International Journal of Accounting and Management Information Systems (IJAMIS)
ISSN 2656-2448, Vol 3, No 2, 2025, 137-155 https://doi.org/10.35912/ijamis.v3i2.3334

Comparative analysis of Black-Scholes and GARCH models using collar strategy for hedging in telecommunication industry (Telkom, Xl, Indosat)

Abdul Mukti Soma[1], Victor Bastanta Sitepu[2]
Telkom University, Bandung, Jawa Barat, Indonesia[1,2]
muktisoma@telkomuniversity.ac.id[1], victorsitepu2018@gmail.com[2]

Article History
Received on 23 June 2025
1st Revision on 1 July 2025
2st Revision on 21 July 2025
3rd Revision on 4 August 2025
Accepted on 14 August 2025

Abstract

Purpose: This study examines the implementation of option contracts in the Black-Scholes model by comparing historical volatility and GARCH volatility using a collar strategy on TLKM, EXCL, and ISAT shares for the 2007–2024 period, aiming to determine the most appropriate model under crisis and normal conditions.

Research/methodology: The Black-Scholes model is applied with two volatility estimation methods historical and GARCH on options with 1-month and 3-month maturities, analyzed across crisis and non-crisis periods.

Results: For TLKM, with a 1-month maturity, GARCH outperformed historical volatility except during the 2008–2009 crisis; for 3 months, historical volatility outperformed in 2007, 2008–2009, and 2023–2024. For EXCL, historical volatility outperformed at 3 months in all conditions and at 1 month during crises; GARCH outperformed at 1 month in non-crisis periods. For ISAT, GARCH outperformed at 1 month except during the 2008–2009 crisis; historical volatility outperformed at 3 months during the non-crisis periods of 2007, 2023–2024, and the 2008–2009 crisis.

Conclusions: Performance varies by volatility method, maturity, and market condition. GARCH tends to perform better for short-term maturities in non-crisis periods, while historical volatility performs better for longer maturities and certain crisis periods.

Limitations: This study is limited to TLKM, EXCL, and ISAT stocks from 2007–2024, using only Black-Scholes and GARCH models with collar strategy, and may not generalize to other sectors or instruments.

Contribution: The study offers empirical evidence on optimal volatility modeling for hedging in Indonesia's telecommunications sector.

Keywords: *Black-Scholes, Collar, GARCH, Option Contract, Stock*

How to Cite: Soma, A. M., & Sitepu, V. B. (2025). Comparative analysis of Black-Scholes and GARCH models using collar strategy for hedging in telecommunication industry (Telkom, Xl, Indosat). *International Journal of Accounting and Management Information Systems*, 3(2), 137-155.

1. Introduction

This study analyzes a comparative application of the Black-Scholes model using historical volatility and GARCH volatility with a collar strategy as a hedging effort within the telecommunications industry, specifically focusing on the stocks of TLKM, EXCL, and ISAT (Karagozoglu, 2022). The Black-Scholes model is a well-established theory for pricing options, requiring five variables: strike price, current stock price, time to maturity, volatility, and the risk-free interest rate (Farahani, Babaei, & Esfahani, 2024; Irawan, 2017). GARCH is a model employed to forecast the volatility of returns on financial assets (Martin, Tang, & Yao, 2021; Naimy & Hayek, 2018). PT Telkom Indonesia (Persero)

Tbk is a state-owned enterprise in Indonesia operating in the fields of information technology, infrastructure services, and telecommunications (Widiarma & Yulianto, 2023). PT Indosat Ooredoo Hutchison Tbk and PT XLSMART Telecom Sejahtera Tbk are private telecommunications providers (mobile network operators) in Indonesia, focusing on mobile communication and data services. The infrastructure sector, particularly telecommunications companies, plays a significant role in the country's economic, educational, and business advancement (Mahmood, Misra, Sun, Luqman, & Papa, 2024; Thoyibah & Sugiharti, 2022).

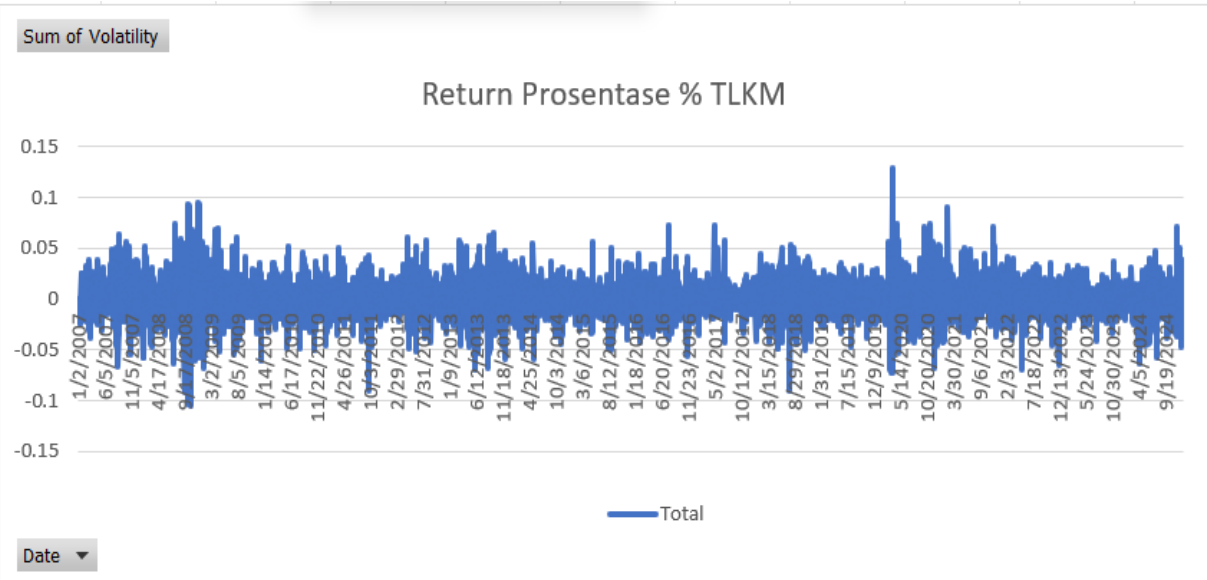

Figure 1. TLKM Stock Returns, 2007–2024
Source: Processed Data

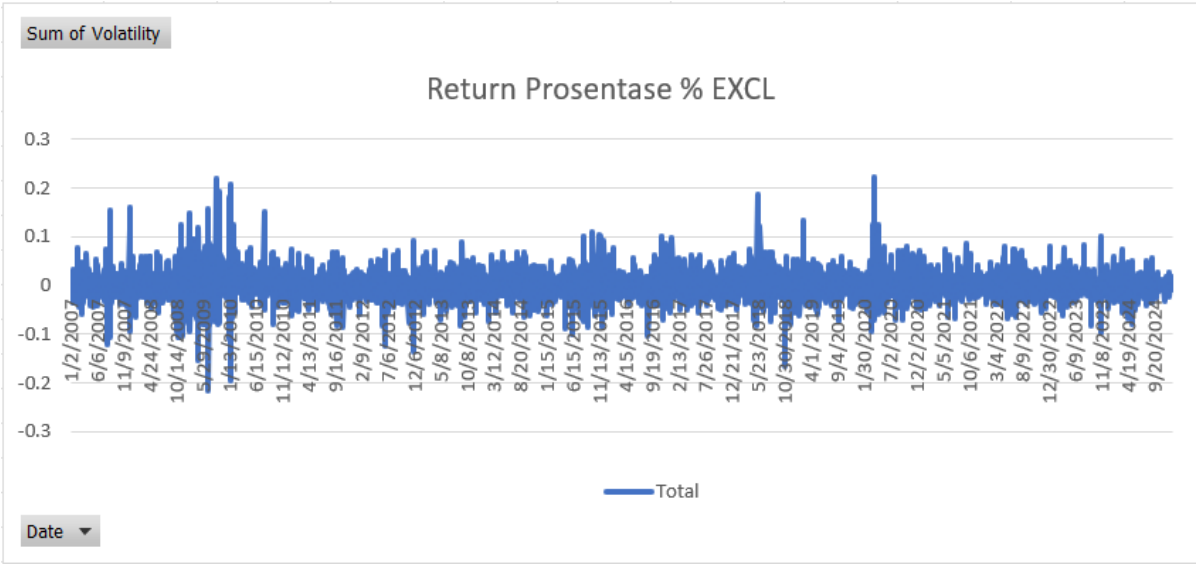

Figure 2. EXCL Stock Returns, 2007–2024
Source: Processed Data

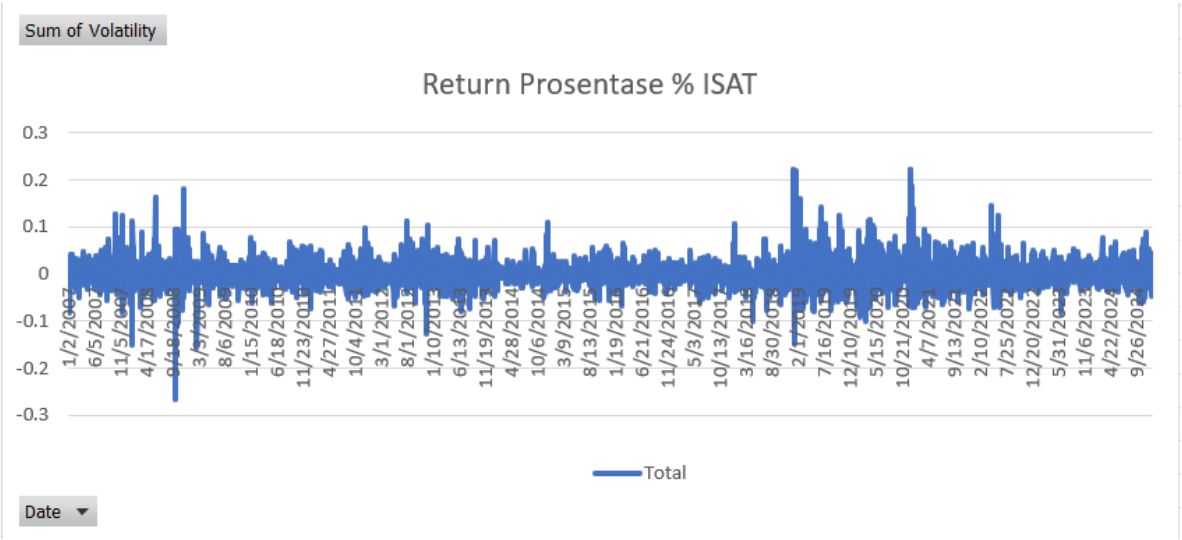

Figure 3. ISAT Stock Returns, 2007–2024
Source: Processed Data

Based on Figure 1, the daily return movements of PT Telekomunikasi Indonesia Tbk (TLKM) from 2007 to 2024 indicate a highest return of 12.87% (on March 26, 2020) and a lowest return of -10.45% (on October 24, 2008). Based on Figure 2, the daily returns of PT XLSMART Telecom Sejahtera Tbk (EXCL) over the same period show a peak return of 22.17% (on March 26, 2020) and a lowest return of -21.47% (on September 30, 2009). Based on Figure 3, the daily returns of PT Indosat Ooredoo Hutchison Tbk (Husnul, Setiyono, & Annasr) from 2007 to 2024 reveal the highest return of 22.19% (on January 9, 2019) and the lowest of -26.52% (on October 8, 2008).

2. Literature review

According to El-Hassan, Hall, and Tulunay (2021), unexpected sharp increases in market indices can result in substantial investment losses. For instance, following the global financial crisis of 2008–2009, the deviation in returns for the S&P/ASX 200 index from September 4, 2009, to October 1, 2009, was 6% (equivalent to 70% per annum). Isynuwardhana and Surur (2018) emphasize that risk management anticipations involve implementing hedging strategies for asset protection. Several types of option strategies can be used for either speculation or hedging purposes. According to their study, a long straddle strategy yields substantial profits when market prices rise or fall sharply. Li and Yang (2017) explains that collar strategies involve generating limited returns, typically by combining a short call option with a long put option position. Among derivative-based risk management strategies, collars attract significant interest from investors.

Hendrawan and Arifin (2023) examined the use of collar strategies in option contracts applying both the GARCH and Black-Scholes models on JII stocks. GARCH was employed to estimate the volatility variance used in the Black-Scholes calculation, which was then compared to results from the model using historical volatility (Bi, Yousuf, & Dash, 2014). During crisis periods, options with GARCH volatility and a 1-month collar strategy generated an average profit 3.07% higher, and 7.01% for 3-month options. In non-crisis periods, GARCH-based options with a collar strategy produced a slightly higher average return of 0.16% for 1-month options but dropped by 1.45% for 3-month options. Collar strategies resulted in maximum volatility levels of 12.71%, 15.18%, and 17.14%. It was also found that the GARCH model outperformed Black-Scholes according to AMSE scores during crisis periods for both 1-month and 3-month options, and in non-crisis periods for 1-month options.

Hendrawan, Laksana, and Aminah (2020) studied the volatility of the IHSG index between 2009 and 2018 using the long strangle strategy, evaluating its accuracy through AMSE across two volatility models: historical volatility under Black-Scholes and GARCH volatility under the ARIMA lag structure. The study found that the GARCH model offered more precision and detail for 1- and 2-month call options, with respective results of 0.26% and 0.92%. For 1- and 2-month put options, the

Black-Scholes model was more accurate, at 0.18% and 0.26%, respectively. For 3-month options, Black-Scholes was more accurate for both put and call options, with values of 2% and 0.31%, respectively.

3. Research methodology

3.1. Option Theory

An option is a contract with a defined time period that grants the holder the right to buy (call option) or sell (put option) an asset at a specified price (strike/exercise price) (Mooy, Rusgiyono, & Rahmawati, 2017). If the contract is not exercised by the expiration date, the option becomes worthless. There are four basic option positions: Long Call Option – the right to buy an asset at a specified price in the future, Short Call Option – the position of selling a call option based on the belief that the asset's price will decrease, Long Put Option – the purchase of a put option in anticipation of a price decline, Short Put Option – the sale of a put option, anticipating a price increase. There are also different types of options. The American option allows execution at any point before the expiration date as per contract terms, while the European option can only be exercised on the expiration date.

3.2. Volatility

Volatility reflects how frequently and to what extent the price of a stock or security fluctuates over a given period (Fajrina, Lubis, & Mustangin, 2024). It is a key factor in assessing the potential return or risk of an investment. High volatility implies high risk, while low volatility implies lower risk. Volatility can be classified into two types: Historical Volatility and Implied Volatility. Implied Volatility represents investors' expectations of future price fluctuations, derived from market sentiment and trading activity (supply and demand) (Gupta & Mishra, 2024). It serves as a forecast of future movements. Historical Volatility measures the variability in asset prices over a past time period. It can be calculated using the daily returns of stock prices. According to (Jain, 2001):

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

Where:

R_t = Natural log return
S_t = Today's stock price
S_{t-1} = Yesterday's stock price

Next, the average daily return over a certain period (n) is calculated:

$$R_m = \frac{\sum n\, R_t}{n} \quad \text{(2)}$$

Where:

R_m = Mean of daily returns
R_t = Daily return
n = Number of observation periods

Then, the standard deviation of daily returns is determined:

$$HV = \sqrt{\frac{\sum (R_t - R_m)^2}{n-1}} \quad \text{(3)}$$

Where:

HV = Historical volatility
R_m = Average daily return
R_t = Daily return
n = Number of observation periods

Lastly, to compute the annual historical volatility, the result is multiplied by the square root of 252 (the average number of trading days in a year).

$$annual\ HV = \sqrt{252} * HV \quad \text{(4)}$$

3.3. GARCH Volatility

The GARCH (Generalized Autoregressive Conditional Heteroscedasticity) model is an extension of the ARCH (Autoregressive Conditional Heteroscedasticity) model. The original ARCH model was introduced by Engle and Bollerslev (1986) to form the GARCH model. The autoregressive (AR) condition in this model requires that the data be stationary, meaning the data fluctuates around a constant mean or variance over time. Stationarity testing can be conducted using methods such as the Augmented Dickey-Fuller (ADF) test. In the GARCH model, conditional variance is influenced by past residuals and lagged conditional variance (Hardianti & Widarjono, 2017). The GARCH model is defined as follows:

$$\sigma_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \cdots + \alpha_p e_{t-p}^2 + \lambda_1 \sigma_{t-1}^2 + \cdots + \lambda_q \sigma_{t-q}^2 \quad (5)$$

Where:
p = represents the ARCH component,
q = represents the GARCH component,
$et{-}p$ = refers to residuals from previous time periods.
The influence time horizon can be limited in the GARCH model.

Engle and Bollerslev (1986) proposed the GARCH(1,1) model for volatility modeling, where σ_n^2 is calculated from the long-term average variance, V_L the previous variance σ_{n-1} and the previous squared residual u_{n-1}. According to Hull (2009), the GARCH(1,1) model is formulated as:

$$\sigma_n^2 = \gamma V_L + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \quad (6)$$

If γ represents V_L, α represents u_{n-1}^2, dan β represents σ_{n-1}^2, These constants satisfy the equation:

$$\gamma + \alpha + \beta = 1 \quad (7)$$

This indicates that in the GARCH(1,1) model σ_n^2 depends on the most recent observation of u^2 and the most recent estimate of variance. The more general GARCH(p,q) model calculates σ_n^2 based on p past observations of u^2 and q most recent variance estimates. if $\omega = \gamma V_L$, then the GARCH(1,1) model can also be expressed as:

$$\sigma^2 = \omega + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2 \quad (8)$$

Once ω, α, and β are estimated, γ can be calculated as $1-\alpha-\beta$. and the long variance V_L can be derived as ω/γ. A stable GARCH process satisfies the condition $\alpha + \beta < 1$.

3.4. Black-Scholes Model

The Black-Scholes model is used in financial derivatives pricing, investment banking, and risk management (Lindgren, 2023). The model was originally proposed by Fischer Black and Myron Scholes in 1973 and later extended by Robert Merton. Its primary objective is to calculate the price of European options based on stock price, time to maturity, risk-free interest rate, stock volatility, and strike price. Common applications of the Black-Scholes model include.

1. Fair valuation of options.
2. Derivative portfolio risk management.
3. Hedging strategy determination

According to Hull (2009), the Black-Scholes formula for a call option is:

$$C = SN(d1) - e^{-RfT} XN(d2) \quad (9)$$

The formula for a put option is:

$$P = Xe^{-RfT}\,N(-d2) - SN(d1) \quad \text{(10)}$$

Where:

$$d1 = \left(\ln\frac{[S/X] + \left[Rf - \frac{\sigma^2}{2}\right]}{\sigma\sqrt{T}}\,T\right) \quad \text{(11)}$$

$$d2 = d1 - \sigma\sqrt{T} \quad \text{(12)}$$

With:

C	= call option price
P	= put option price
S	= spot stock price
X	= strike/exercise price
T	= time to maturity
Rf	= risk-free interest rate
σ	= stock price volatility
N{.}	= cumulative standard normal distribution
d1 dan d2	= calculated parameters based on the formulas above

3.5. Collar Strategy

The collar strategy is a combination of holding the underlying stock/index, writing a covered call option, and purchasing a protective put option (Budiarti, Isynuwardhana, & Hendratno, 2018). This strategy manages price volatility by stabilizing potential losses and gains. It involves buying a put option and simultaneously selling a call option on the same stock (Israelov, Klein, & Moore, 2017). The payoff diagram of a collar strategy is illustrated in Figure 2.1. The protective put provides a benefit when the market price of the stock falls below the strike price of the put (K_P) offering downside protection. On the other hand, the covered call caps potential gains since the call will be exercised if the market price exceeds the call strike price (K_C) While the collar strategy limits upside potential, it provides hedging benefits at a low or potentially zero net cost if the premiums from the sold call and purchased put are equal.

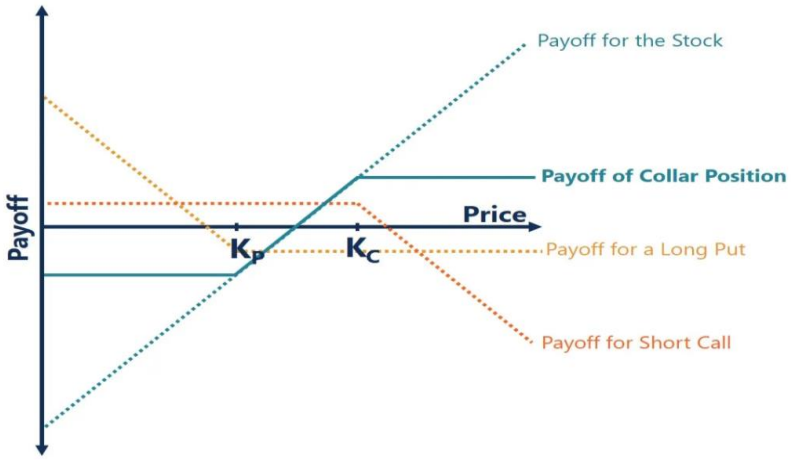

Figure 4. Collar strategy return graph

4. Results and discussion

This study uses the closing prices of TLKM, EXCL, and ISAT stocks sourced from https://www.marketwatch.com/ over the 2007–2024 period.

4.1. Historical Volatility Calculation

To calculate historical volatility, the daily returns of TLKM, EXCL, and ISAT are computed, followed by the standard deviation of these returns. The annualized historical volatility is then derived from this standard deviation.

Table 1. Historical Volatility (HV) of TLKM and EXCL and ISAT

Kode Saham	Tanggal	Harga	Return	HV 1 Bulan	Annual HV 1 Bulan	HV 3 Bulan	Annual HV 3 Bulan
	4/2/2007	1980	0.005063302	0.018818687	0.298737394	0.016443042	0.261025201
	4/3/2007	2000	0.010050336	0.017162273	0.272442641	0.016459639	0.261288668
	4/4/2007	2040	0.019802627	0.017147564	0.272209138	0.016333942	0.259293287
	4/5/2007	2020	-0.009852296	0.014639793	0.232399506	0.016531136	0.262423656
	4/9/2007	2040	0.009852296	0.014161218	0.22480237	0.016468637	0.261431508
	4/10/2007	2060	0.009756175	0.014178784	0.225081225	0.016500265	0.261933585
	4/11/2007	2090	0.014458083	0.014222039	0.225767869	0.016199204	0.257154386
TLKM	4/12/2007	2050	-0.019324273	0.013894784	0.220572855	0.016268941	0.258261429
	4/2/2007	1588	0.015868311	0.021011013	0.333539489	0.022048185	0.350004093
	4/3/2007	1600	0.007528266	0.021168978	0.336047113	0.022137828	0.351427132
	4/4/2007	1588	-0.007528266	0.020969246	0.332876467	0.022147753	0.351584672
	4/5/2007	1575	-0.008220091	0.017242497	0.273716159	0.02214608	0.351558125
	4/9/2007	1575	0	0.017209004	0.273184475	0.022150943	0.351635313
	4/10/2007	1575	0	0.01720924	0.273188216	0.021953893	0.34850725
	4/11/2007	1600	0.015748357	0.016972505	0.269430157	0.01929829	0.306350849
ISAT	4/12/2007	1588	-0.007528266	0.017156458	0.272350332	0.019284588	0.306133352
	4/2/2007	2170	0.011587615	0.02160004	0.34289	0.021924888	0.348046812
	4/3/2007	2318	0.065977577	0.02122295	0.336903883	0.021986581	0.349026151
	4/4/2007	2343	0.010727415	0.025783561	0.409301346	0.023669449	0.37574085
	4/5/2007	2318	-0.010727415	0.021462207	0.340701981	0.0237084	0.376359186
	4/9/2007	2318	0	0.019507399	0.309670354	0.023754591	0.377092446
	4/10/2007	2343	0.010727415	0.019507399	0.309670354	0.023561232	0.374022967
	4/11/2007	2392	0.020697677	0.01955933	0.310494732	0.023134107	0.367242567
EXCL	4/12/2007	2343	-0.020697677	0.019855784	0.315200807	0.023269454	0.369391127

Source: Processed Data

4.2. GARCH Volatility Calculation Results

In estimating volatility using the GARCH model, and following the parsimony principle as applied in ARMA models, GARCH(1,1) is selected for simplicity.

Table 2. Complete GARCH(1,1) Variables

Stock	Model	ω	α	β	γ (1-α-β)	VL (ω/γ)
	GARCH (1,1) Maturity 1 Month	14.16717	0.067546	0.931354	0.0011	12879.24545
TLKM	GARCH (1,1) Maturity 1 Month	14.50266	0.068306	0.930397	0.001297	11181.69622
	GARCH (1,1) Maturity 1 Month	52.01457	0.04941	0.946089	0.004501	11556.22528
EXCL	GARCH (1,1) Maturity 1 Month	68.40694	0.050164	0.943189	0.006647	10291.40063
	GARCH (1,1) Maturity 1 Month	28.03542	0.164619	0.834028	0.001353	20720.93126
ISAT	GARCH (1,1) Maturity 1 Month	29.97075	0.169908	0.827334	0.002758	10866.84191

Source: Processed Data

4.3. Bank Indonesia Interest Rate (BI Rate / 7-Day Reverse Repo Rate)

The BI rate represents the monetary policy benchmark rate announced by Bank Indonesia. The following table shows the rates from 2007 to 2024.

Table 3. Bank Indonesia Interest Rates during the 2007-2024 period

Year	RF (1 month, BI, 7DRRR) %
2007	8.604166667
2008	8.666666667
2009	7.145833333
2010	6.5
2011	6.583333333
2012	5.770833333
2013	6.479166667
2014	7.541666667
2015	7.520833333
2016	6
2017	4.5625
2018	5.104166667
2019	5.625
2020	4.25
2021	3.520833333
2022	4
2023	5.8125
2024	6

Source: Processed data

Changes in BI interest rates reflect the government's policy stance during the 2011–2022 period. For the Black-Scholes computations under both Historical Volatility and GARCH Volatility frameworks, the prevailing BI interest rates for the relevant periods are used.

4.4. Black-Scholes Model Calculation using Historical Volatility

To apply the Black-Scholes model using historical volatility over 1- and 3-month periods, data on the stock spot price, strike (exercise) price, and the applicable BI interest rate are required. This study applies the collar strategy using strike prices less than and greater than 5% as boundary criteria. The calculation steps for 1- and 3-month Black-Scholes options are provided below.

Table 4. Black-Scholes Variable Values with Historical Volatility

Stock	Variable	Value	Description
TLKM	S	1960	Closing stock price
	Xp	1862	Put strike price (assumed -5% of S)
	Xc	2058	Call strike price (+5% of S)
		2107	Call strike price (+7.5% of S)
		2156	Call strike price (+10% of S)
	T	0.083333333	1-month maturity (1 month as a fraction of 1 year)
		0.25	3-month maturity (3 months as a fraction of 1 year)
	Rf	0.086041667	Risk-free interest rate (applicable BI Rate)
	σ	0.330094755	1-month historical volatility
		0	3-month historical volatility
EXCL	S	2170	Closing stock price
	Xp	2061.5	Put strike price (-5% of S)
	Xc	2278.5	Call strike price (+5% of S)
		2332.75	Call strike price (+7.5% of S)
		2387	Call strike price (+10% of S)

	T	0.083333333	1-month maturity
		0.25	3-month maturity
	Rf	0.086041667	Risk-free rate (BI Rate)
	σ	0.34289	1-month historical volatility
		0.348046812	3-month historical volatility
ISAT	S	1600	Closing stock price
	Xp	1520	Put strike price (-5% of S)
	Xc	1680	Call strike price (+5% of S)
		1720	Call strike price (+7.5% of S)
		1760	Call strike price (+10% of S)
	T	0.083333333	1-month maturity
		0.25	3-month maturity
	Rf	0.086041667	Risk-free rate (BI Rate)
	σ	0.320647693	1-month historical volatility
		0.350004093	3-month historical volatility

Source: Processed data

Table 5. Stock Values Using Black-Scholes with Historical Volatility

Stock	Scenario	Xp	Xc	C	P	BEP Call	BEP Put	Time Maturity
TLKM	Xp = 95%*So Xc = 105%*So	2061.556592	2079	35.41191415	24.57943316	2089.832481	1891.832481	1 month
		2061.556592	2079	79.33522496	44.93531873	2113.399906	1915.399906	3 months
	Xp = 95%*So Xc = 107.5%*So	2061.556592	2128.5	22.90818602	24.57943316	2105.410437	1860.410437	1 month
		2061.556592	2128.5	61.99989994	44.93531873	2145.564581	1898.064581	3 months
	Xp = 95%*So, Xc = 110%*So	2061.556592	2178	14.24475146	24.57943316	2167.665318	1870.665318	1 month
		2061.556592	2178	47.7656612	44.93531873	2180.830342	1883.830342	3 months
EXCL	Xp = 95%*So Xc = 105%*So	2061.556592	2278.5	48.97849507	35.70162541	2291.77687	2074.77687	1 month
		2061.556592	2278.5	124.4031767	81.47970062	2321.423476	2104.423476	3 months
	Xp = 95%*So Xc = 107.5%*So	2061.556592	2332.75	33.98873411	35.70162541	2331.037109	2059.787109	1 month
		2061.556592	2332.75	104.3465568	81.47970062	2355.616856	2084.366856	3 months
	Xp = 95%*So,	2061.556592	2387.065527	22.92422202	35.70162541	2374.222597	2048.722597	1 month

	Xc = 110%*So							
		2061.556592	2387.065527	86.92212031	81.47970062	2392.44242	2066.94242	3 months
ISAT	Xp = 95%*So Xc = 105%*So	2061.556592	1667.4	34.24990402	24.73985478	1676.910049	1518.110049	1 month
		2061.556592	1667.4	91.65641259	60.17253892	1698.883874	1540.083874	3 months
	Xp = 95%*So Xc = 107.5%*So	2061.556592	1707.1	23.46055762	24.73985478	1718.68144	1518.68144	1 month
		2061.556592	1707.1	76.96775535	60.17253892	1723.895216	1525.395216	3 months
	Xp = 95%*So, Xc = 110%*So	2061.556592	1746.8	15.58838254	24.73985478	1737.648528	1499.448528	1 month
		2061.556592	1746.8	64.19539994	60.17253892	1750.822861	1512.622861	3 months

Source: Processed data

4.5. Black-Scholes Model Calculation with GARCH Volatility

The Black-Scholes model, developed in 1973 by Fischer Black and Myron Scholes, is a primary method for option pricing. It assumes dividends are paid under stable market conditions and stock prices follow a stochastic process. Fair pricing of call/put options depends on six variables: time, risk-free rate, volatility, option type, stock price, and strike price. The GARCH method is a statistical approach for modeling and forecasting volatility in financial time-series data. It assumes heteroskedasticity error variance varies based on past residuals and variances. To compute Black-Scholes volatility with GARCH (for 1- and 3-month horizons), spot prices, strike prices, and BI Rate/7-Day Repo Rate are required. This study employs a collar strategy with strike prices set at ±5% bounds.

Table 6. Black-Scholes Variables with GARCH Volatility

Stock	Variable	Value	Description
TLKM	S	1960	Closing stock price
	Xp	1862	Put strike price (assumed -5% of S)
	Xc	2058	Call strike price (+5% of S)
		2107	Call strike price (+7.5% of S)
		2156	Call strike price (+10% of S)
	T	0.083333333	1-month maturity period (1 month as a fraction of 1 year)
		0.25	3-month maturity period (3 months as a fraction of 1 year)
	Rf	0.086041667	Applicable interest rate (BI Rate)
	σ	3.804735158	GARCH (1,1) Volatility (1-month)
		0	GARCH (1,1) Volatility (3-month)
EXCL	S	2170	Closing stock price
	Xp	2061.5	Put strike price (-5% of S)
	Xc	2278.5	Call strike price (+5% of S)
		2332.75	Call strike price (+7.5% of S)
		2387	Call strike price (+10% of S)
	T	0.083333333	1-month maturity period
		0.25	3-month maturity period
	Rf	0.086041667	Applicable interest rate (BI Rate)

	σ	7.235769327	GARCH (1,1) Volatility (1-month)
		7.212112728	GARCH (1,1) Volatility (3-month)
ISAT	S	1600	Closing stock price
	Xp	1520	Put strike price (-5% of S)
	Xc	1680	Call strike price (+5% of S)
		1720	Call strike price (+7.5% of S)
		1760	Call strike price (+10% of S)
	T	0.083333333	1-month maturity period
		0.25	3-month maturity period
	Rf	0.086041667	Applicable interest rate (BI Rate)
	σ	5.317082041	GARCH (1,1) Volatility (1-month)
		5.29484844	GARCH (1,1) Volatility (3-month)

Source: Processed data

Table 7. Black-Scholes Stock Values with GARCH Volatility

Stock	Scenario	Xp	Xc	C	P	BEP Call	BEP Put	Time Maturity
TLKM	Xp = 95%*So Xc = 105%*So	1881	2079	801.3302191	746.6929651	2133.637254	1935.637254	1 month
		1881	2079	1295.448657	1190.041037	2184.40762	1986.40762	3 months
	Xp = 95%*So Xc = 107.5%*So	1881	2128.5	787.80955	746.6929651	2169.616585	1922.116585	1 month
		1881	2128.5	1287.436538	1190.041037	2225.895501	1978.395501	3 months
	Xp = 95%*So, Xc = 110%*So	1881	2178	774.6342484	746.6929651	2205.941283	1908.941283	1 month
		1881	2178	1279.570658	1190.041037	2267.529622	1970.529622	3 months
EXCL	Xp = 95%*So Xc = 105%*So	2061.5	2278.5	1513.571229	1422.448368	2369.62286	2152.62286	1 month
		2061.5	2278.5	2084.941476	1936.731153	2426.710323	2209.710323	3 months
	Xp = 95%*So Xc = 107.5%*So	2061.5	2332.75	1505.905697	1422.448368	2416.207329	2144.957329	1 month
		2061.5	2332.75	2083.938326	1936.731153	2479.957173	2208.707173	3 months
	Xp = 95%*So, Xc = 110%*So	2061.5	2387.065527	1498.374347	1422.448368	2462.925978	2137.425978	1 month
		2061.5	2387.065527	2082.948872	1936.731153	2533.21772	2207.71772	3 months
ISAT	Xp = 95%*So Xc = 105%*So	1508.6	1667.4	870.723737	815.6635431	1722.460194	1563.660194	1 month
		1508.6	1667.4	1312.55065	1214.54136	1765.409289	1606.609289	3 months

	Xp = 95%*So Xc = 107.5%*So	1508.6	1707.1	862.4054537	815.6635431	1753.841911	1555.341911	1 month
		1508.6	1707.1	1309.312252	1214.54136	1801.870891	1603.370891	3 months
	Xp = 95%*So, Xc = 110%*So	1508.6	1746.8	854.2586168	815.6635431	1785.395074	1547.195074	1 month
		1508.6	1746.8	1306.124178	1214.54136	1838.382818	1600.182818	3 months

Source: Processed data

4.6. Profit Probability Calculation for Collar Strategy

Based on the calculation of call and put option values using the Black-Scholes model with both historical volatility and GARCH volatility for 1-month and 3-month maturity periods, the subsequent step involves computing the profit and loss probabilities under the following criteria:

a. $X < Xp$ (below the put strike price),
b. $Xp \leq X \leq Xc$ (between the put and call strike prices),
c. $X > Xc$ (above the call strike price).

Table 8. Comparison of Profit Probabilities for Black-Scholes with Historical Variance (HV) vs. GARCH Variance (GV) in Collar Strategy Options (TLKM Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham TLKM							
			HV Black Scholes dengan Strategi Collar				GARCH Volatility Black Scholes dengan Strategi Collar			
			X < Xp	X > Xc	Xp < X < So	So < X < Xc	X < Xp	X > Xc	Xp < X < So	So < X < Xc
Non Krisis (2007)	1 bulan	Xp = 95%*So, Xc = 105%*So	26.34%	30.80%	22.32%	20.54%	26.34%	30.80%	22.32%	20.54%
		Xp = 95%*So, Xc = 107.5%*So	26.34%	24.55%	22.32%	26.79%	26.34%	24.55%	22.32%	26.79%
		Xp = 95%*So, Xc = 110%*So	26.34%	14.73%	22.32%	36.61%	26.34%	14.73%	22.32%	36.61%
	3 bulan	Xp = 95%*So, Xc = 105%*So	37.16%	36.61%	12.02%	14.21%	37.16%	36.61%	12.02%	14.21%
		Xp = 95%*So, Xc = 107.5%*So	37.16%	29.51%	12.02%	21.31%	37.16%	29.51%	12.02%	21.31%
		Xp = 95%*So, Xc = 110%*So	37.16%	24.04%	12.02%	26.78%	37.16%	24.04%	12.02%	26.78%
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	28.69%	28.27%	19.96%	23.08%	28.69%	28.27%	19.96%	23.08%
		Xp = 95%*So, Xc = 107.5%*So	28.69%	20.79%	19.96%	30.56%	28.69%	20.79%	19.96%	30.56%
		Xp = 95%*So, Xc = 110%*So	28.69%	14.35%	19.96%	37.01%	28.69%	14.35%	19.96%	37.01%
	3 bulan	Xp = 95%*So, Xc = 105%*So	36.59%	43.87%	11.23%	8.32%	36.59%	43.87%	11.23%	8.32%
		Xp = 95%*So, Xc = 107.5%*So	36.59%	36.80%	11.23%	15.38%	36.59%	36.80%	11.23%	15.38%
		Xp = 95%*So, Xc = 110%*So	36.59%	28.27%	11.23%	23.91%	36.59%	28.27%	11.23%	23.91%
Non Krisis (2010 - 2019)	1 bulan	Xp = 95%*So, Xc = 105%*So	15.68%	23.64%	28.07%	32.62%	15.68%	23.64%	28.07%	32.62%
		Xp = 95%*So, Xc = 107.5%*So	15.68%	13.54%	28.07%	42.72%	15.68%	13.54%	28.07%	42.72%
		Xp = 95%*So, Xc = 110%*So	15.68%	6.03%	28.07%	50.23%	15.68%	6.03%	28.07%	50.23%
	3 bulan	Xp = 95%*So, Xc = 105%*So	23.96%	38.04%	20.07%	17.93%	23.96%	38.04%	20.07%	17.93%
		Xp = 95%*So, Xc = 107.5%*So	23.96%	29.91%	20.07%	26.06%	23.96%	29.91%	20.07%	26.06%
		Xp = 95%*So, Xc = 110%*So	23.96%	23.80%	20.07%	32.17%	23.96%	23.80%	20.07%	32.17%
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	25.31%	25.71%	25.85%	25.85%	25.31%	25.71%	25.85%	25.85%
		Xp = 95%*So, Xc = 107.5%*So	25.31%	15.24%	25.85%	25.85%	25.31%	15.24%	25.85%	25.85%
		Xp = 95%*So, Xc = 110%*So	25.31%	9.66%	25.85%	25.85%	25.31%	9.66%	25.85%	25.85%
	3 bulan	Xp = 95%*So, Xc = 105%*So	33.88%	40.54%	15.24%	15.24%	33.88%	40.54%	15.24%	15.24%
		Xp = 95%*So, Xc = 107.5%*So	33.88%	34.56%	15.24%	15.24%	33.88%	34.56%	15.24%	15.24%
		Xp = 95%*So, Xc = 110%*So	33.88%	26.53%	15.24%	15.24%	33.88%	26.53%	15.24%	15.24%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	27.48%	17.55%	56.15%	54.72%	27.48%	17.55%	56.15%	54.72%
		Xp = 95%*So, Xc = 107.5%*So	27.48%	9.51%	56.15%	57.62%	27.48%	9.51%	56.15%	57.62%
		Xp = 95%*So, Xc = 110%*So	17.76%	3.17%	41.64%	46.22%	27.48%	3.38%	56.15%	59.59%
	3 bulan	Xp = 95%*So, Xc = 105%*So	52.23%	19.75%	77.70%	77.12%	52.23%	19.75%	77.70%	77.12%
		Xp = 95%*So, Xc = 107.5%*So	52.23%	11.04%	77.70%	79.40%	52.23%	11.04%	77.70%	79.40%
		Xp = 95%*So, Xc = 110%*So	52.23%	7.01%	77.70%	80.44%	52.23%	7.01%	77.70%	80.44%

Source: Processed Data

Table 9. Comparison of Profit Probabilities for Black-Scholes with Historical Variance (HV) vs. GARCH Variance (GV) in Collar Strategy Options (EXCL Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham EXCL							
			HV Black Scholes dengan Strategi Collar				GARCH Volatility Black Scholes dengan Strategi Collar			
			X < Xp	X > Xc	Xp < X < So	So < X < Xc	X < Xp	X > Xc	Xp < X < So	So < X < Xc
Non Krisis (2007)	1 bulan	Xp = 95%*So, Xc = 105%*So	28.04%	19.16%	28.97%	23.83%	28.04%	19.16%	28.97%	23.83%
		Xp = 95%*So, Xc = 107.5%*So	28.04%	15.42%	28.97%	27.57%	28.04%	15.42%	28.97%	27.57%
		Xp = 95%*So, Xc = 110%*So	28.04%	9.35%	28.97%	33.64%	28.04%	9.35%	28.97%	33.64%
	3 bulan	Xp = 95%*So, Xc = 105%*So	59.09%	7.39%	23.30%	10.23%	59.09%	7.39%	23.30%	10.23%
		Xp = 95%*So, Xc = 107.5%*So	59.09%	5.11%	23.30%	12.50%	59.09%	5.11%	23.30%	12.50%
		Xp = 95%*So, Xc = 110%*So	59.09%	4.55%	23.30%	13.07%	59.09%	4.55%	23.30%	13.07%
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	21.62%	45.14%	11.62%	21.62%	21.62%	45.14%	11.62%	21.62%
		Xp = 95%*So, Xc = 107.5%*So	21.62%	38.92%	11.62%	27.84%	21.62%	38.92%	11.62%	27.84%
		Xp = 95%*So, Xc = 110%*So	21.62%	31.35%	11.62%	35.41%	21.62%	31.35%	11.62%	35.41%
	3 bulan	Xp = 95%*So, Xc = 105%*So	21.08%	66.76%	3.24%	8.92%	21.08%	66.76%	3.24%	8.92%
		Xp = 95%*So, Xc = 107.5%*So	21.08%	63.51%	3.24%	12.16%	21.08%	63.51%	3.24%	12.16%
		Xp = 95%*So, Xc = 110%*So	21.08%	58.92%	3.24%	16.76%	21.08%	58.92%	3.24%	16.76%
Non Krisis (2010 - 2019)	1 bulan	Xp = 95%*So, Xc = 105%*So	28.95%	32.94%	18.56%	19.55%	28.95%	32.94%	18.56%	19.55%
		Xp = 95%*So, Xc = 107.5%*So	28.95%	24.44%	18.56%	28.05%	28.95%	24.44%	18.56%	28.05%
		Xp = 95%*So, Xc = 110%*So	28.95%	17.66%	18.56%	34.83%	28.95%	17.66%	18.56%	34.83%
	3 bulan	Xp = 95%*So, Xc = 105%*So	38.56%	44.11%	8.95%	8.38%	38.56%	44.11%	8.95%	8.38%
		Xp = 95%*So, Xc = 107.5%*So	38.56%	38.93%	8.95%	13.55%	38.56%	38.93%	8.95%	13.55%
		Xp = 95%*So, Xc = 110%*So	38.56%	34.33%	8.95%	18.15%	38.56%	34.33%	8.95%	18.15%
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	35.10%	30.07%	16.05%	16.05%	35.10%	30.07%	16.05%	16.05%
		Xp = 95%*So, Xc = 107.5%*So	35.10%	24.90%	16.05%	16.05%	35.10%	24.90%	16.05%	16.05%
		Xp = 95%*So, Xc = 110%*So	35.10%	20.14%	16.05%	16.05%	35.10%	20.14%	16.05%	16.05%
	3 bulan	Xp = 95%*So, Xc = 105%*So	43.67%	35.78%	10.61%	10.61%	43.67%	35.78%	10.61%	10.61%
		Xp = 95%*So, Xc = 107.5%*So	43.67%	30.34%	10.61%	10.61%	43.67%	30.34%	10.61%	10.61%
		Xp = 95%*So, Xc = 110%*So	43.67%	26.67%	10.61%	10.61%	43.67%	26.67%	10.61%	10.61%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	24.05%	21.52%	31.62%	28.42%	24.95%	22.32%	33.58%	30.27%
		Xp = 95%*So, Xc = 107.5%*So	24.05%	17.30%	31.62%	29.93%	24.05%	17.30%	31.62%	29.93%
		Xp = 95%*So, Xc = 110%*So	24.05%	12.24%	31.62%	32.31%	24.05%	12.24%	31.62%	32.31%
	3 bulan	Xp = 95%*So, Xc = 105%*So	28.84%	32.42%	23.81%	25.00%	28.84%	32.42%	23.81%	25.00%
		Xp = 95%*So, Xc = 107.5%*So	28.84%	24.21%	23.81%	27.27%	28.84%	24.21%	23.81%	27.27%
		Xp = 95%*So, Xc = 110%*So	28.84%	20.63%	23.81%	30.18%	28.84%	20.63%	23.81%	30.18%

Source: Processed data

Table 10. Comparison of Profit Probabilities for Black-Scholes with Historical Variance (HV) vs. GARCH Variance (GV) in Collar Strategy Options (ISAT Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham ISAT							
			HV Black Scholes dengan Strategi Collar				GARCH Volatility Black Scholes dengan Strategi Collar			
			X < Xp	X > Xc	Xp < X < So	So < X < Xc	X < Xp	X > Xc	Xp < X < So	So < X < Xc
Non Krisis (2007)	1 bulan	Xp = 95%*So, Xc = 105%*So	12.50%	41.52%	16.96%	29.02%	12.50%	41.52%	16.96%	29.02%
		Xp = 95%*So, Xc = 107.5%*So	12.50%	30.36%	16.96%	40.18%	12.50%	30.36%	16.96%	40.18%
		Xp = 95%*So, Xc = 110%*So	12.50%	20.98%	16.96%	49.55%	12.50%	20.98%	16.96%	49.55%
	3 bulan	Xp = 95%*So, Xc = 105%*So	31.69%	58.47%	1.64%	8.20%	31.69%	58.47%	1.64%	8.20%
		Xp = 95%*So, Xc = 107.5%*So	31.69%	48.63%	1.64%	18.03%	31.69%	48.63%	1.64%	18.03%
		Xp = 95%*So, Xc = 110%*So	31.69%	40.98%	1.64%	25.68%	31.69%	40.98%	1.64%	25.68%
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	38.13%	23.96%	18.33%	19.58%	38.13%	23.96%	18.33%	19.58%
		Xp = 95%*So, Xc = 107.5%*So	38.13%	17.92%	18.33%	25.63%	38.13%	17.92%	18.33%	25.63%
		Xp = 95%*So, Xc = 110%*So	38.13%	15.42%	18.33%	28.13%	38.13%	15.42%	18.33%	28.13%
	3 bulan	Xp = 95%*So, Xc = 105%*So	43.33%	24.17%	13.13%	19.38%	43.33%	24.17%	13.13%	19.38%
		Xp = 95%*So, Xc = 107.5%*So	43.33%	19.17%	13.13%	24.38%	43.33%	19.17%	13.13%	24.38%
		Xp = 95%*So, Xc = 110%*So	43.33%	14.58%	13.13%	28.96%	43.33%	14.58%	13.13%	28.96%
Non Krisis (2010 - 2019)	1 bulan	Xp = 95%*So, Xc = 105%*So	32.01%	27.78%	20.35%	19.86%	32.01%	27.78%	20.35%	19.86%
		Xp = 95%*So, Xc = 107.5%*So	32.01%	21.17%	20.35%	26.47%	32.01%	21.17%	20.35%	26.47%
		Xp = 95%*So, Xc = 110%*So	32.01%	15.68%	20.35%	31.97%	32.01%	15.68%	20.35%	31.97%
	3 bulan	Xp = 95%*So, Xc = 105%*So	40.38%	31.51%	15.43%	12.68%	40.38%	31.51%	15.43%	12.68%
		Xp = 95%*So, Xc = 107.5%*So	40.38%	26.92%	15.43%	17.28%	40.38%	26.92%	15.43%	17.28%
		Xp = 95%*So, Xc = 110%*So	40.38%	22.86%	15.43%	21.34%	40.38%	22.86%	15.43%	21.34%
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	30.51%	36.53%	17.37%	17.37%	30.51%	36.53%	17.37%	17.37%
		Xp = 95%*So, Xc = 107.5%*So	30.51%	29.82%	17.37%	17.37%	30.51%	29.82%	17.37%	17.37%
		Xp = 95%*So, Xc = 110%*So	30.51%	23.80%	17.37%	17.37%	30.51%	23.80%	17.37%	17.37%
	3 bulan	Xp = 95%*So, Xc = 105%*So	34.34%	47.33%	9.99%	9.99%	34.34%	47.33%	9.99%	9.99%
		Xp = 95%*So, Xc = 107.5%*So	34.34%	44.73%	9.99%	9.99%	34.34%	44.73%	9.99%	9.99%
		Xp = 95%*So, Xc = 110%*So	34.34%	40.90%	9.99%	9.99%	34.34%	40.90%	9.99%	9.99%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	21.15%	35.26%	42.26%	49.50%	21.15%	35.26%	42.26%	49.50%
		Xp = 95%*So, Xc = 107.5%*So	21.15%	26.71%	42.26%	53.50%	21.15%	26.71%	42.26%	53.50%
		Xp = 95%*So, Xc = 110%*So	21.15%	19.87%	42.26%	56.29%	21.15%	19.87%	42.26%	56.29%
	3 bulan	Xp = 95%*So, Xc = 105%*So	29.94%	47.77%	57.31%	56.30%	22.76%	53.27%	50.50%	48.98%
		Xp = 95%*So, Xc = 107.5%*So	22.76%	45.52%	50.50%	50.25%	22.76%	45.52%	50.50%	50.25%
		Xp = 95%*So, Xc = 110%*So	22.76%	39.47%	50.50%	53.27%	22.76%	39.47%	50.50%	53.27%

Source: Processed data

When X is less than Xp, the long put will be exercised, resulting in a loss equal to So-Xp-option premium. Under this condition, hedging applies. If X is between Xp and So, the loss for the collar strategy is So-X. If X is between So and Xc, the gain for the collar strategy is X-So. If X is greater than Xc, the short call will be exercised, resulting in a gain equal to Xc-So-option premium. Based on the comparison table of profit and loss opportunities above, it can be explained that the collar strategy with the Black Scholes historical volatility model and the Black Scholes GARCH volatility model is able to provide protection against losses of X < Xp 52.23% (Xp = 95% * So, Xc = 110% * So) and X > Xc 28.27% (Xp = 95% * So, Xc = 105% * So) for TLKM shares and X < Xp 59.09% (Xp = 95% * So, Xc = 110% * So) and X > Xc 45.15% (Xp = 95% * So, Xc = 105% * So) for EXCL shares as well as X < Xp 43.33% (Xp = 95% * So, Xc = 110% * So) and X > Xc 47.77% (Xp = 95% * So, Xc = 105%*So) for ISAT shares.

4.7. Comparison of Profit/Loss: Collar Strategy vs. Unhedged Position

The option calculations for the collar strategy (using Black-Scholes with Historical Volatility and GARCH Volatility) are compared to unhedged positions. The comparison includes minimum, maximum, and average profit/loss values

Table 11. Profit Comparison for Black-Scholes HV vs. GV with/without Collar Strategy (TLKM Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham TLKM											
			HV Black Scholes dengan Strategi Collar				GARCH Black Scholes dengan Strategi Collar				tanpa strategi collar			
			rata-rata	min	max	range	rata-rata	min	max	range	rata-rata	min	max	range
Non Krisis (2007)	1 bulan	= 95%*So, Xc = 105%*So	0.78%	-4.66%	5.80%	10.46%	2.99%	-2.26%	7.77%	10.03%				
		= 95%*So, Xc = 107.5%*So	0.85%	-5.08%	7.47%	12.55%	3.00%	-2.95%	9.59%	12.54%				
		= 95%*So, Xc = 110%*So	0.91%	-5.71%	9.90%	15.60%	2.82%	-3.62%	11.43%	15.04%	0.39%	-24.32%	18.04%	42.37%
	3 bulan	= 95%*So, Xc = 105%*So	1.96%	-3.01%	6.90%	9.91%	5.42%	0.35%	10.35%	9.99%				
		= 95%*So, Xc = 107.5%*So	0.85%	-5.08%	7.47%	12.55%	5.85%	-0.05%	12.45%	12.49%				
		= 95%*So, Xc = 110%*So	1.78%	-4.74%	-4.74%	14.91%	6.12%	-0.44%	14.55%	14.99%	-0.63%	-31.98%	19.05%	51.03%
Krisis (2008-2009)	1 Bulan	= 95%*So, Xc = 105%*So	0.59%	-4.62%	6.19%	10.81%	2.69%	-2.36%	7.81%	10.17%				
		= 95%*So, Xc = 107.5%*So	0.52%	-5.14%	7.75%	12.89%	2.62%	-3.04%	9.63%	12.68%				
		= 95%*So, Xc = 110%*So	0.43%	-5.80%	9.79%	15.59%	2.39%	-3.71%	11.47%	15.18%	0.44%	-26.09%	26.96%	53.04%
	3 bulan	= 95%*So, Xc = 105%*So	2.18%	-3.73%	7.66%	11.40%	5.44%	0.00%	10.40%	10.40%				
		= 95%*So, Xc = 107.5%*So	0.52%	-5.14%	7.75%	12.89%	6.06%	-0.40%	12.51%	12.91%				
		= 95%*So, Xc = 110%*So	2.30%	-5.09%	-5.09%	15.93%	6.49%	-0.80%	14.62%	15.42%	-0.12%	-33.33%	32.48%	65.81%
Non Krisis (2010 - 2019)	1 bulan	= 95%*So, Xc = 105%*So	0.86%	-4.99%	5.76%	10.75%	3.05%	-2.57%	7.68%	10.25%				
		= 95%*So, Xc = 107.5%*So	0.79%	-5.24%	7.45%	12.69%	2.82%	-3.26%	9.50%	12.76%				
		= 95%*So, Xc = 110%*So	0.69%	-5.86%	9.92%	15.78%	2.40%	-3.93%	11.33%	15.26%	0.84%	-20.08%	21.43%	41.51%
	3 bulan	= 95%*So, Xc = 105%*So	1.91%	-4.47%	6.77%	11.24%	5.36%	-0.62%	10.10%	10.72%				
		= 95%*So, Xc = 107.5%*So	0.79%	-5.24%	7.45%	12.69%	5.81%	-1.02%	12.20%	13.22%				
		= 95%*So, Xc = 110%*So	1.91%	-5.44%	-5.44%	15.50%	6.08%	-1.41%	14.31%	15.73%	2.34%	-34.83%	28.57%	63.40%
Krisis (2020-2022)	1 Bulan	= 95%*So, Xc = 105%*So	0.25%	-4.86%	5.80%	10.66%	2.32%	-2.65%	7.45%	10.10%				
		= 95%*So, Xc = 107.5%*So	0.19%	-5.32%	7.39%	12.71%	2.14%	-3.33%	9.28%	12.61%				
		= 95%*So, Xc = 110%*So	0.11%	-5.96%	9.76%	15.72%	1.78%	-4.00%	11.12%	15.12%	0.27%	-29.00%	31.56%	60.56%
	3 bulan	= 95%*So, Xc = 105%*So	1.21%	-4.17%	6.30%	10.47%	4.45%	-0.85%	9.34%	10.18%				
		= 95%*So, Xc = 107.5%*So	0.19%	-5.32%	7.39%	12.71%	4.98%	-1.25%	11.44%	12.68%				
		= 95%*So, Xc = 110%*So	1.38%	-5.61%	-5.61%	15.18%	5.34%	-1.64%	13.55%	15.19%	1.46%	-22.08%	34.33%	56.41%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	-0.43%	-4.89%	5.58%	10.47%	1.80%	-2.47%	7.56%	10.03%				
		Xp = 95%*So, Xc = 107.5%*So	-0.56%	-5.20%	7.37%	12.56%	1.45%	-3.15%	9.38%	12.53%				
		Xp = 95%*So, Xc = 110%*So	-0.35%	-5.74%	9.62%	15.36%	0.94%	-3.82%	11.21%	15.03%	-1.46%	-23.43%	18.01%	41.44%
	3 bulan	Xp = 95%*So, Xc = 105%*So	-0.55%	-4.15%	6.47%	10.61%	2.98%	-0.32%	9.74%	10.06%				
		Xp = 95%*So, Xc = 107.5%*So	-0.56%	-5.20%	7.37%	12.56%	2.94%	-0.72%	11.84%	12.56%				
		Xp = 95%*So, Xc = 110%*So	-1.38%	-5.26%	-5.26%	15.04%	2.77%	-1.11%	13.95%	15.06%	-4.99%	-31.83%	18.86%	50.69%

Source: Processed data.

Tabel 12. Profit Comparison for Black-Scholes HV vs. GV with/without Collar Strategy (EXCL Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham EXCL											
			HV Black Scholes dengan Strategi Collar				GARCH Black Scholes dengan Strategi Collar				tanpa strategi collar			
			rata-rata	min	max	range	rata-rata	min	max	range	rata-rata	min	max	range
Non Krisis (2007)	1 bulan	Xp = 95%*So, Xc = 105%*So	-0.20%	-4.72%	6.00%	10.72%	3.35%	-0.81%	9.21%	10.01%				
		Xp = 95%*So, Xc = 107.5%*So	-0.43%	-5.08%	7.60%	12.69%	3.45%	-1.16%	11.35%	12.51%				
		Xp = 95%*So, Xc = 110%*So	-0.65%	-5.72%	9.70%	15.41%	3.41%	-1.51%	13.51%	15.02%	-1.19%	-34.81%	38.48%	73.29%
	3 bulan	Xp = 95%*So, Xc = 105%*So	-0.82%	-3.27%	7.46%	10.73%	3.87%	1.83%	11.83%	10.00%				
		Xp = 95%*So, Xc = 107.5%*So	-0.43%	-5.08%	7.60%	12.69%	3.97%	1.79%	14.29%	12.50%				
		Xp = 95%*So, Xc = 110%*So	-2.31%	-4.86%	-4.86%	15.48%	4.05%	1.74%	16.74%	15.00%	-5.32%	-26.85%	34.97%	61.82%
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	2.12%	-4.48%	6.37%	10.84%	5.42%	-0.91%	9.22%	10.13%				
		Xp = 95%*So, Xc = 107.5%*So	2.37%	-5.08%	7.95%	13.04%	6.13%	-1.26%	11.37%	12.63%				
		Xp = 95%*So, Xc = 110%*So	2.55%	-5.80%	9.80%	15.60%	6.65%	-1.61%	13.53%	15.13%	3.17%	-63.60%	65.44%	129.04%
	3 bulan	Xp = 95%*So, Xc = 105%*So	4.80%	-3.03%	7.83%	10.87%	9.13%	1.50%	11.85%	10.35%				
		Xp = 95%*So, Xc = 107.5%*So	2.37%	-5.08%	7.95%	13.04%	10.71%	1.45%	14.30%	12.85%				
		Xp = 95%*So, Xc = 110%*So	6.18%	-4.75%	-4.75%	15.88%	12.20%	1.41%	16.76%	15.35%	14.37%	-66.04%	89.15%	155.19%
Non Krisis (2010 - 2019)	1 bulan	Xp = 95%*So, Xc = 105%*So	0.74%	-4.81%	6.35%	11.16%	4.19%	-1.12%	9.12%	10.24%				
		Xp = 95%*So, Xc = 107.5%*So	0.74%	-5.26%	7.95%	13.21%	4.56%	-1.48%	11.27%	12.75%				
		Xp = 95%*So, Xc = 110%*So	0.72%	-5.92%	9.78%	15.70%	4.74%	-1.82%	13.42%	15.25%	0.90%	-34.70%	51.34%	86.04%
	3 bulan	Xp = 95%*So, Xc = 105%*So	1.88%	-3.87%	7.64%	11.51%	6.49%	0.89%	11.59%	10.70%				
		Xp = 95%*So, Xc = 107.5%*So	0.74%	-5.26%	7.95%	13.21%	7.49%	0.84%	14.04%	13.20%				
		Xp = 95%*So, Xc = 110%*So	2.11%	-5.44%	-5.44%	16.36%	8.36%	0.80%	16.49%	15.70%	1.78%	-57.40%	89.15%	146.55%
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.16%	-4.76%	6.07%	10.83%	3.56%	-1.21%	8.88%	10.08%				
		Xp = 95%*So, Xc = 107.5%*So	0.15%	-5.32%	7.64%	12.96%	3.89%	-1.56%	11.03%	12.59%				
		Xp = 95%*So, Xc = 110%*So	0.18%	-6.00%	9.64%	15.64%	4.10%	-1.91%	13.18%	15.09%	-0.06%	-48.91%	68.79%	117.71%
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.75%	-4.15%	6.89%	11.04%	5.29%	0.64%	10.82%	10.18%				
		Xp = 95%*So, Xc = 107.5%*So	0.15%	-5.32%	7.64%	12.96%	6.07%	0.60%	13.27%	12.68%				
		Xp = 95%*So, Xc = 110%*So	0.62%	-5.61%	-5.61%	15.71%	6.73%	0.55%	15.73%	15.18%	0.25%	-45.17%	92.91%	138.08%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.29%	-4.73%	5.61%	10.34%	3.83%	-1.02%	9.00%	10.02%				
		Xp = 95%*So, Xc = 107.5%*So	#DIV/0!	#####	#DIV/0!	#DIV/0!	3.96%	-1.38%	11.14%	12.52%				
		Xp = 95%*So, Xc = 110%*So	#DIV/0!	#####	#DIV/0!	#DIV/0!	3.97%	-1.73%	13.30%	15.02%	0.21%	-20.00%	25.07%	45.07%
	3 bulan	Xp = 95%*So, Xc = 105%*So	1.69%	-3.68%	6.63%	10.31%	6.46%	1.18%	11.23%	10.04%				
		Xp = 95%*So, Xc = 107.5%*So	#DIV/0!	#####	#DIV/0!	#DIV/0!	7.11%	1.13%	13.68%	12.55%				
		Xp = 95%*So, Xc = 110%*So	1.31%	-5.25%	-5.25%	15.11%	7.62%	1.09%	16.13%	15.05%	1.05%	-25.52%	32.37%	57.89%

Source: Processed data.

Table 13. Profit Comparison for Black-Scholes HV vs. GV with/without Collar Strategy (ISAT Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham ISAT											
			HV Black Scholes dengan Strategi Collar				GARCH Black Scholes dengan Strategi Collar				tanpa strategi collar			
			rata-rata	min	max	range	rata-rata	min	max	range	rata-rata	min	max	range
Non Krisis (2007)	1 bulan	105%*So	2.25%	-4.59%	5.97%	10.56%	5.08%	-1.54%	8.48%	10.02%				
		107.5%*So	2.47%	-5.08%	7.57%	12.66%	5.47%	-2.06%	10.46%	12.52%				
		110%*So	2.58%	-5.71%	9.61%	15.33%	5.58%	-2.58%	12.44%	15.02%	2.72%	-35.35%	24.29%	59.64%
	3 bulan	105%*So	3.54%	-3.25%	7.10%	10.35%	7.71%	1.18%	11.18%	10.00%				
		107.5%*So	2.47%	-5.08%	7.57%	12.66%	8.85%	0.98%	13.48%	12.51%				
		110%*So	4.29%	-4.85%	-4.85%	15.18%	9.78%	0.78%	15.78%	15.01%	3.60%	-29.41%	39.44%	68.85%
Krisis (2008-2009)	1 Bulan	105%*So	-0.11%	-4.81%	6.18%	11.00%	2.62%	-1.65%	8.49%	10.14%				
		107.5%*So	-0.32%	-5.14%	7.76%	12.91%	2.61%	-2.18%	10.47%	12.65%				
		110%*So	-0.47%	-5.80%	9.72%	15.52%	2.52%	-2.69%	12.46%	15.15%	-0.89%	-37.78%	40.91%	78.69%
	3 bulan	105%*So	1.17%	-3.37%	7.76%	11.14%	5.07%	0.84%	11.21%	10.37%				
		107.5%*So	-0.32%	-5.14%	7.76%	12.91%	5.42%	0.64%	13.51%	12.87%				
		110%*So	0.38%	-5.03%	-5.03%	15.96%	5.65%	0.44%	15.82%	15.38%	-2.73%	-37.27%	44.23%	81.50%
Non Krisis (2010 - 2019)	1 bulan	105%*So	0.15%	-4.88%	6.17%	11.06%	2.96%	-1.86%	8.39%	10.25%				
		107.5%*So	0.14%	-5.25%	7.76%	13.01%	3.04%	-2.38%	10.37%	12.75%				
		110%*So	0.16%	-5.92%	9.98%	15.89%	2.99%	-2.90%	12.36%	15.26%	0.23%	-37.19%	97.96%	135.15%
	3 bulan	105%*So	0.94%	-4.22%	7.26%	11.48%	5.06%	0.23%	10.93%	10.71%				
		107.5%*So	0.14%	-5.25%	7.76%	13.01%	5.58%	0.03%	13.23%	13.21%				
		110%*So	0.67%	-5.44%	-5.44%	15.95%	6.01%	-0.17%	15.53%	15.71%	-0.25%	-58.79%	113.79%	172.58%
Krisis (2020-2022)	1 Bulan	105%*So	0.70%	-4.78%	6.13%	10.91%	3.31%	-1.93%	8.16%	10.09%				
		107.5%*So	0.78%	-5.32%	7.72%	13.04%	3.60%	-2.46%	10.14%	12.60%				
		110%*So	0.84%	-6.01%	9.60%	15.61%	3.75%	-2.97%	12.13%	15.10%	4.77%	-45.45%	185.66%	231.12%
	3 bulan	105%*So	1.91%	-3.97%	6.89%	10.85%	5.66%	-0.01%	10.18%	10.19%				
		107.5%*So	0.78%	-5.32%	7.72%	13.04%	6.60%	-0.21%	12.48%	12.69%				
		110%*So	2.40%	-5.60%	-5.60%	15.72%	7.48%	-0.41%	14.79%	15.20%	16.67%	-45.96%	220.08%	266.04%
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	1.25%	-4.68%	5.69%	10.38%	4.05%	-1.76%	8.27%	10.03%				
		Xp = 95%*So, Xc = 107.5%*So	1.38%	-5.20%	7.41%	12.61%	4.29%	-2.28%	10.25%	12.53%				
		Xp = 95%*So, Xc = 110%*So	1.50%	-5.86%	9.70%	15.56%	4.36%	-2.80%	12.24%	15.03%	2.44%	-22.48%	26.64%	49.11%
	3 bulan	Xp = 95%*So, Xc = 105%*So	2.23%	-3.73%	6.53%	10.27%	7.14%	0.53%	10.57%	10.05%				
		Xp = 95%*So, Xc = 107.5%*So	1.38%	-5.20%	7.41%	12.61%	8.20%	0.32%	12.87%	12.55%				
		Xp = 95%*So, Xc = 110%*So	3.72%	-5.26%	-5.26%	15.05%	9.09%	0.12%	15.17%	15.05%	3.79%	-49.24%	39.39%	88.63%

Source: Processed data.

4.8. AMSE Comparison for Collar Strategy Using HV and GARCH

The model's performance is evaluated by calculating the error between the collar strategy's break-even price (BEP) and the actual maturity price. The optimal model is identified by its smaller Mean Squared Error (MSE).

Table 14. AMSE Comparison for Black-Scholes HV vs. GV (TLKM Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham TLKM		Hasil
			MSE HV Black Scholes	MSE GARCH Volatility Black Scholes	
Non Krisis (2007)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.008751097	0.007698409	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.009158242	0.007903592	
		Xp = 95%*So, Xc = 110%*So	0.009479718	0.008194542	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.015713085	0.016908264	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.015642882	0.016601122	
		Xp = 95%*So, Xc = 110%*So	0.015657364	0.016332256	
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.009839211	0.008956521	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.010266831	0.009138244	
		Xp = 95%*So, Xc = 110%*So	0.010642178	0.009406319	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.022067765	0.024424009	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.021917117	0.024051217	
		Xp = 95%*So, Xc = 110%*So	0.02196386	0.023718087	
Non Krisis (210 - 2019)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.005808099	0.004227744	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.006349685	0.004621197	
		Xp = 95%*So, Xc = 110%*So	0.006738878	0.005093865	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.011045124	0.009420219	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.011784865	0.009487089	
		Xp = 95%*So, Xc = 110%*So	0.012488912	0.009583365	
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.007371614	0.006268511	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.007868045	0.006546866	
		Xp = 95%*So, Xc = 110%*So	0.008264157	0.006908898	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.014580399	0.013914911	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.015095489	0.013881975	
		Xp = 95%*So, Xc = 110%*So	0.015633306	0.013881172	
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.005616522	0.005113867	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.00586569	0.005161179	
		Xp = 95%*So, Xc = 110%*So	0.007359042	0.005301317	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.014723191	0.019313834	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.014182949	0.018663631	
		Xp = 95%*So, Xc = 110%*So	0.013896911	0.018061357	

Source: Processed data.

Table 15 AMSE Comparison for Black-Scholes HV vs. GV (EXCL Stock)

Kondisi	Maturity	Tipe Strategi Collar	Saham EXCL		Hasil
			MSE HV Black Scholes	MSE GARCH Volatility Black Scholes	
Non Krisis (2007)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.008613718	0.008674522	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.008844306	0.008542116	
		Xp = 95%*So, Xc = 110%*So	0.009062565	0.008437486	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.007393922	0.013811258	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.006726606	0.013725415	
		Xp = 95%*So, Xc = 110%*So	0.00630331	0.013641205	
Krisis (2008-2009)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.071319395	0.075415859	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.071036954	0.074929519	
		Xp = 95%*So, Xc = 110%*So	0.071055097	0.074477797	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.289641097	0.320486227	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.284592081	0.320180472	
		Xp = 95%*So, Xc = 110%*So	0.280494318	0.319879419	
Non Krisis (210 - 2019)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.012594921	0.011745655	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.013116047	0.01172607	
		Xp = 95%*So, Xc = 110%*So	0.01360982	0.011731544	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.041062426	0.046353163	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.040647564	0.046280404	
		Xp = 95%*So, Xc = 110%*So	0.040462934	0.046209083	
Krisis (2020-2022)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.019451533	0.020178906	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.019645166	0.019995959	
		Xp = 95%*So, Xc = 110%*So	0.01988692	0.019841974	Model GARCH lebih baik dibandingkan dengan Model HV
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.031082082	0.035474932	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.030779947	0.035408899	
		Xp = 95%*So, Xc = 110%*So	0.030665918	0.035344216	
Non Krisis (2023-2024)	1 Bulan	Xp = 95%*So, Xc = 105%*So	0.007274342	0.006072105	Model GARCH lebih baik dibandingkan dengan Model HV
		Xp = 95%*So, Xc = 107.5%*So	0.007721626	0.00595232	
		Xp = 95%*So, Xc = 110%*So	0.008077946	0.005992149	
	3 bulan	Xp = 95%*So, Xc = 105%*So	0.014272473	0.01486046	Model HV lebih baik dibandingkan dengan model GARCH
		Xp = 95%*So, Xc = 107.5%*So	0.014678542	0.014832882	
		Xp = 95%*So, Xc = 110%*So	0.015156375	0.014806101	Model GARCH lebih baik dibandingkan dengan Model HV

The results demonstrate that:

1. For TLKM stock, the Black-Scholes model with Historical Volatility outperformed GARCH Volatility during both:
   - The 2008-2009 financial crisis,
   - Non-crisis periods (2007 and 2023-2024) for 3-month maturities.
2. For EXCL stock, the GARCH Volatility model yielded superior results compared to Historical Volatility for 1-month maturities in both crisis and non-crisis scenarios.
3. For ISAT stock, the Black-Scholes model with Historical Volatility was more effective than GARCH Volatility during the 2008-2009 crisis.

5. Conclusion

5.1. Conclusion

In normal market conditions, the application of the Black-Scholes model incorporating GARCH volatility for TLKM, ISAT, and EXCL with both 1-month and 3-month maturities demonstrated superior profit-generating capability compared to the historical volatility approach. The GARCH volatility specification also exhibited stronger value protection within the Black-Scholes framework, highlighting its robustness in preserving asset worth. Moreover, the implementation of a collar strategy substantially mitigated return volatility relative to unhedged positions, thereby reinforcing its suitability for investors with a primary emphasis on asset stability. Under crisis conditions, the GARCH model consistently yielded lower Average Mean Squared Error (AMSE) values for both 1-month and 3-month option contracts, indicating enhanced predictive accuracy. In contrast, during non-crisis periods, GARCH volatility delivered superior performance for 1-month maturities, whereas for 3-month maturities, the Black-Scholes model employing historical volatility owing to its lower variance achieved a smaller AMSE than its GARCH-based counterpart. These findings underscore the importance of aligning volatility modeling techniques with prevailing market conditions and investment horizons to optimize hedging effectiveness and risk management outcomes.

5.2. Suggestions

Future research should expand the scope beyond the telecommunications sector by including multiple industries to enhance generalizability. Comparative analysis involving additional volatility forecasting models, such as EGARCH or stochastic volatility, may provide deeper insights into model performance under varying market dynamics. Extending the observation period to capture more recent market events, including post-2024 developments, could improve the robustness of findings. Moreover, applying the collar strategy to alternative financial instruments, such as exchange-traded funds (ETFs) or commodity derivatives, may reveal broader applicability in hedging practices. Incorporating macroeconomic variables such as inflation, currency fluctuations, and interest rate volatility into the volatility modeling framework is also recommended to assess their impact on option pricing accuracy. Finally, integrating simulation-based stress testing could provide practical insights for policymakers and practitioners in designing adaptive hedging strategies under extreme market conditions.

References

Bi, Z., Yousuf, A., & Dash, M. (2014). A Study on Options Pricing Using GARCH and Black-Scholes-Merton Model. *Asian Journal of Finance & Accounting, 6*(1), 423-439. doi:https://doi.org/10.5296/ajfa.v6i1.4830

Budiarti, A., Isynuwardhana, D., & Hendratno. (2018). Imbal Hasil Kontrak Opsi Menggunakan Covered Call Writing Strategy dan Protective Put Buying Strategy. *JRAK, 10*(1), 16-21. doi:https://doi.org/10.23969/jrak.v10i1.1057

El-Hassan, N., Hall, A., & Tulunay, I. (2021). Methods and Analysis of Collar Strategies. *Journal of Applied Business and Economics, 23*(8), 160-187. doi:https://doi.org/10.33423/jabe.v23i8.4882

Engle, R. F., & Bollerslev, T. (1986). Modelling the Persistence of Conditional Variances. *Econometric reviews, 5*(1), 1-50. doi:https://doi.org/10.1080/07474938608800095

Fajrina, N., Lubis, A., & Mustangin. (2024). Analisis Faktor Inflasi dan Suku Bunga Terhadap Volatilitas Harga Saham (Studi Kasus pada Perusahaan yang Terdaftar dalam Indeks LQ-45 di Bursa Efek Indonesia). *Jurnal Akuntansi dan Keuangan Entitas, 4*(1), 42-52.

Farahani, M. S., Babaei, S., & Esfahani, A. (2024). "Black-Scholes-Artificial Neural Network": A Novel Option Pricing Model. *International Journal of Financial, Accounting, and Management, 5*(4), 475-509. doi:https://doi.org/10.35912/ijfam.v5i4.1684

Gupta, A., & Mishra, R. (2024). A Comprehensive Study of Stock Market Volatility: Types, Determinants, and Measurement Methods. *International Journal For Multidisciplinary Research, 6*(6), 1-14. doi:http://dx.doi.org/10.36948/ijfmr.2024.v06i06.30054

Hardianti, N. I., & Widarjono, A. (2017). Dampak Penerbitan Sukuk dan Obligasi Konvensional Terhadap Return Saham Perusahaan di Indonesia. *Jurnal Ekonomi & Keuangan Islam, 3*(1), 43-51. doi:https://doi.org/10.20885/jeki.vol3.iss1.art6

Hendrawan, R., & Arifin, Z. (2023). Comparison of Black-Scholes and GARCH Option Models on The Jakarta Islamic Index with Collar Strategy. *Journal of Finance & Banking Review (JFBR), 7*(4), 16-27. doi:https://doi.org/10.35609/jfbr.2023.7.4(2)

Hendrawan, R., Laksana, G. T., & Aminah, W. (2020). Can The IDX Be Hegded?: Comparison of Black Scholes Option Model and Garch Option Model Using Long Strangle Strategy. *Jurnal Manajemen Indonesia, 20*(3), 252-259. doi:https://doi.org/10.25124/jmi.v20i3.3521

Hull, J. (2009). *Options, Futures, and Other Derivatives 7th Edition*. New Jersey: Pearson Education.

Husnul, N., Setiyono, A., & Annasr, N. N. (2023). Pendidikan dan Pelatihan Pembuatan Makanan Tambahan pada Ibu Balita dan Kader Menuju Masyarakat Sadar Stunting di Kota Tasikmalaya. *Jurnal Abdimas Kedokteran Dan Kesehatan, 1*(1), 27-33. doi:https://doi.org/10.24853/jaras.1.1.27-33

Irawan, W. O. (2017). Penentuan Harga Opsi dengan Model Black-Scholes Menggunakan Metode Beda Hingga Center Time Center Space (CTCS). *EKSAKTA: Berkala Ilmiah Bidang MIPA, 18*(2), 191-199. doi:https://doi.org/10.24036/eksakta/vol18-iss02/77

Israelov, R., Klein, M., & Moore, H. (2017). Practical Applications of Risk and Return of Equity Index Collar Strategies. *Practical Applications, 19*(1), 1-5. doi:https://doi.org/10.3905/pa.2017.4.5.221

Isynuwardhana, D., & Surur, G. N. I. (2018). Return Analysis on Contract Option Using Long Straddle Strategy and Short Straddle Strategy with Black Scholes. *International Journal of Academic Research in Accounting, Finance and Management Sciences, 8*(4), 16-20. doi:https://doi.org/10.6007/ijarafms/v8-i4/5181

Jain, R. K. (2001). *Putting Volatility to Work*. New York: Active Trader.

Karagozoglu, A. K. (2022). Option Pricing Models: From Black-Scholes-Merton to Present. *Journal of Derivatives, 29*(4). doi:10.3905/jod.2022.1.158

Li, P., & Yang, J. (2017). Pricing Collar Options with Stochastic Volatility. *Discrete Dynamics in Nature and Society*, 1-7. doi:https://doi.org/10.1155/2017/9673630

Lindgren, J. (2023). A Generalized Model for Pricing Financial Derivatives Consistent with Efficient Markets Hypothesis—A Refinement of the Black-Scholes Model. *Risks, 11*(2), 1-5. doi:https://doi.org/10.3390/risks11020024

Mahmood, S., Misra, P., Sun, H., Luqman, A., & Papa, A. (2024). Sustainable Infrastructure, Energy Projects, and Economic Growth: Mediating Role of Sustainable Supply Chain Management. *Annals of operations research*, 1-32. doi:https://doi.org/10.1007/s10479-023-05777-6

Martin, V. L., Tang, C., & Yao, W. (2021). Forecasting the Volatility of Asset Returns: The Informational Gains from Option Prices. *International Journal of Forecasting, 37*(2), 862-880. doi:https://doi.org/10.1016/j.ijforecast.2020.09.012

Mooy, M. N., Rusgiyono, A., & Rahmawati, R. (2017). Penentuan Harga Opsi Put dan Call Tipe Eropa Terhadap Saham Menggunakan Model Black-Scholes. *Jurnal Gaussian, 6*(3), 407-417. doi:https://doi.org/10.14710/j.gauss.6.3.407-417

Naimy, V. Y., & Hayek, M. R. (2018). Modelling and predicting the Bitcoin volatility using GARCH models. *International Journal of Mathematical Modelling and Numerical Optimisation, 8*(3), 197-215. doi:https://doi.org/10.1504/IJMMNO.2018.088994

Thoyibah, Q. A. y. P., & Sugiharti, L. (2022). The Effect of Telecommunication Infrastructure on Economic Growth in the Six ASEAN Countries. *Media Trend, 17*(1), 156-167. doi:https://doi.org/10.21107/mediatrend.v17i1.13640

Widiarma, I. a., & Yulianto, A. E. (2023). The Effect of the Indihome Spin Off from PT Telkom Indonesia (Persero) and the Merger of Indihome with Telkomsel on TLKM Shares on the IDX and TLK Shares on the NYSE. *Journal of Trends Economics and Accounting Research, 4*(2), 487-497. doi:https://doi.org/10.47065/jtear.v4i2.1051