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Analysis of Put and Call Option Pricing on BCA Stock Using the Black-Scholes Model: Financial and Risk Management Perspective

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Abstract

The Indonesian stock market, especially PT Bank Central Asia (BCA) stock experiences high volatility. Therefore, this research is very important to provide a deeper understanding of the pricing of put and call options as a risk management instrument. This study aims to analyze the pricing of put and call options on PT Bank Central Asia (BCA) shares using the Black-Scholes model and identify factors that affect stock price fluctuations on option prices. This study aims to understand the changes in put and call option prices on PT Bank Central Asia (BCA) shares caused by fluctuations in stock prices. This study uses historical data of PT Bank Central Asia (BCA) shares, volatility, and current interest rates as the basis for analysis. The Black-Scholes method is used as a framework to analyze the pricing of put and call options by considering volatility and interest rates. The results of this study analyze the price changes of put and call options in the face of stock price fluctuations and the factors that affect option prices so as to provide insight into risk management and investment decision making. This research is expected to provide practical guidance for investors and risk managers in making decisions related to put and call options on PT Bank Central Asia (BCA) shares.

Keywords: PT. Bank Central Asia (BCA) stock, Black-Scholes, Put and Call Options, Volatility, Interest rate.

1. Introduction

The Indonesian stock market, particularly BCA stock, experiences significant volatility. Therefore, this research is essential to provide a deeper understanding of the determination of put and call option prices as risk management instruments (McNeil, 2015). This research aims to analyze how the Black-Scholes model can be used to determine put and call option prices on BCA stock and how stock price fluctuations affect option prices.

This research utilizes the theoretical framework of the Black-Scholes model in determining option prices, considering volatility and interest rates. The findings of this research are expected to provide practical guidance for investors and risk managers in making decisions regarding put and call options on BCA stock.

2. Literature Review

2.1. Option

According to Luenberger (1998), an option is a right, not an obligation, to buy or sell an asset at a specified price and at a specified time. The party that obtains the right is called the option buyer or option holder, while the party that sells the option and is responsible for the option buyer's decision on when to exercise the option is called the option issuer. The time limit within which the option is valid is called the maturity time, and the price of the asset agreed upon by the writer and buyer is called the exercise price.
Options can be distinguished based on the time of exercise (Wilmott et al, 1995), namely:

(a) European-type options, which are options that can only be exercised at maturity.
(b) American-type options, which are options that can be exercised before or on the maturity date.

Options can also be distinguished based on their function (Higham, 2004), namely:

(a) A call option is an option that gives the holder the right (but not the obligation) to buy a certain asset at a predetermined price and time.
(b) A put option is an option that gives the holder the right (but not the obligation) to sell a certain asset at a certain price and time.

2.2. Black-Scholes Model

The Black-Scholes Model is a mathematical model commonly used for calculating the theoretical price of European-style options. Developed by economists Fischer Black and Myron Scholes in collaboration with Robert Merton in the early 1970s, this model has had a profound impact on the field of finance. The primary application of the Black-Scholes Model is in estimating the fair market value of financial options, particularly stock options, by taking into account various factors that influence option pricing. To determine the option price, the following black Scholes model is used:

$$C = N(\omega d_1)S - N(\omega d_2)Xe^{-r(T-t)} \tag{1}$$

with:

C : option price
$\omega = 1$ for call option and $\omega = -1$ for put option

Calculation of Call Option Prices

The Black-Scholes formula for pricing a European call option is given by:

$$C(S,t) = N(d_1)S - N(d_2)Xe^{-r(T-t)} \tag{2}$$

Calculation of Put Option Prices

The Black-Scholes formula for pricing a European put option is given by:

$$P(S,t) = Xe^{r(T-T)} - S + C(S,t) = N(-d_2)Xe^{-r(T-t)} - N(-d_1)S \tag{3}$$

With

$$d_1 = \frac{lnln\left(\frac{S}{X}\right) + (r+\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \tag{4}$$

$$d_2 = d_1 - \sigma\sqrt{T-t} \tag{5}$$

$C(S,t)$: Call option price
$P(S,t)$: Put option price
S : Stock price
X : Strike price
r : Risk-free interest rate
T : Time to expiration (in years)
σ : Volatility of stock return

2.3. Volatility

According to Bittman (2009), volatility is a measure of asset price changes regardless of direction. Annualized volatility is calculated using the following formula (Hull, 2009):

$$\sigma = \sqrt{ks^2} = \sqrt{k\frac{\sum_{t=1}^{n} \ (r_t - r_{t-1})^2}{n_r - 1}} \quad (6)$$

where k is the number of trading periods in a year. If the data is daily, then the trading period is also daily with $k = 252$.

2.4. Interest Rate

Interest rates play an important role in determining the time value of options. Changes in interest rates can significantly affect option prices. High interest rates increase the value of call options as they add to the present value of future purchases. Conversely, low interest rates may increase the value of put options due to the lack of opportunity cost of owning the asset (Cairns, 2004).

3. Materials and Methods

3.1. Materials

This research seeks to examine the dynamics of European options through the application of the Black-Scholes Model. The analysis utilizes closing stock prices of Bank Central Asia (BCA) retrieved from Google Finance, spanning the period from December 11 to December 15, 2023. The study aims to provide insights into the behavior of options based on the observed stock price movements during this specified timeframe.

3.2. Methods

3.2.1. Closing Stock Price Data

The following is the closing share price of Central Bank of Asia (BCA) for the period December 11 to December 15, 2023.

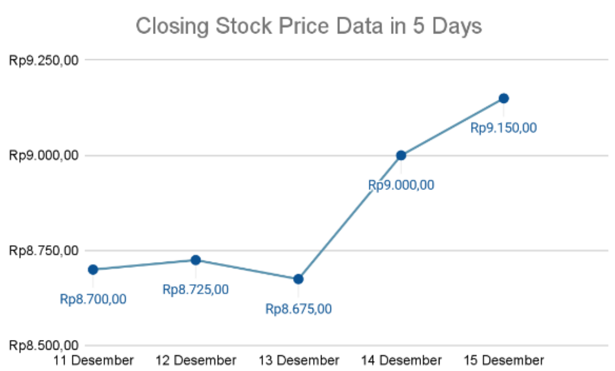

Figure 1: Closing Stock Price Data in 5 Days

3.2.2. Steps

The steps used in this study, namely:

(a) Determine and indicate the data to be used
(b) Calculate the data using the black scholes model to determine call and put options
(c) Determine call and put options to determine option price fluctuations with volatility and interest rate using the formula below:

Volatility Changes

a. Calculate d_{1new} and d_{2new} with Changed Volatility

$$d_{1new} = \frac{\ln \ln \left(\frac{S}{X}\right) + (r + \frac{1}{2}\sigma_{new}^2)(T-t)}{\sigma_{new}\sqrt{T-t}} \quad (7)$$

$$d_{2new} = d_{1new} - \sigma_{new}\sqrt{T-t} \quad (8)$$

b. Calculation New Option Price

For put option, the formula is given by:

$$P(S,t) = N(-d_{new2})Xe^{-r(T-t)} - N(-d_{new1})S \quad (9)$$

For call option, the formula is given by:

$$C(S,t) = N(d_{new1})S - N(d_2)Xe^{-r(T-t)} \quad (10)$$

Interest Rate Changes

a. Calculate d_{1new} and d_{2new} with Changed Interest Rate

$$d_{1new} = \frac{\ln \ln \left(\frac{S}{X}\right) + (r_{new} + \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$
(11)

$$d_{2new} = d_{1new} - \sigma\sqrt{T-t} \quad (12)$$

b. Calculation New Option Price

For put option, the formula is given by:

$$P(S,t) = N(-d_{new2})Xe^{-r_{new}(T-t)} - N(-d_{new1})S \quad (13)$$

For call option, the formula is given by:

$$C(S,t) = N(d_{new1})S - N(d_{new2})Xe^{-r_{new}(T-t)} \quad (14)$$

4. Results and Discussion

The research data used in this study is historical PT Bank Central Asia (BCA) stock data in a span of 5 days, namely on December 11 to December 15, 2023.

4.1 Option Price Determining Variables

The variables used to calculate the European type option price include S (closing stock price), X (strike/exercise price between the seller and buyer of the option), r (risk-free interest rate), T (time remaining to maturity in years), σ (volatility of stock price returns). The value of S can be seen in the historical closing price data of PT Bank Central Asia (BCA). On December 15, 2023, the closing stock price of PT Bank Central Asia (BCA) was Rp9,150.00. The maturity time is set for 6 months, while the risk-free interest rate is 3.5%. The strike/exercise price between the seller and buyer of the option is set at Rp9,250. The volatility value (σ) can be determined with the following steps:

(a) Determine the value of Stock Return

$$R_t = \ln\left(\frac{S_t}{S_{t-1}}\right) \quad (15)$$

(b) Determine the expectation value

$$E[R_t] = \frac{1}{n}\sum_{t=1}^{n} \quad R_t \tag{16}$$

(c) Determina the variance value

$$Var = \sum_{t=1}^{n} \quad \frac{[(R_t - E[R_t])^2]}{n} \tag{17}$$

(d) Determine the volatility value

$$\sigma = \sqrt{Var}$$

First, we will find the return value for $t = 2$ (the return value for $t = 1$ is assumed to be 0), using equation (15) is obtained:

$$R_2 = ln\left(\frac{S_2}{S_1}\right) = ln(92009050) = 0.0164387263$$

Second, we will find the value of $E[R_t]$ by using equation (16):

$$E[R_t] = \frac{1}{n}\sum_{t=1}^{n} \quad R_t \; = \; \frac{1}{6}\sum_{t=1}^{6} \quad R_t = 0.001831520263$$

Third, the value of the variance will be calculated using equation (17), obtained:

$$Var = \sum_{t=1}^{n} \quad \frac{[(R_t - E[R_t]))^2]}{n} = 0.0001867748268$$

Finally, the value of the closing stock volatility of PT Bank Central Asia (BCA) will be calculated using equation (18):

$$\sigma = \sqrt{Var} = 0.0001867748268 \; = 0.0136665587$$

It can be seen that the stock volatility of PT Bank Central Asia (BCA) is 0.0137 or 1.37%.

4.2 Option Pricing with the Black-Scholes Model

The Black-Scholes model is a mathematical model in finance. Based on the Black- Scholes model, the forecast price of European Options can be analytically determined. Manually, the calculation of prices of call options and put options using the Black-Scholes method can be done as follows:

Determine the value of d_1 by using equation (4):

$$d_1 \; = \; \frac{ln\left(\frac{S}{X}\right) + \left(r + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

$$d_1 \; = \; \frac{ln\left(\frac{9{,}150}{9{,}250}\right) + \left(0.035 + \frac{1}{2}(0.0001867748268)\right)(0.5)}{0.01236665587\sqrt{0.5}}$$

$$d_1 \; = \; 0.6909372377$$

Determine the value of d_2 by using equation (5):

$$d_2 \; = \; d_1 - \sigma\sqrt{T}$$

$$d_2 \; = \; 0.6909372377 - 0.0136665587\sqrt{0.5}$$

$$d_2 \; = \; 0.6909372377 - 0.009663716334$$

$d_2 \; = \; 0.6812735214$

After determining the values of d_1 and d_2, the forecast of the call option price can be calculated using equation (2):

$$C(S,t) = \; N(d_1)S - N(d_2)Xe^{-rT}$$

$$C(S,t) = \; N(0.6909372377)9{,}150 - N(0.6812735214)9{,}250e^{(-0.035(0.5))}$$

$$C(S,t) = \; 0.968391768266943(9{,}150) - 0.96764755832745(9{,}250e^{-0.0175}$$

$$C(S,t) = \; 8860.78468 - 8795.464588$$

$C(S,t) = \text{Rp}65.32$

Meanwhile, by using equation (3), we can calculate the forecast of the call option price, namely:

$P(S,t) \; = \; N(-d2)Xe - rT - N(-d1)S$

$P(S,t) = N(-0.6812735214)9{,}250e - 0.035(0.5) - N(-0.6909372377)9{,}150$

$P(S,t) = 0.0323524416725491(9{,}250e - 0.0175) - 0.0316317330566082(9{,}150)$

$P(S,t) = 294.068592 - 289.4303575$

$P(S,t) = \text{IDR}4.64$

After that, the results of the call and put option calculations were also obtained in the closing stock price data for 5 days from December 11 to December 15 2023.

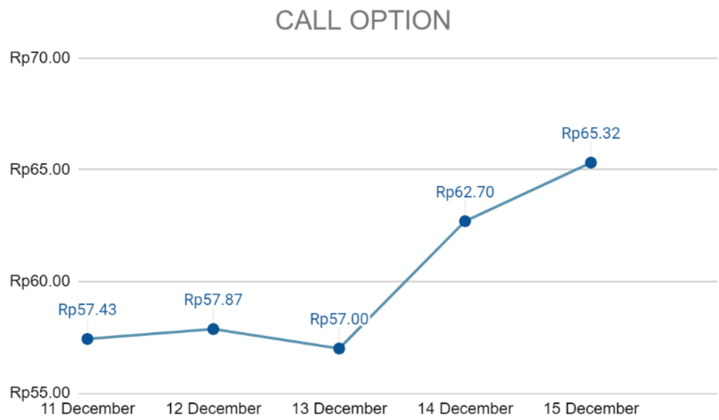

Figure 2: Call Option fluctuations from 11 December to 15 December 2023

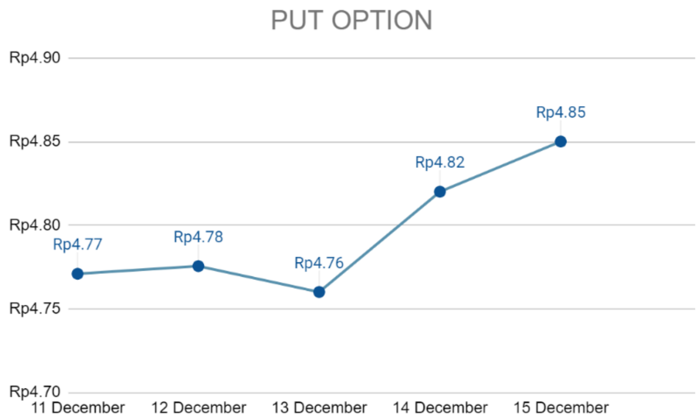

Figure 3: Put Option fluctuations from 11 December to 15 December 2023

The calculation is based on the current interest rate set by PT Bank Central Asia. But what about the results of different interest rates, assuming that the interest rate is not the same as the interest rate issued by Bank Central Asia, for example with an interest rate of 6.00% set by Bank Indonesia, the calculation is obtained as follows:

Determine the value of d_1 by using equation (11):

$$d_1 = \frac{ln\left(\frac{S}{X}\right) + \left(r + \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

$$d_1 = \frac{ln\left(\frac{9{,}150}{9{,}250}\right) + (0.06 + 120.0001867748268)(0.5)}{0.0136665587\sqrt{0.5}}$$

$d_1 = 1.988443547$

Determine the value of d_2 by using equation (12):

$d_2 = d_1 - \sigma\sqrt{T}$

$d_2 = 1.988443547 - 0.0136665587\sqrt{0.5}$

$d_2 = 1.988443547 - 0.009663716334$

$d_2 = 1.97477175$

The forecast price of a put option, by using equation (14), is:

$C(S,t) = N(d1)S - N(d2)Xe^{-rT}$
$C(S,t) = N(1.98443547)9{,}150 - N(1.974771757)9{,}250e^{-0.04(0.5)}$
$C(S,t) = 0.97639634(9{,}150) - 0.97585297(9{,}250e^{-0.02})$
$C(S,t) =$ IDR0.79

Meanwhile, by using equation (13), we can calculate the forecast of the call option price, namely:
$P(S,t) = N(-d2)Xe^{-rT} - N(-d1)S$
$P(S,t) = N(-1.97477175)9{,}250e^{-0.04(0.5)} - N(-1.98443547)9{,}150$
$P(S,t) = 0.02414703(9{,}250e^{-0.02}) - 0.02360366(9.150)$
$P(S,t) =$ IDR174.16

The calculation for a different volatility, for example with a volatility of 1.00%, is as follows:
Determine the value of d_1 by using equation (7):

$$d_1 = \frac{ln\left(\frac{S}{X}\right)+\left(r+\frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

$$d_1 = \frac{ln\left(\frac{9{,}150}{9{,}250}\right)+\left(0.035+\frac{1}{2}(0.0001)\right)(0.5)}{0.1\sqrt{0.5}}$$

$d_1 = 0.94120548$

Determine the value of d_2 by using equation (8):
$d_2 = d_1 - \sigma\sqrt{T}$
$d_2 = 0.94120548 - 0.01\sqrt{0.5}$
$d_2 = 0.94120548 - 0.007071067812$
$d_2 = 0.93413441$

After determining the values of d_1 and d_2, the forecast of the call option price can be calculated using equation (10):
$C(S,t) = N(d_1)S - N(d2)Xe^{-rT}$
$C(S,t) = N(0.94120548)9{,}150 - N(0.93413441)9{,}250e^{-0.035(0.5)}$
$C(S,t) = 0.826700215499954(9{,}150) - 0.824882717982589(9{,}250e^{-0.0175})$
$C(S,t) = 7564.306972 - 7497.796972$
$C(S,t) =$ IDR66.51

Meanwhile, by using equation (9), we can calculate the forecast of the call option price, namely:
$P(S,t) = N(-d2)Xe^{-rT} - N(-d1)S$
$P(S,t) = N(-0.93413441)9{,}250e^{-0.035(0.5)} - N(-0.94120548)9{,}150$
$P(S,t) = 0.17511728(9{,}250e^{-0.0175}) - 0.17329978(9{,}150)$
$P(S,t) = 1575.21313 - 1602.32313$
$P(S,t) = -$IDR27.11

Table 1: Table of Votality Changes on Option Pricing

Parameters (r)	6%	5.50%	4.00%	3.75%	3.25%
Stock price			Rp9,150		
Ecercise price			Rp9,250		
Maturity time			6 months		
Volatility			1.37%		
Call Option Forecast (Price)	Rp174.16	Rp152.43	Rp91.30	Rp82.12	-Rp15.95
Put Option Forecast (Price)	Rp0.79	Rp1.52	Rp8.14	Rp10.30	Rp15.95

Table 2: Table of Votality Changes on Option Pricing

Parameters (r)			3.50%		
Stock price			Rp9,150		
Ecercise price			Rp9,250		
Maturity time			6 months		
Volatility	2%	1.75%	1.25%	0.75%	1.00%
Call Option Forecast (Price)	Rp87.24	Rp81.57	Rp71.04	Rp62.91	Rp66.51
Put Option Forecast (Price)	Rp47.00	Rp21.10	Rp10.57	Rp2.45	-Rp27.11

5. Conclussion

The Black-Scholes model, which is used to price options, suggests that higher interest rates can increase the value of a call option, primarily because it increases the time value of the option. Conversely, higher interest rates can reduce the value of a put option because the opportunity cost of holding a put option becomes higher. Market volatility also plays an important role; an increase in volatility tends to increase the price of call and put options because it increases the expected price movement of the asset. Call and put options can be used as an effective risk management tool, especially in terms of hedging against asset price fluctuations. Buying a call option grants the right (not the obligation) to purchase an asset at a specific price (the strike price) within a certain period. If the asset's price rises above the strike price, the call option can be used to buy the asset at a lower price, mitigating the risk of losses. Conversely, purchasing a put option provides the right (not the obligation) to sell an asset at a predetermined price (the strike price) within a specified timeframe. If the asset's price falls below the strike price, the put option can be utilized to sell the asset at a higher price, thus reducing the risk of losses.

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