Performance of the Delta- neutral Hedging Strategy on Meme Stock

Haozhou Liang*

School of social science, University of California, Irvine, USA

*Corresponding author: haozhoul@uci.edu

Abstract. This paper studies the performance of delta-neutral hedging strategies on meme stocks under the Black-Scholes-Model to help investors find possibilities of reducing the risk caused by high volatility in meme stock trading. In the study, one of the most followed stocks by individual investors on the r/wallstreetbets forum-GameStop (GME)-is selected as the underlying, and data of 10 options with different strike prices in the short term are collected and the daily implied volatility are calibrated by using the minimum square error approach. After constructing the portfolio, the model is used to derive the Greek-delta within each trading day and hedged. The results of the study show that the delta-neutral strategy is less effective on meme stocks, compares with the delta-neutral hedging results for other core stocks of index. This study will help investors understand the feasibility of delta-neutral hedging strategies on meme stocks.

Keywords: Hedging strategy; delta-neutral hedging; Black Scholes; implied volatility.

1. Introduction

Hedging strategies ensure that investments are prepared to against risk and maintain profits in volatile markets by trading the corresponding financial products in the opposite direction. Among the many trading strategies to hedge market risk, hedging through derivatives is one of the practical ways to reduce risk [1]. Nowadays, hedging strategies are widely used by individual investors as well as asset management firms to mitigate risk without significantly reducing the returns [2]. To date, researchers have done much research on hedging strategies for financial derivatives, for example, Galai [2] analyzed the payoff components of hedging options against stocks. And Platen and Schweizer provide a new interpretation of the smile and skewness effects in implied volatility from hedging derivatives [3]. Also, Bakshi, Cao and Chen compare the pricing and hedging of short-term and long-term stock options [4], and Kumar investigate the efficacy of option Greeks and their significance in risk hedging strategies [5]. In addition, Mark and Ashish conducted further research on pricing and hedging derivatives of volatility, building a complete pricing and risk management model [6].

As the number of individual investors and their influence in the stock market grows. a forum on reddit called r/Wallstreetbet are formed, where individual investor discusses and forecast stocks, making many stocks, also known as meme stock, become more attractive for individual investors to follow and invest money in. Bradley's research found that individual investors had a high success rate in forecasting meme stocks between 2018 and 2020, however, with the GME short squeeze happening in 2021, more new users join the forum in 2021, meme stocks experience greater volatility and forum predictions become less accurate [7]. In addition, Charlie and Ben conducted a more detailed analysis of r/Wallstreetbet users' comments to predict the future movement of meme stock by using investors' sentiment towards the stock [8]. However, the results of the study showed that individual investors' sentiment do not have a strong relationship with stock price movement. Therefore, investors who hold the meme stock with the high volatility that caused by individual investors need to employ hedging strategies to ensure that their portfolios are not overly influenced.

In this study, GameStop's stock (GME) is selected as the underlying to test the delta-neutral hedging strategy, which features in the short squeeze event in 2021 and is one of the most followed meme stocks by individual investors in the r/Wallstreetbet forum. Since the activity of individual investors' attention on meme stocks is maintained for a short period of time, the study will test the delta-neutral hedging strategy in the short-term using the Black-Scholes pricing model. By using

GME options data within the past one week, the daily GME options implied volatility is calibrated using a minimum square error approach and the Greek letters in the Black-Scholes model are referenced to execute a hedging strategy on the underlying. The results of the study show that the delta-neutral hedging strategy plays a small role in hedging meme stocks and compares favorably with the results of delta-neutral hedging strategies for other core stocks, such as the NASDAQ 100 constituents.

The paper is structured as follows. Section 2 shows the data and methodology. Section 3 mentions the results and discussion, and Section 4 concludes the paper.

2. Data

All the GameStop (NYSE: GME) stock and options data used will be obtained from Yahoo Finance(https://ca.finance.yahoo.com). To ensure that the data fits the short-term hedging strategy, the periodicity of all data collected will be limited to two weeks of trading date. For this purpose, daily data for five GME Call options and Put options from July 6, 2022, to July 22, 2022, will be used to calibrate the implied volatility of the options. At the same time, the closing price of GME stocks on July 22 will be used to determine the underlying options and prices chosen for the hedging strategy from July 25, 2022, to July 29, 2022. Some detailed information is shown below in Table 1, 2 and 3, respectively.

Table 1. The 10 options chosen for calibration

Call options chosen for calibration				
GME220722C00 119000	GME220722C00 120000	GME220722C00 121000	GME220722C00 122000	GME220722C00 123000
Put options chosen for calibration				
GME220722P00 119000	GME220722P00 120000	GME220722P00 121000	GME220722P00 122000	GME220722P00 123000

The GME stock data and movements during the calibration of the option implied volatility are shown below.

Table 2. The GME Stock price

DATE	**Open**	**High**	**Low**	**Close**
2022/7/6	$ 120.69	$ 122.28	$ 113.37	$ 117.43
2022/7/7	$ 124.49	$ 135.50	$ 121.81	$ 135.12
2022/7/8	$ 126.66	$ 132.67	$ 122.51	$ 128.54
2022/7/11	$ 128.56	$ 131.74	$ 124.65	$ 130.09
2022/7/12	$ 130.80	$ 142.59	$ 127.26	$ 137.12
2022/7/13	$ 135.00	$ 145.35	$ 135.00	$ 141.28
2022/7/14	$ 139.19	$ 151.95	$ 136.20	$ 136.20
2022/7/15	$ 139.44	$ 142.37	$ 134.03	$ 141.64
2022/7/18	$ 145.00	$ 149.60	$ 143.10	$ 146.64

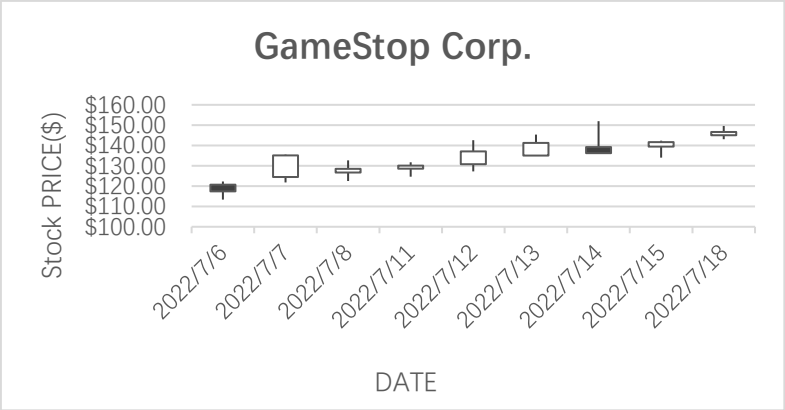

Fig. 1 Stock price trend for GME

Table 3. Descriptive statistics of GME

Indicator	Value
Mean	0.14873
Standard Error	0.02457
Median	0.15984
Standard deviation	0.07371
Variance	0.00543
Kurtosis	1.05868
Skewness	-0.86613

As can be seen from the chart above, the price of GME stock has been on the rise during the period from July 6, 2022, to July 18, 2022, influenced by the stock split as well as market sentiment, with large fluctuations taught during the period. The stock price rose $29.21 during the period, or 24.87%. Investors can still make profits while holding the underlying stock without hedging. The Investor holding the short position would be substantial losses without hedging. In addition, when pricing options using the Black Scholes model, the federal funds rate, will be used as the risk-free rate in the model.

3. Method

The Black-Scholes model initiated modern financial theory based on the no-arbitrage principle. Its development has led to a wealth of research that has revolutionized financial practice. This model was developed under the assumption that the underlying stock of an option follows a geometric Brownian motion and can be described by the Ito process [9-10]. The model extrapolates the unique price of the option under the specific situation. In addition, it is used to derive option Greeks to construct a portfolio of hedge assets to eliminate risk.

Suppose that the price of a security is governed by the geometric Brownian motion process and the interest rate is r. A derivative of this security has a price f(S, t), which satisfies the partial differential equation:

$$\frac{\partial f}{\partial t}+\frac{\partial f}{\partial S}rS+\frac{1}{2}\frac{\partial^2 f}{\partial S^2}\sigma^2S^2=rf \tag{1}$$

The Call option price:

$$C\big(t,S(t)\big)=S(t)N(d_1)-Ke^{-rt}N(d_2) \tag{2}$$

The Put option price:

$$P\big(t,S(t)\big) = Ke^{-rt}N(-d_2) - S(t)N(-d_1) \tag{3}$$

Where:

$$d_1 = \frac{1}{\sigma\sqrt{(t)}}\ln\left(\frac{S(t)}{K} + \left(r + \frac{\sigma^2}{2}\right)t\right) \tag{4}$$

$$d_2 = \frac{1}{\sigma\sqrt{(t)}}\ln\left(\frac{S(t)}{K} + \left(r - \frac{\sigma^2}{2}\right)t\right) = d_1 - \sigma\sqrt{t} \tag{5}$$

where σ is the volatility. In this study, the implied volatility calculation method is used. Implied Volatility (IV) is the volatility value that derived by substituting the option actual trading price in the market into the theoretical Black-Scholes model, and this value reflects the level of uncertainty or risk perceived by traders. In the Black-Scholes model there exists a quantitative relationship between all of the five fundamental variables (K-underlying stock price, S-strike price, r-interest rate, T-time to expiration, σ- implied volatility), from which the unique unknown variable can be solved as long as four of the other parameters are available. In this study, the only unknown variable is volatility(σ), which can be inferred from the other known variables observed from the market.

In this study, the actual market data (K, S, r, T) for the selected 10 underlying options from July 6 to July 22 and the actual option market price C are used to perform the calculation of implied volatility. Theoretically, the implied volatility of an option is not supposed to be affected by time. In this study, implied volatility of the option needs to be set consistent from day to day. Because of the daily vagaries of the market, the implied volatility inferred from the formula alone is in error with the actual price when calculating each option price, the minimum sum of squares error method can be used to calibrate the implied volatility.

In practice, the squared error formula is calculated by the square of option theoretical price minus option market price divided by option market price, and the sum of squares error is the sum of the squares error for each day. Since the option theoretical price formula includes the unknown variable-implied volatility, the value of implied volatility can be captured by changing it with an exhaustive approach and take the value when it meets the minimum of sum of squares error.

After calibrating the implied volatility, its data is used to perform option price as well as Greeks for hedging. In the hedging process, data are collected for stocks and underlying options from July 25, 2022, to July 29, 2022. The Black-Scholes model and calibrated implied volatilities are then used daily to calculate option prices as well as Delta. The hedged portfolio consists of one call option, and several underlying stocks equal to the number of deltas. On a daily basis, the latest delta value is compared with the previous day's delta value, and the corresponding stocks are sold or purchased to ensure that the portfolio remains delta neutral. The following formulas can be used each day to compose the portfolio value, the loss/profit without hedging, and the loss or profit with hedging:

Day 1:

$$Portfolio\ value\ (t) = C(1,S(1)) \tag{6}$$

Day 2-5:

$$Portfolio\ value\ (t) = portfolio\ value\ (t-1) + N(d_1)(S(t) - S(t-1)) \tag{7}$$

$$Loss\ without\ hedging(t) = S(t) - K - C\big(1,S(1)\big) \tag{8}$$

$$Loss\ with\ hedging(t) = S(t) - K - portfolio\ value(t) \tag{9}$$

4. Results and Discussion

4.1 Results

In practice, the sample data was collected for options from July 6 to July 22, and the daily data for implied volatility calibration by using the minimum sum of squared errors formula are shown below.

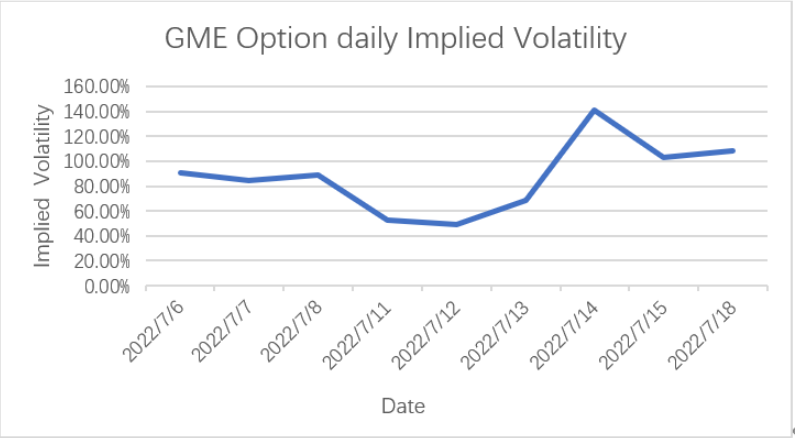

Fig 2. GME Option daily Implied Volatility

As shown in the figure above, the implied volatility of the options was highly fluctuated between July 12 and July 15, with a low of 65.59% and a high of 141.16% during the calibration period, for an overall average daily volatility of approximately 16.73%. This implied volatility was used to calculate and compare the theoretical prices of the selected options on a case-by-case basis. Take the option that expires on July 22 with a strike price of $119 as an example. The theoretical price and the actual price are shown in the table below.

Table 4. Theoretical and actual call prices of GME

Theoretical Call Price	Actual Call Price
8.17	7.50
19.05	17.20
14.24	15.30
14.00	15.95
18.79	16.85
22.65	16.85
21.38	16.85
23.51	16.85
27.85	30.10

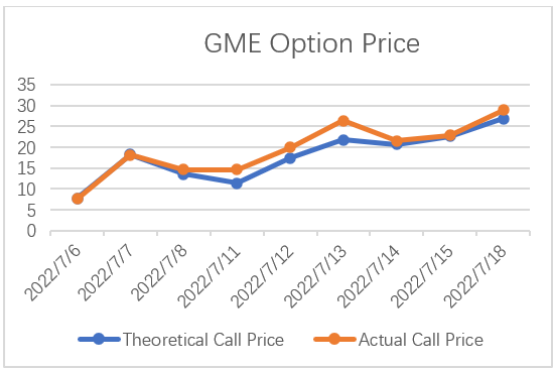

Fig 3. Theoretical and actual prices

The average squared errors between the actual price and the theoretical price of the five corrected call options is approximately 0.8003. Some of the options have low trading volume, resulting in a higher degree of deviation from the theoretical value for the actual price of the options on individual dates, and the average variance is approximately 0.1657 after excluding such low trading volume option data.

During the calibration period, 1 GME stock was split to 4, and all the underlying prices will be changed to one-fourth of the original price. With reference to the closing price on July 22, the options with a strike price of $35.75($143 before split) were selected to measure the delta in combination with the calibrated implied volatility, and the results of hedging by using these data is shown below.

Table 5. Portfolio Overview

Date	Stock Price	Option Price	Delta	Portfolio
2022/7/25	33.98	0.78	0.3381	0.78
2022/7/26	32.43	0.25	0.1676	0.25595
2022/7/27	33.78	0.28	0.2186	0.48221
2022/7/28	33.84	0.08	0.1146	0.49532
2022/7/29	34.01	0.03	0.0612	0.5148

According to the calculation, the profit with hedging is -2.25, while the result of not hedging is -2.52, which implies that with hedging, investors can reduce their losses by 11.9%.

4.2 Discussion

In summary, hedging strategies do not significantly reduce investor losses in the short term when facing meme stocks with delta hedging strategies, but investors still have the opportunities to use delta hedging to reduce potential risk compared to the absence of hedging.

In delta hedging strategies for conventional large index stocks or ETF, such as Apple, S&P 500 ETF, and other underlying stocks, delta hedging strategies can reduce up to higher than 90% of potential losses for investors, allowing them to maintain a relatively stable net value of their assets in a volatile market. However, as a meme stock, GME has relatively small options market volume, although its daily volume has exceeded $100 million with individual investor participation. As demonstrated earlier, GME 's options often deviate significantly from the theoretical price due to low volume, which also creates potential arbitrage space for investors. However, this goes against the no-arbitrage assumption established by the Black-Scholes-Model, which also leads to a large divergence between the calculated implied volatility, the theoretical price, the historical volatility, and the actual price, which in turn leads to a certain error in the judgment of the delta value. All these factors will affect the calculation in the hedging strategy.

5. Conclusion

This study tests the practice of delta-neutral hedging strategy in short-term meme stocks. Since meme stocks are highly followed by individual investors in the market, their high volatility exposes investors' portfolios to a large amount of potential risk. Therefore, in this study, GME, the stock with the highest retail investors' attention, was selected as the underlying, and use the delta-neutral hedging strategy to reduce portfolio losses. Since individual investors are more active in the market in short periods, the data period chosen for the study is between one and two weeks, which is in line with the research direction and the topic. After obtaining the data on stocks and options, the implied volatility of the options is calibrated, and the delta of the options is calculated. The daily delta data is then referred to buy or sell stocks to maintain the overall portfolio delta and reducing the portfolio losses. At the end of the study, the data results show that the delta-neutral hedging strategy achieves the goal of reducing losses on meme stocks. However, the delta-neutral hedging strategy does not perform as well compared to other core stocks, such as the NASDAQ 100 constituents. The main reason for this

phenomenon is that the options market for meme stocks is not active and some options are traded at prices that deviate significantly from the theoretical price. These deviations also lead to potential arbitrage opportunities in the market, which also violates the assumptions of the Black-Scholes-Model. Therefore, the Black-Scholes option pricing model generates errors in the application of options on such meme stocks. More research is needed on hedging strategies and pricing model for such meme stocks to ensure that the portfolio can cope with the potential risks.

References

[1] Petersen, M. A., Thiagarajan, S. R. Risk measurement and hedging: With and without derivatives. Financial Management, 2000: 5-29.

[2] Galai, D. The components of the return from hedging options against stocks. Journal of Business, 1983: 45-54.

[3] Platen, E., Schweizer, M. On feedback effects from hedging derivatives. Mathematical Finance, 1998, 8(1): 67-84.

[4] Bakshi, G., Cao, C., Chen, Z. Pricing and hedging long-term options. Journal of econometrics, 2000, 94(1-2): 277-318.

[5] Kumar, A. A Study on Risk Hedging Strategy: Efficacy Of Option Greeks. Abhinav National Monthly Refereed Journal of Research in Commerce & Management, 2018, 7(4): 77-85.

[6] Broadie, M., Jain, A. Pricing and hedging volatility derivatives. The Journal of Derivatives, 2008, 15(3): 7-24.

[7] Bradley, D., Hanousek Jr, J., Jame, R., Xiao, Z. Place Your Bets? The Market Consequences of Investment Research on Reddit's Wallstreetbets. The Market Consequences of Investment Research on Reddit's Wallstreetbets, 2021

[8] Wang, C., Luo, B. Predicting $ gme stock price movement using sentiment from reddit r/wallstreetbets. In Proceedings of the Third Workshop on Financial Technology and Natural Language Processing, 2021: 22-30

[9] David G. Investment Science. Oxford University Press, 2017

[10] MACBETH, James D., MERVILLE, Larry J. An empirical examination of the Black-Scholes call option pricing model. The journal of finance, 1979, 34.5: 1173-1186.