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TEST OF VOLATILITY AND ITS APPLICATION ON OPTION PRICING STRATEGYON THE OIL PRICE INDEX USING 1995-2020 DATA

Riko Hendrawan[a],*, Sahat VP Silalahi[b],
[a] YARSI University, [b]Telkom University

ABSTRACT: *During the 1995-2020 period, yields on the West Texas Intermediate (WTI) oil price index fluctuated widely, resulting in risk encountered by investors through volatility. Thus, investors should minimize the risk by using derivative instruments as a hedging tool, namely options. This research aimed to compare the accuracy of the Black Scholes and GARCH option models on index options based on data from the 1995-2020 WTI Oil Commodity Price Index using the long straddles strategy. This research employed quantitative methods with comparative and descriptive approaches. Option accuracy was analyzed using the smallest percentage of average root mean squared error (AMSE). The findings revealed that, in the one-month model option, GARCH was more accurate for call by 1.90%. Meanwhile, the Black Scholes model was more accurate for put by 1.56%. The Black Scholes model was more accurate for put by 6.38% in the three-month option. Then, the GARCH model was more accurate for call by 8.13%*

KEYWORDS: *Black Scholes OptionsModel, Derivative Securities, GARCH Option Model, Oil, Volatility*

INTRODUCTION

Indonesia is relatively dependent on petroleum commodities, as perceived by one representative indicator: the oil share of primary energy. In 2018, Indonesia consumed 83.4 mtoe of oil (million tonnes of oil equivalent) out of 185.5 mtoe of energy consumed. Thus, Indonesia's oil share of primary energy consumption was 44.96%. Compared to the total world consumption (33.62%) and the total consumption of Asia-Pacific (28.32%), this value was higher. The comparison of Indonesia's oil share of primary energy consumption with other countries is presented in Figure 1 below,

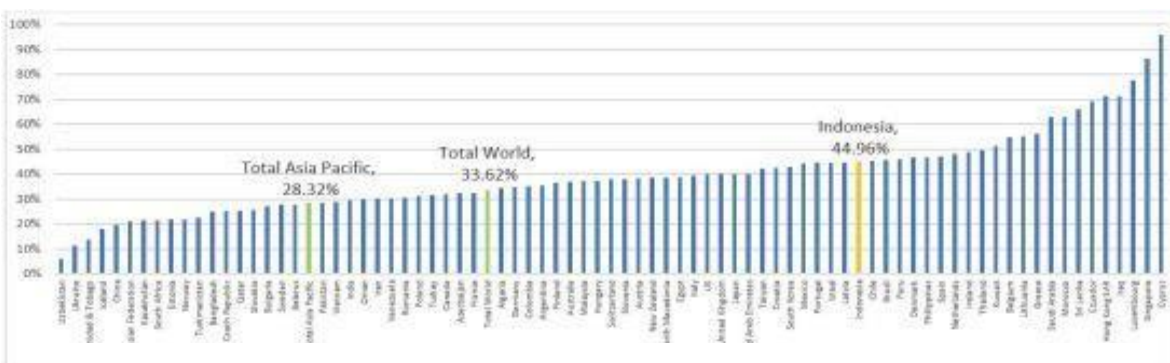

Figure 1 . Share of petroleum in the country's primary energy consumption (%), 2018

(Sources British Petroleum, 2019; processed)

In fulfillment, Indonesia has become a net oil importer country since 2004, considering that the consumption rate continued to increase while production levels declined. Therefore,imports were inevitable to fulfill these needs, both in crude and refined oil.

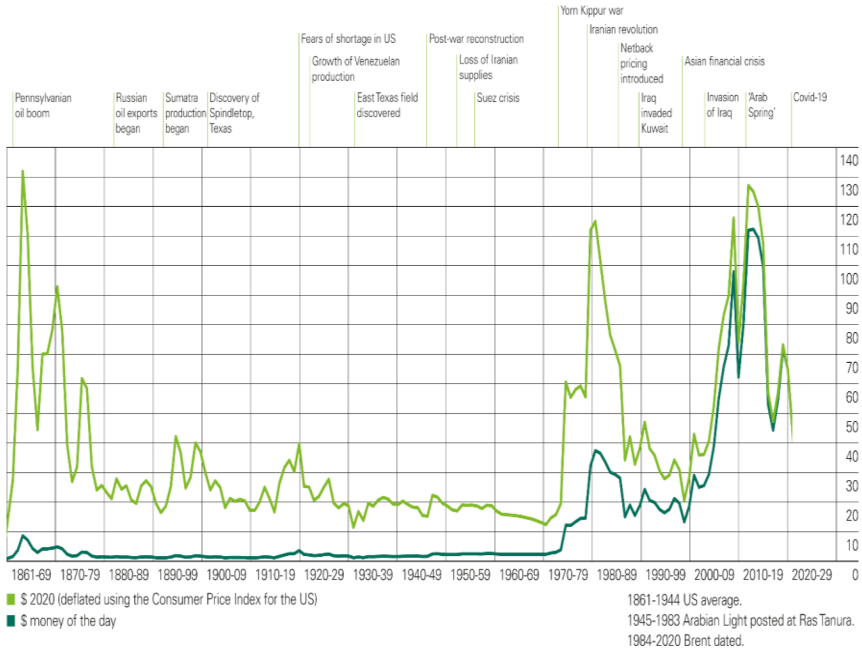

Figure 2 Oil share and the country's primary energy price index (%),

Sources British Petroleum, 2020; processed

Globally, the oil price index declined drastically in 2020, in which oil trading dropped to 5.3 million b/d (7.6%). The majority of this decline occurred in crude oil trading (3.3 million b/d) and was concentrated in Europe (1.6 million b/d) and the US (920,000 b/d). China,which was boosted by its rapid economic recovery from the pandemic, had crude oil imports increased by 970,000 b/d. The COVID-19 lockdowns and other restrictions caused the trade in oil products to drop by approximately 2.1 million barrels per day. This was concentrated in Europe (620,000 b/d), the US (360,000 b/d) reflecting the reduced use of air and ground transportation, and Singapore as the major trading center (325,000 b/d).
Oil prices fluctuate, impacting the economic conditions of each country. They also have a major influence on almost all production activities since oil is one of the main energies used directly or indirectly to produce goods and services.

LITERATURE REVIEW

The development of analytical option theory began with Bachelier (1900) as the foundation stone for option theory by using a mathematical approach in calculating prices to calculate the value of options, the basis of option theory which was developed by assuming that changes in stock prices follow Brownian motion and stock returns are follows a normal distribution.

Sprenkle (1964) modified the model developed by Bachelier by assuming that changes in stock prices are lognormally distributed and adding a drift variable with a random walk. This change will avoid negative results on security prices. Bones (1964) modified the Sprenkle model again by adding the variable time value of money. Samuelson (1965) modified and extended the Bones model by adding a variable for the average growth rate of calls.

However, the four models above can be implemented. Still, their practical application is complex because the models developed all use the expected return variable to calculate the return from investing in options so that each investor has different expectations regarding the expected return. Will produce an option value that is different from the calculation.

2.1. BLACK SCHOLES AND GARCH MODEL

Black Scholes was introduced in 1973 as a pricing model used to determine the fair price or value for call options and put options based on six variables: volatility, option type, stock price, time, strike price, and risk-free interest rate (Hull, 2009). According to Hendrawan (2010), in the Black & Scholes model, the basis of the risk-free asset variable replacing the expected return variable is used to calculate the expected rate of return.

Bollerslev (1986) developed the GARCH Model,which was parsimony or had a simpler model so that the variance was always positive.Hull (2009), the GARCH Model is formulated as follows:

$$\sigma^2 = \gamma V_L + \alpha u_{n-1}^2 + \beta \sigma_{n-1}^2$$

$$\omega = \gamma V_L$$

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

With :

- σ^2 = error variation at time n
- ω = constant component
- α = ARCH parameters
- β = GARCH parameters
- V_L = long-term variation

If $\omega, \alpha\ dan\ \beta$ can be estimated, γ can be calculated as $1 - \alpha - \beta$. In a stable GARCH process, it will conform to the equation $\alpha + \beta < 1$.

2.2. PREVIOUS RESEARCH

Using the Monte Carlo simulation method, Kallsen and Taqqu (1998) tried to develop continuous time GARCH. This method was developed as a form of criticism of the discrete-time GARCH method developed by Duan (1995). The results of the study showed that the continuous time GARCH model framework can be used to create a GARCH option model. Heston and Nandi (2000), applied the continuous time GARCH model by assuming that the current stock price has a variance that follows the GARCH process.

The model built by Heston and Nandi is based on two assumptions, namely: First, the current price follows the equation:

$$Log(S(t)) = Log(S(t-\Delta)) + r + \lambda h(t) + \sqrt{h(t)z(t)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

$$h_t = \omega + \sum_{t=1}^{p} \alpha_1 z(t-1\Delta) - \gamma_1 \sqrt{h(t-1\Delta))}^2 + \sum_{t=1}^{q} \beta_1 h(t-1\Delta) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Second, the option value at maturity follows the Black – Scholes Option Pricing Model. Based on the model built, using intraday S&P index options data on the Chicago Board Options Exchange (CBOE), using data every Wednesday for the period 1992 – 1994, it results that the money option, the GARCH Model corrects the error in determining the Black-Scholes Model price by 45%. The GARCH Model is very accurate when using historical data; in the out-the-money option, the GARCH Model is superior to the Black-Scholes Model with a range of 27%. The Heston and Nandi Model only focuses on a single lag (one lag), so the gap for further research is creating a model with multiple lags or the best lag obtained from the estimation results.

Fofana and Brorsen (2001) used implied volatility to compare the performance of the GARCH option pricing model with the Black-Scholes model. The data used is daily data from the Chicago wheat option premia obtained from the Wall Street Journal from July 1987 to July 1993 by comparing the Mean Squared Error, the average level of the most minor root error in predicting the option premium value. The results of their research using GARCH (1.1.) -t, which is an error following the student - t distribution, resulted in the conclusion that the GARCH option pricing model with implied volatility is superior to the Black-Scholes model for predicting the premium value with a period of 6 - 15 days before maturity. At the same time, the Black-Scholes model with implied volatility is superior to the GARCH option pricing model for predicting the option value for 16 - 20 days before the option maturity. While for the period between 21 - 50 days, neither of the two models is dominant.

Chang (2002), using daily data from the S&P 500 for June 1996 on the Chicago Board Options Exchange, tried to evaluate the accuracy of the GARCH(1.1) model with the Black-Scholes model. The model tested followed the model developed by Heston and Nandi (2000). Based on the results of his research showed that in the money option, the Black-Scholes model was better, with an average percentage of the root mean square error of 0.8528, while the average percentage of the root mean square error of the GARCH model was 0.8918. In the out-the-money option, the GARCH model was better, with an average percentage of the root mean square error of 0.4827, while the average percentage of the root mean square error of the Black-Scholes model was 0.7061. This means there is no dominant model for assessing the price of an option.

Harikumar, Boyrie, and Pak (2004) evaluated the Black-Scholes and GARCH option pricing models using Currency Exchange and Currency Call Option Data. GARCH – in Mean was used to predict currency movements. The currencies observed were the British Pound, Japanese Yen, and Swiss Franc for the period from January 5, 1987, to December 29, 1995, so each currency was observed as many as 2,289 which were obtained from the Wharton Research Data Base Service Foreign Currency, while the currency call option data was obtained from the Philadelphia Stock Exchange (PHLX) currency option database for the period 1982 to 2004. By comparing the Black-Scholes Model and GARCH-in Mean (1.1) and GARCH-in Mean (3.3), the research results showed that by comparing the percentage of the average root mean square error of the British Pound currency, the Black-Scholes Model was better than the GARCH (3.3) in Mean model. At the same time, the GARCH (3.3)-in Mean Model was better than the GARCH (1.1)-in Mean. The Black-Scholes Model was better at predicting currency call options for the Swiss Franc currency than the GARCH (3.3)-in the Mean model. Mean or GARCH(1.1)-in Mean. There is no dominant model for the Japanese Yen currency predicting currency call options.

Hasanah et al. (2019) researched the best way to model the volatility of the gold price using the GARCH and ARIMA methods. Bentes (2015) conducted a test to find the best model of three types of gold price yield volatility prediction models: GARCH, IGARCH, and FIGARCH.

Kristjanpoller and Minutolo (2015)conducted a study on predictinggold price volatility using a combined Artificial Neural Network and GARCH method to provide better predictions than the GARCH method. Similarly, Basher et al. (2015) tested the prediction of volatility in the gold price by using the modified GARCH method, GO-GARCH. Ahmad & Sara (2012) proved the existence of volatility in gold prices using the GARCH method.

In addition, several studies have been conducted to compare the Black Scholes and GARCH models. Zhang & Watada (2019) compared the two models on the object of the Shanghai 50ETF price index. The research found that the volatility value of the Black Scholes model provided a smaller AMSE value than the GARCH volatility value, so the Black Scholes model was considered better for the price index. Another study was conducted byJiratumpradub & Chavanasporn (2017), who studied SET50. The results showed that the Black Scholes and GARCH models had different results on the actual prices, and the Black Scholes model obtained better results than GARCH.

Other studies have also investigated options contracts and long straddle strategies. Shanmugam & Madathil (2019) conducted a study on the efficiency level of option contracts on gold commodities in India and concluded that the efficiency level of hedging options contracts on gold prices reached 88%. Hendrawan (2018) conducted a test of surprise volatility with the JCI object using the long-straddle method with 8,960 simulation options contracts resulting in the volatility level on the IDX Composites by 40.51%.

Isynuwardhana & Surur (2018)conducted a study and analysis on the rate of return on options contracts using a long straddles and short straddles strategy with the Black Scholes method on 5 companies listed on the IDX Composites, namely PT Astra, Tbk.(ASCII), PT BCA, Tbk. (BBCA), PT Indofood Sukses Makmur (INDF), PT Telekomunikasi Indonesia (TLKM), and PT HM Sampoerna, Tbk. (HMSP). Similarly, Krishnan & Raju (2018) compared the straddles and strangles strategy to obtain positive results to the volatility of the Indian stock price index (National Stock Exchange of India).

Stapleton (1991:92-93) stated that forward and options contracts are the most accurate instruments for risk management in the financial market or hedging. Several studies have investigated the impact of hedging. Hendrawan (2017) tested forward and forward options, and there was no hedging on the Rupiah exchange rate. Kamau et al. (2015) examined the usage of hedging using swaps, forwards, and options. Vargas & Kessakorn (2013) examined hedging using forward and options contracts.

Lee et al. (2009) stated that option contracts are an obligatory investment if someone is eager to compete and survive in today's financial markets. Using options contracts, investors can obtain the same benefits as direct stocks or commodities but gain less risk. In accordance with this, Hendrawan (2009) stated that the dominant factor in investing using stock option contracts is the way to model and predict the volatility of an underlying asset that trades the option. The better the volatility modelling and prediction in directly impacting the premium of the option contract, the better the function of the option contract as an investment tool.

This research tested and analyzed the application of option theory to oil prices over a period of one and three months using the Black Scholes and GARCH methods in 1995-2020 because the time range, based on previous research, was sufficient to represent the entire data for that year.

DATA AND RESEARCH METHOD

3.1. Research Method

The method used in the research is a hypothesis-generating study, which tests hypotheses that are created repeatedly and then tested for stability. The type of research carried out is a combination of exploratory and verification. Observations of changes in world oil price index prices were conducted to determine the best model to use in simulations to determine the premium price of a call or put. The analytical method used is the difference test method, which is used to compare the differences in testing two models, providing the most minor average level of error to be used as a reference for a better model.

3.1. Sources and Methods of Determining Data

The data sources used in this research are grouped into three, namely:

(1) Estimation Period Data, the data used to make estimates is daily movements in world oil prices for January 1995 - December 2020, where changes in world oil prices are observed daily. This data is used to estimate the volatility that occurs during the observation period (2). Model Testing Period Data: Data used to carry out model testing by simulating world oil option index contacts that occurred from February 1995 – December 2020. (3) Investment Period:Data used to test problem-solving plans and experiment period investment strategies March 1995 – April 2021. finally,the analysis design is built based on the following stages:

1. Dailyoil price index data collection is captured every day..
2. Volatility is calculated based on two assumptions, namely being constant during the option period (Black-Scholes-Merton Model) and changing (GARCH Model)
3. Volatility calculations are formed from the best ARIMA results and the best lag from the GARCH model.
4. The models compared are the Black-Scholes model and the GARCH model.

To get the best analysis of the model, a mathematical function was needed to calculate the percentage of average root mean squared error (AMSE).

$$AMSE = \frac{1}{N}\sum_{t=1}^{N}\left(\frac{APt - SPt}{APt}\right)^2$$

With:

Apt = actual option premium value

SPt = option premium value calculated by model

N = number of experiments performed

RESULTS AND DISCUSSION

4.1. Comparison of Volatility

The object of this research was the closing value/price of the WTI oil price index in the USD exchange rate analyzed using the Black Scholes model calculation with the long straddles strategy. An example of the closing value/price is presented in the following table.

Tanggal	Harga ($)	Return (%)	Standart Deviasi
3-Apr-95	19.03	-0.73%	1.22%
4-Apr-95	19.18	0.79%	1.16%
5-Apr-95	19.56	1.96%	1.12%
6-Apr-95	19.77	1.07%	1.10%
7-Apr-95	19.67	-0.51%	1.09%
10-Apr-95	19.59	-0.41%	1.02%
11-Apr-95	19.88	1.47%	1.04%
12-Apr-95	19.55	-1.67%	1.16%
13-Apr-95	19.15	-2.07%	1.28%
17-Apr-95	19.73	2.98%	1.40%
18-Apr-95	20.05	1.61%	1.40%
19-Apr-95	20.41	1.78%	1.32%
20-Apr-95	20.52	0.54%	1.31%
21-Apr-95	20.41	-0.54%	1.31%
24-Apr-95	20.12	-1.43%	1.34%
25-Apr-95	20.29	0.84%	1.35%
26-Apr-95	20.15	-0.69%	1.36%
27-Apr-95	20.43	1.38%	1.37%
28-Apr-95	20.38	-0.25%	1.38%

The Long straddles strategy is a high-risk strategy. There is a potential to generate significant profits, and losses from price movements are limited to the premium paid. This happens if the stock price on the maturity date is close to the strike price (Hull, 2009)

Year	DataAmount	Black Scholes Volatility			GARCH Volatility		
		Average	Lowest	Highest	Average	Lowest	Highest
1995	250	20.00%	11.53%	29.86%	18.05%	10.42%	26.91%
1996	252	38.13%	18.16%	61.79%	34.34%	16.36%	55.89%
1997	252	29.04%	14.53%	41.40%	26.29%	13.11%	37.30%
1998	251	42.93%	17.82%	88.28%	38.63%	16.06%	81.70%
1999	250	36.02%	18.48%	66.33%	32.61%	16.66%	60.01%
2000	249	41.36%	20.96%	62.76%	37.24%	18.88%	56.66%
2001	248	42.38%	22.81%	80.32%	38.31%	20.55%	72.41%
2002	250	34.61%	21.06%	61.55%	31.30%	19.00%	55.94%
2003	250	38.31%	24.26%	67.84%	34.60%	21.85%	61.12%
2004	249	35.19%	18.42%	57.79%	31.70%	16.59%	52.30%
2005	251	32.89%	17.38%	53.54%	29.76%	15.68%	48.54%
2006	251	27.46%	14.54%	38.77%	24.80%	13.12%	34.99%
2007	252	29.96%	13.98%	53.59%	27.00%	12.64%	48.31%
2008	253	50.09%	23.48%	123.14%	44.97%	21.15%	110.25%
2009	252	54.17%	25.82%	127.00%	49.30%	23.39%	116.72%
2010	252	27.34%	13.42%	40.50%	24.71%	12.12%	36.72%
2011	252	33.58%	13.09%	50.28%	30.25%	11.80%	45.35%

2012	252	25.12%	13.29%	48.24%	22.71%	11.98%	43.50%
2013	252	18.11%	10.15%	28.47%	16.34%	9.15%	25.66%
2014	252	20.35%	10.44%	55.91%	18.28%	9.41%	50.49%
2015	252	45.09%	25.47%	74.99%	40.69%	22.96%	67.78%
2016	252	45.07%	19.65%	96.05%	40.79%	17.72%	88.36%
2017	251	24.96%	16.88%	34.70%	22.53%	15.24%	31.64%
2018	252	27.09%	13.38%	58.80%	24.31%	12.07%	53.38%
2019	252	33.98%	16.66%	62.05%	30.81%	15.04%	55.93%
2020	253	68.19%	15.29%	230.94%	61.86%	13.78%	214.91%
2021	253	32.87%	15.68%	65.56%	29.62%	14.15%	59.05%
1995 - 2021	**6,785**	**35.35%**	**10.15%**	**230.94%**	**31.92%**	**9.15%**	**214.91%**

Throughout 1995-2021, with a total daily data of 6785, the result of the average volatility value used for the calculation of Black Scholes was 35.35%, with the lowest value being 10.15% and the highest value being 230.94%. Meanwhile, for the GARCH model, the average value obtained was 31.92%, with the lowest value being 9.15%, and the highest value being 214.91%.
In 1996, 252 daily data were used. Based on the calculation results, the average volatility value used for calculating Black Scholes was 38.13%, with the lowest value being 18.16% and the highest value being 61.79%. Meanwhile, for the GARCH model, the average value obtained was 34.34%, with the lowest value being 16.36% and the highest value being 55.89%.
Based on the sampling period from 1995-2021, the average volatility value calculated using Black Scholes was highest in 2020 at 68.19% and lowest in2013 at9.47%. For the GARCH model, the highest average value was in 2020 at 61.86%, and the lowest average value was in 2013 at 16.34%.

The following table shows the percentage of gains and losses from buying options using the long straddles strategy for one and three-month contract periods in the period 1995-2021 :

Period	**Model**	Condition	Lowest	Average	Highest
1 month	Black Scholes	Profit	55.1%	29.8%	74.4%
		Loss	44.9%	70.2%	25.6%
	GARCH	Profit	51.2%	\31.9%	69.0%
		Loss	48.8%	68.1%	31.0%
3 months	Black Scholes	Profit	58.7%	22.6%	99.2%
		Loss	41.3%	77.4%	0.8%
	GARCH	Profit	47.9%	23.7%	80.6%
		Loss	52.1%	76.3%	19.4%

During this period, the Black Scholes Model provided higher profit potential and lower losses than the GARCH model. In the one-month and three-month periods, Black Scholes's profits were higher than those of the GARCH model. This research found that the maximum profit possible was 55.1% (Black Scholes for one month) and 58.7% (Black Scholes for three months).

This is in line with Hendrawan, Laksana et al. (2020), who found that the use of the long straddles strategy on the LQ45 index in the 2009-2019 period (non-crisis year period) reached a maximum of 60% possible profit, with an average possible profit of approximately 30%. The best model was determined based on the smallest AMSE value (Hendrawan, 2010). The more accurate the variance modeling used for calculating option prices, the better the options function as a tool for hedging, arbitrage, or speculation.

Period	AMSE	Model		Result
		Black Scholes	GARCH	

1 month	Call	1.93%	1.90%	The GARCH model was better than the Black-Scholes model
	Put	1.56%	1.56%	The GARCH model was the same as the Black Scholes Model
3 month	Call	8.38%	8.13%	The GARCH model was better than the Black-Scholes model
	Put	6.38%	6.42%	Black Scholes model was better than GARCH. Model

The table above shows that the AMSE Black Scholes value was smaller than GARCH in the three months of the put option contract, while the AMSE GARCH was smaller than the Black Scholes in the one-month and three-month call periods. For the one-month Put period, the AMSE values of Black Scholes and GARCH tended to have similar values.

This research found that the GARCH model was better at conditions for a period of one month and three months, this is in line with research conducted by Wibowo (2005) stating that the Black Scholes pricing model was not suitable to be used as a basis for setting premium prices because it gives unfair results. Hendrawan (2010) conducted research on four stocks listed on the stock exchange, which showed that the GARCH model was more accurate than the Black Scholes for 1, 2, and 3-month option periods.

4.2. DISCUSSION

In this period, the Black Scholes Model provided higher profit potential and lower losses than the GARCH model. In the one-month and three-month periods, the profits of Black Scholes were higher than the GARCH model. This research found that the maximum profit possible was 55.1% (Black Scholes for one month) and 58.7% (Black Scholes for three months). This is in line with Hendrawan, Laksana et al. (2020),who found that the use of the long straddles strategy on the LQ45 index in the 2009-2019 period (non-crisis year period) reached a maximum of 60% possible profit, with an average possible profit of approximately 30%. Also, Hendrawan, Akbar, et al. (2020) found that the maximum profit potential was 54.98%, with an average profit potential of around 25-30% with the implementation of the long straddles strategy on gold price index option contracts for the 2014-2018 period (period non-crisis year).

CONCLUSION

This research draws several conclusions according to the research objectives as follows:

The GARCH model provided higher profit potential and lower losses than the Black Scholes model. One monthly period provided higher profit potential than the three-month period. This was demonstrated by both the Black Scholes and GARCH models. Furthermore, the three-month period provided higher profit potential than the one-month period for both black school and GARCH models. This research found that the maximum possible profit obtained was 99.2% (Black Scholes for three months) with an average profit of one month period of 51.2% - 55.1% and a three-month period of 47.9% - 58.7%. The GARCH model was less valuable than the Black Scholes model in the one and three-month period of call option contracts (1.90% and 8.13%).The Black Scholes model was less valuable than the Black Scholes model for a three-month period of put option contracts (6.38%).

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