \le T$, the changes in *W(t)-W(s)* and *W(u)-W(v)* are independent.

3.5.1. Standard Brownian Motion

According to Higham (2001), a stochastic process {W(t), tT} is supposed to be standard Brownian motion if the process meets the following criteria:

1. W(0) = 0 (with probability 1).
2. For $0 \leq s < t \leq T$, the random variable given by the change in *W(t)-W(s)* is normally distributed with mean 0 and variance *t-s*.
3. For $0 \leq s < t < u < v \leq T$, the changes in *W(t)-W(s)* and *W(u)-W(v)* are independent.

3..5.2. Brownian Motion with *drift* terms

Basen on **Dmouj [6],** Brownian motion with *drift* terms has the following equation:

$$B(t) = \mu(t) + \sigma\, W(t) \tag{6}$$

where $\mu(t)$ is the mean value and σ is the process standard deviation value of t. $W(t) = Z\sqrt{t}$, Z is a random number with a Standard Normal distribution.

3.5.3. Brownian Motion Geometri

Suppose a stochastic process {P(t),t > 0}, where P(t) represents the stock price in period t, then P(t) is supposed to follow Geometric Brownian Motion if the following equation applies:

$$B(t) = \ln \frac{P(t)}{P(t-1)} \text{ dan } B(t) = \mu^*(t) + \sigma\, W(t) \tag{7}$$

where, $\mu^*(t) = \mu(t) - \frac{1}{2}\sigma^2(t)$ which is *drif* terms parameter.

3.6. *Geometric Brownian Motion* (GBM) Model for Stock Prices Exchange

Geometric Brownian Motion is a derivative of the Brownian Motion process which is applied as a method to simulate stock prices based on stock returns. The Geometric Brownian Motion model will be effectively applied if the company or agency is in a good and well-built condition, the stock price of the company or agency is continuous in time, and the stock return value is Normal distribution. The Geometric Brownian Motion model has two parameters, the first parameter is which is the expected value of stock returns, the second parameter is which is the volatility of stock prices [16].

Menentukan Persamaan Diferensial Stochastic untuk mendapatkan model harga saham *Geometric Brownian Motion* can be obtained by the *Itô* theorem[8].

If there is an equation:

$$dS(p) = \mu S(p)dp + \sigma S(p)dW(p) \tag{8}$$

Hence based on *Itô* theorem, the function $G = G(s, p)$ is following:

$$dG = \left(\frac{\partial G}{\partial S(p)} \mu S(P) + \frac{\partial G}{\partial p} + \frac{1}{2} \frac{\partial^2 G}{\partial S(p)^2} \sigma^2 S(p)^2 \right) dp + \frac{\partial G}{\partial S(p)} \sigma \; S(p) \; dW(p) \tag{9}$$

For example, the function $G = \ln S(p)$, with equation $\frac{\partial G}{\partial S(p)} = \frac{1}{S(p)}$, $\frac{\partial^2 G}{\partial S(p)^2} = -\frac{1}{S(p)^2}$, and $\frac{\partial G}{\partial p} = 0$, from the equation (9) thus the obtained :

$$dG = \left(\mu S(p) \frac{1}{S(p)} + 0 + \frac{1}{2} \sigma^2 \; S(p)^2 \left(-\frac{1}{S(p)^2} \right) \right) dp + \sigma \frac{1}{S(p)} S(p) \; dW(p)$$

$$dG = \left(\mu - \frac{\sigma^2}{2} \right) dp + \sigma \; dW(p) \tag{10}$$

Following through integrating both sides from 0 to p, we be able to :

$$\int_o^p d \; G = \int_0^p \left(\mu - \frac{\sigma^2}{2} \right) dp + \int_0^p \sigma \; dW(p)$$

$$\Leftrightarrow \ln(S(p)) - \ln(S(0)) = \left(\mu - \frac{\sigma^2}{2} \right) p + \sigma \; (W(p) - W(0))$$

$$\Leftrightarrow \ln \frac{S(p)}{S(0)} = \left(\mu - \frac{\sigma^2}{2} \right) p + \sigma \; (W(p) - W(0))$$

$$\Leftrightarrow \frac{S(p)}{S(0)} = \exp\left(\left(\mu - \frac{\sigma^2}{2} \right) p + \sigma (W(p) - W(0)) \right)$$

$$\Leftrightarrow S(p) = S(0) \; \exp\left(\left(\mu - \frac{\sigma^2}{2} \right) p + \sigma \; (W(p) - W(0)) \right) \tag{11}$$

3.7. Value at Risk with Historical Simulation Approach

Historical Simulation is a nonparametric method for measuring VaR. Historical simulation is regarded as the simplest method for predicting VaR because it is relatively easy to implement and there are no distribution assumptions that must be satisfied. In the Historical Simulation method, there are two assumptions that must be met in order to present accurate VaR predictions, viz [12]:

1. The decided sample period can be described with very satisfying conditions.
2. There is a feasibility of repeating the past in the expectation. That is the replication of models in volatility and the similarity of historical returns, on expected returns.

The predicted value of VaR-HS can be accomplished through the following equation:

$$VaR(X) = (1-\alpha)^{th}\ percentile \times \sqrt{T} \tag{12}$$

where, X is *return* stock, α is interval, T is *holding period* length

3.8. **Value at Risk** with **Cornish Fisher** Expansion Approach

In the VaR measurement, if it is observed that the stock return is not properly distributed, it is characterized by an excess of kurtosis value, it is also necessary to return attention to the value of skewness and excess Curtosis. This sights to reach a more efficient VaR value. Using the Cornish-Fisher Expansion method, Quantile-(1-α) which is used for VaR prediction is extended by the following formula [12]:

$$ECF = q_{1-\alpha} + \frac{\left((q_{1-\alpha})^2 - 1\right)S(X)}{6} + \frac{\left((q_{1-\alpha})^3 - 3q_{1-\alpha}\right)\psi(X)}{24} - \frac{\left(2(q_{1-\alpha})^3 - 5q_{1-\alpha}\right)S^2(X)}{36} \tag{13}$$

When the Curtosis value is less than 3, hence the ECF formula is as follow

$$ECF = q_{1-\alpha} + \frac{\left((q_{1-\alpha})^2 - 1\right)S(X)}{6} + \frac{\left((q_{1-\alpha})^3 - 3q_{1-\alpha}\right)K(X)}{24} - \frac{\left(2(q_{1-\alpha})^3 - 5q_{1-\alpha}\right)S^2(X)}{36} \tag{14}$$

where,

ECF	:	Cornish-Fisher Growth Value
$q_{1-\alpha}$	:	Quantile Value to (1-α) Normal Distribution Standard
S(X)	:	*Skewness Return* Stock Value
K(X)	:	Curtosis *return* Stock Value
$\psi(X)$	:	The Differences Excess Curtosis Value

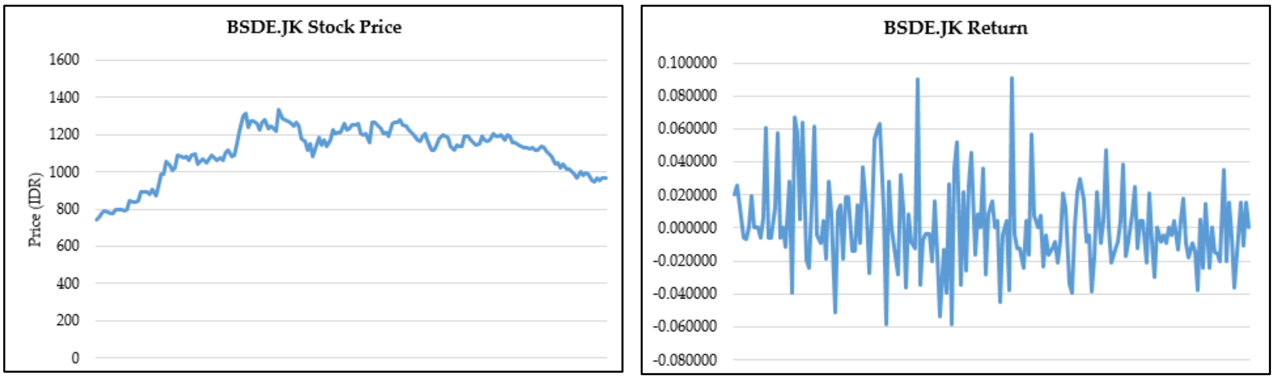
If the given confidence interval is α, and the *holding period* is T, then the VaR prediction formula with adjustment using Cornish-Fisher Expansion can be determined as:

$$VaR(X) = -(\mu_X - ECF\ \sigma_X) \times \sqrt{T} \tag{15}$$

4. Analysis and Results

In this research, the total data on BSDE.JK stock prices used were 181 data from 01/10/20 – 05/07/21. The data is then divided into in-sample and out sample. 140 data in the selected sample (01/10/20 – 30/04/21). Furthermore, 41 since becoming a sample of the outgoing data, namely

03/05/21 – 05/06/21. Price movements and stock returns during the period 01/10/20 – 05/07/21 are depicted through the following time series plot:



(a) (b)

Figure 1. Plot time series prices dan return stock BSDE.JK from the period 01/10/20 – 05/07/21

Based on Figure 1, during that period the stock price and return value of BSDE.JK tended to be stable and did not present any extreme changes. Later, exceeding complete data characteristics can be seen through the following table:

Table 1. Descriptive Statistics Stock price and return value BSDE.JK

Title 1	Mean	St.dev	Min	Max	Skewness	Kurtosis
Stock Price	1109.09	138.26	745	1335	-0.935	0.162
Return	0.003255	0.02657	-0.05872	0.09060	0.707	1.047

During the period 01/10/20 – 05/07/21, it is appreciated that the average return is positive. This proves that in general in that period the potential profit provided is greater than the potential loss that may be received. The slope of the negative value indicates that most of the data are clustered to the right of the mean value.

In stock price modeling using the GBM method, there is an assumption that the data returns are Normal Distribution. Therefore, the first step that requires to be done is to perform a normality test. Through applying the Kolmogorov-Smirnov test, the results of the data return normality test are:

Table 2. Normality Test Results using Kolmogorov-Smirnov Test

Title 1	D	Sig
BSDE.JK Return	1.30	0.069

Using $\alpha = 5\%$, hence the test provides the result that the data returns to normal distribution because the value of Sig (0.069) > α.

Subsequent the normality test results show that the return data is Normal Distribution, these the following method is to determine the parameter values of the GBM model which include μ, σ, and σ^2. The value for the third parameter is $\mu = 0.003255$, $\sigma = 0.02657$, dan $\sigma^2 = 0.0007059$. Based on equation (11), the GBM model for predicting BSDE.JK stock prices with an interval of 1 day are as ensues:

$$\hat{S}(p_i) = \hat{S}(p_{i-1})\exp\left(\left((0.003255) - \frac{0.0007059}{2}\right)(p_i - p_{i-1}) + 0.02657\sqrt{p_i - p_{i-1}}Z_{i-1}\right)$$

The stock price prediction results for the sample time period are as follows:

Table 3. Actual and Predicted Price Bumi Serpong Damai Ltd (IDR)

Period	Forecast	Actual	Period	Forecast	Actual
03/05/21	1189.77	1205	08/06/21	1112.44	1085
04/05/21	1127.25	1190	09/06/21	1176.94	1045
05/05/21	1090.09	1195	10/06/21	1080.39	1050
06/05/21	1046.39	1200	11/06/21	1017.80	1025
07/05/21	1055.16	1175	14/06/21	964.30	1040
10/05/21	1016.03	1200	15/06/21	952.29	1015
11/05/21	1046.28	1190	16/06/21	943.96	1015
17/05/21	1052.36	1155	17/06/21	966.70	1000
18/05/21	1067.87	1155	18/06/21	965.44	985
19/05/21	1049.59	1145	21/06/21	939.38	965
20/05/21	1050.95	1140	22/06/21	944.73	1000
21/05/21	1078.26	1130	23/06/21	956.62	980
24/05/21	1107.12	1130	24/06/21	985.27	995
25/05/21	1104.94	1125	25/06/21	1006.23	990
27/05/21	1062.52	1130	28/06/21	987.72	955
28/05/21	1069.75	1115	29/06/21	989.62	950
30/05/21	1075.95	1120	30/06/21	990.75	965
02/06/21	1098.34	1140	01/07/21	990.06	955
03/06/21	1080.39	1130	02/07/21	978.80	970
04/06/21	1088.47	1110	05/07/21	1040.09	970
07/06/21	1115.29	1100			

To measure the accuracy of the GBM model in predicting the stock price of BSDE.JK, use MAPE as a model. The MAPE value obtained is 5.17%, hence as to ensure that the prediction results are accurate. For the period 21/06/07, the predicted value of BSDE.JK stock is Rp. 990.

In addition to price predictions, this principle likewise points to measure the benefits of using VaR using the Historical Simulation and Cornish Fisher Expansion methods. The following table is the profit gain for the period 21/06/07 at several confidence levels:

Table 4. VaR values at various confidence levels

	Significance Level				
	90%	95%	97%	98%	99%
VaR-HS	-0.0432	-0.0597	-0.0644	-0.6831	-0.7115
VaR-CFE	-0.0498	-0.0623	-0.6773	-0.6931	-0.7309

At some level of certainty, the yield loss is in the range of 4% to 7.3%. This designates that if the investment made is IDR. Y, then the minimum possible nominal loss is 4% of Y, while the maximum nominal loss is 7.3% of Y.

4. Conclusions

Using *Geometric Brownian Motion* Method to predict the stock price of BSDE.JK obtained the following model:

$$\hat{S}(p_i) = \hat{S}(p_{i-1})\exp\left(\left((0.003255) - \frac{0.0007059}{2}\right)(p_i - p_{i-1}) + 0.02657\sqrt{p_i - p_{i-1}}Z_{i-1}\right)$$

with the predicted price for the period 21/06/07 is Rp.990. The prediction error value is 5.17% which means that the prediction accuracy is very good. Furthermore, based on the results of the VaR calculation through the Historical Simulation and Cornish Fisher Expansion methods, at a 95% confidence level, the results of the loss assessment for 06/07/21 are -0.0597 and -0.0623.

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