Monte-Carlo Stimulation for European Rainbow Call Options BASED on Meta and NEM's Case Study

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Abstract. Recently, investors have paid great attention to the metaverse sector and the investing instruments for metaverse. Metaverse has become the most popular investment sector since 2021. Due to the rapid development of the industry, coupled with the social instability, it is critical to search for the appropriate investment. Previous literature proposed many advantages of the rainbow options and the expected growth of the metaverse industry. However, there is currently a lack of research on the combination of metaverse assets and the rainbow options. Based on this, this paper chooses the stocks of the metaverse enterprise META and the gold enterprise NEM as the safe-haven asset to construct a two-color European rainbow call options and chooses yahoo Finance's transaction data and excel and python as analysis software. The rainbow options return is given by Monte Carlo simulation method, and complete sensitivity analysis of the four parameters. At the end, the pros cons of rainbow options are compared. Besides three findings are obtained, including that options have cost advantages, could gain return from the market volatility by changing the portfolio, and have sharp peaks and thick tails in the distribution.

Keywords: Metaverse, Rainbow options, Monte-Carlo stimulation, Distribution.

1. Introduction

Getting benefit from the popularize of XR (extended reality) devices such as VR (virtual reality) and AR (augmented reality), the rapid progress of 5 and 6th Generation Mobile Communication Technology, the gradually development of the blockchain, nft (non-fungible token), metaverse now attracts all of world investors' vision by through combining them with IOT (Internet of things) and DeFi(decentralized finance)together. Thus, metaverse became the most charming section to invest. According to the IDC issuing latest report, it showed that the global VR/AR head set market's shipment volume increased to 11.23 million sets, and its annual growth rate was up to 92.1%, which indicated the flourishing Metaverse market. Besides, APPLE, TESLA et al well-known enterprises sequentially entered into the market, instilling the vigor into it. According to the growth markets report, the metaverse market size would be expected to reach $659.7 billion in 2030 and would be 17.4 times than the 2020's metaverse market size which revealed there still existed immense areas for global metaverse participants. As the traditional tech giant company, Zuckerberg, Facebook CEO, aimed to transform Facebook as a media company into Meta company and in the meantime intergrate its products like Facebook, Instagram to a metaverse platform so that Facebook changed its name to Meta in 2021.What's more, the action also contains the Zuckerberg ambition to play a pivotal role in metaverse market. Based on it, the paper considers the metaverse section as an appropriate investing project. Furthermore, choosing the Meta on behalf of metaverse industry attributed to 2 reasons as follows. The first reason is active unique visitors. According to motley fool, the widespread media apps under META, Facebook, Facebook messenger, WhatsApp and Instagram have totally exceeded 3.65 billion active monthly visitors at June-ended quarter. Especially, according to statista, the Instagram, which charmed the young most, had over 50 million daily active users. Secondly, META had a veteran and vital status in the metaverse industry as the largest VR device provider. In the first quarter of 2022, the products of Meta's subsidiary Oculus accounted for 90% of the global VR devices. At this time, Meta is at the core of the entire Metaverse industry and has commissioned Analysis Group to publish The Potential of Global Economic Impact of the Metaverse, including 4 parts, the applications and challenges of the Metaverse, the similarity between mobile device technology and

the Metaverse, and the use of economic models to study the impact of mobile devices on global GDP and the potential economic market for the metaverse.

The world has been suffering from the covid-19 pandemic since 2020, and other diseases such as monkeypox are also spreading globally from regional epidemics. With the Fed's hawkish policy of reduction credit line and continuously raising interest rates, consequently the market liquidity was tightened, and interest rates have inverted, which denoting that people were skeptical about future economic development. Meanwhile, the haze of the Russian-Ukrainian war not only hanged over the European energy industry but also shrouded every walk of life. At this period, common safe-haven assets such as gold and crude oil were more likely to be favored by investors. In addition, although the metaverse industry is developing rapidly, it is still in the stage of investment and growth, and it cannot generate profits in short term. Short-term investment may suffer great losses. (For example, figure 1 has experienced violent fluctuations recently). Moreover, metaverse-related concepts such as decentralization are easily subject to serious policy supervision, and may even be resisted by the government; it is worth mentioning that the brain-computer interface technology of Neutral link may also be a path to develop. However, it also may pose a threat to enterprises that have entered the metaverse market, causing losses to investors who haven't holden diversified unsystematic risk.

In 2015, Schwab, the chairman of World Economic Forum prospected a wonderful vision of people being capable to move freely within virtual reality in future. With the metaverse developing, the vision gradually became a reality. Walker (2021) described metaverse as a shared online 3D virtual space [1,10]. As a parallel space of the reality, the functions of metaverse are also extensive. Currently the metaverse play a pivotal role in medicine, especially for chronic disease and emergency medicine including the famous telemedicine company American Well Corp and Teladoc actively investing this part [2,3]. Besides, the application of the metaverse also makes an active role in education [4], and the transportation system will also transition into the metaverse [5]. In order to occupy the appropriate place before the metaverse becoming an independent space parallel to the real world, technology companies (APPLE et al.) and social platforms (META et al.) are actively entering the game and investing to construct the metaverse [1].

Combining the derivatives with Internet technology is a common phenomenon in the current financial market like virtual currency futures. Alexander et al. (2022) made a study on the improvement of the liquidation mechanism of bitcoin futures [6]. Just like Bitcoin, the metaverse, which also originates from the Internet technology, could be speculate to combine with derivatives as well. Based on this, this article attempts to construct a European rainbow call option. The rainbow options are a kind of innovate multi-asset exotic options, its profit or loss depending on certain asset which usually could be called colors in the portfolio. Rainbow options are constantly changing and developing so that they couldn't be clearly classified and analyzed at present. However, the academic circle also conducts continuous research on rainbow options. Boen (2020) presented a semi-closed rainbow options priced formula under Merton jump-diffusion model [7]. Byström (2002) following the Gibson and Boyer (1998) stimulated rainbow options price to evaluate and compare the results of 5 kinds of methods' covariance matrix [8]. While Monte Carlo simulation is a frequently used method to deal with arithmetic Asian rainbow options, Ahmadian et al. (2022) adopted Monte-Carlo method for pricing arithmetic Asian rainbow options [9]. By summarizing the literature, it still exists a large amount of blank of the combination of metaverse and derivatives. According to it, the article chooses Monte-Carlo approach for pricing two-color of European rainbow call options.

To ensure the liquidity of the assets prohibiting the corporate cash flow long-term lock-up, and meanwhile to avoid the individual stocks' loss caused by those companies' poor management level and decision-making mistakes as well as extreme situations occur such as economic or political crises, the fairly new two-color European rainbow call options constructed in this paper selects the gold company NEM stock as the safe-haven asset of META stock, and selects the latest single stock price as the delivery price of the stock. And through the method of Monte Carlo simulation, the price of the option's return is also given. This study helps to improve the research value of rainbow options, besides, and helps to enrich the literature research in this field.

The rest of this paper is organized as follows,section 2 introduces the data and method. Section 3 shows the results. Section 4 discusses the pros and cons of European rainbow call options, section 5 concludes.

Fig 1. META Adj-Closed Volatility

2. Data and Method

2.1 Data selection

This article used two-color European rainbow call options. The underlying assets were shares of META and NEM, respectively. Select 278 transactions from 2021-06-29 to 2022-08-04 to adjust the adjusted closing price of U.S. stocks and calculate its return rate. The data source is Yahoo!Finance.

2.2 Method

2.2.1 Options pricing formula

Two-color European call rainbow options pricing formula are as follow according to the Monte-Carlo method and Black-Scholes pricing model.

$$C_{rM} = CF \times \frac{1}{i}\sum_{i=1}^{n} \max\left(\frac{S_{1_T}{}^{i} - S_{1_0}}{S_{1_0}}, \frac{S_{2_T}{}^{i} - S_{2_0}}{S_{2_0}}, 0\right) \times e^{-rT} \tag{1}$$

Where S_0 represents the latest stock price (the article chooses the 2022/08/04); S_1 , S_2 individually represents the single stock price; T represents maturity; CF represents the investor holds the cash flow to invest the options.

2.2.2 Monte-Carlo stimulation

Step1: Simulate the price path under the risk-neutral assumption

$$S_T = S_0 e^{(\alpha - \frac{1}{2}\sigma^2)T + z_1{}^{i}\sigma\sqrt{T}} \tag{2}$$

where,

$$\alpha = r - \delta \tag{3}$$

$$z_1 = normsinv(rand(\,)\,) \ , \ \ z_2 = \rho z_1 + normsinv(rand(\,)\,) \times \sqrt{1-\rho^2} \tag{4}$$

this research set the Parameter that S_0 equals to the stock price at 2022/08/04. α, denoting the expected yield, equals to risk-free rate(r) minus δ(dividend yield).δ, is equal to the weigh mean of

dividends divided by the current price. σ, stock's yearly volatility, equals to daily volatility's square root times the whole year's trading days.The daily volatility is calculated by excel's stdev function and the trading days are usually 252 days, one year. ρ means correlation coefficient. r, risk free rate, equals to One-year U.S Treasury Securities. T, maturity, is assumed to hold one year.

Table 1. Parameters Explainnation

S_0	170.57		45.28
δ	0.00		0.01
σ	0.52		0.33
CORR		-0.02	
r		0.03	

Step2: According to Formula(2),stimulate the stock prices of Meta and NEM.

Step3: Calculate the two-color European rainbow call option return under the risk-neural assumption

$$C_r^{*i} = \max\left(\frac{S_{1_T}{}^i - S_{1_0}}{S_{1_0}}, \frac{S_{2_T}{}^i - S_{2_0}}{S_{2_0}}, 0\right) \tag{5}$$

Step4: Replicate Step2 and Step3 until getting 1000 times

Step5: Get the average of the result of Step4

$$C_{r\,M}^{*} = \frac{1}{i}\sum_{i=1}^{n} \max\left(\frac{S_{1_T}{}^i - S_{1_0}}{S_{1_0}}, \frac{S_{2_T}{}^i - S_{2_0}}{S_{2_0}}, 0\right) \tag{6}$$

Step6: According to Formula (1), calculate the present value of two-color European rainbow call option return.

3. Result

3.1 Monte-Carlo stimulation results

The Monte Carlo simulation results are shown in Table 2. When simulating 50 times and 100 times, the options yield is approximate 0.35. As the number of Monte Carlo simulations increases gradually, the results of 250 times and 500 times fluctuate between 0.32 and 0.33. When the simulation times reaches 1000 times, the options yield is still approximate 0.32. Hence the return of the European call rainbow can be considered to be 0.32 and its present value is 9434016.05. In conclusion, the option is held with a one-year yield of 32% and a reasonable option expense ratio of 31% (equals to the present value divided by cash cost)

This article used two-color European rainbow call options. The underlying assets were shares of META and NEM, respectively. Select 278 transactions from 2021-06-29 to 2022-08-04 to adjust the adjusted closing price of U.S. stocks and calculate its return rate. Data source: Yahoo!Finance

Table 2. Stimulation Results

50	0.35	10071302.92
100	0.35	10031385.29
250	0.32	9342675.42
500	0.33	9677600.88
1000	0.32	9434016.05

Table 3 also shows the result of calculating the European call option return holding the same period,just one year through the Monte Carlo simulation above. The result shows that the European call options which underlying asset is META has the return yield of 0.23 and NEM has the return yield of 0.14. Compared with the results in Table 2, any single European call option is less than the expected return of the rainbow option. The sum up of both is 0.37 greater than the expected return of the rainbow option. From formula 1, it can be seen that because the rainbow options has the advantage of obtaining the maximum return of the two individual European call options, so its return is better than any European call option of the portfolio. In contrast with longing European rainbow call options,the cost is less than buying two European call options together at the same time. This is because if it is greater than the sum of the prices, the investor will not choose to buy the rainbow option but directly to buy the European options. It reflects the cost advantage of this rainbow options.

Table 3. European call options yield

META	0.23
NEM	0.14

3.2 Sensitivity Analysis

3.2.1 Volatility

Taking volatility to do sensitivity analysis, the results are shown in Figure 2, and there is a positive correlation between returns and volatility. Volatility represents the risk of an asset. In other words, the risk is uncertainty, which means uncertainty of probability distribution. The standard deviation is often used as a measure to represent the average deviation from the expectation. As shown by Figure 3, the article makes the standard normal distribution through numpy in python. The higher the volatility, the higher the deviation from expectations and the higher the probability of falling into the tail. For the call options holder, the holder has the right to decide whether to exercise in the future. Holders of call options are delighted to see higher volatility. Besides, falling into the tail means excess gain or loss. Since the return of the long side of the option is always positive, the higher the volatility, the higher the return. Therefore, volatility is positively correlated with asset prices.

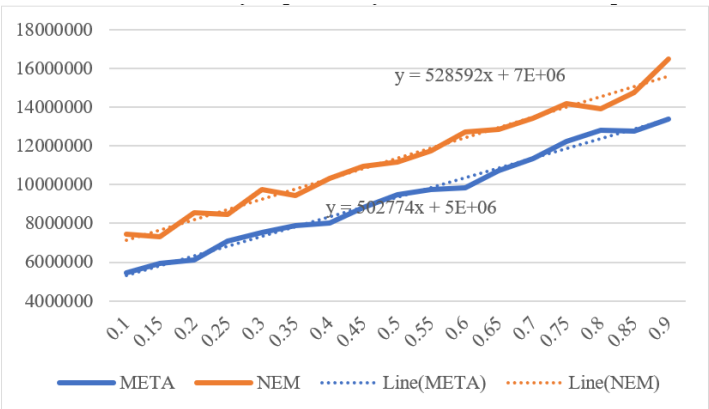

Fig 2. Volatility Sensitivity

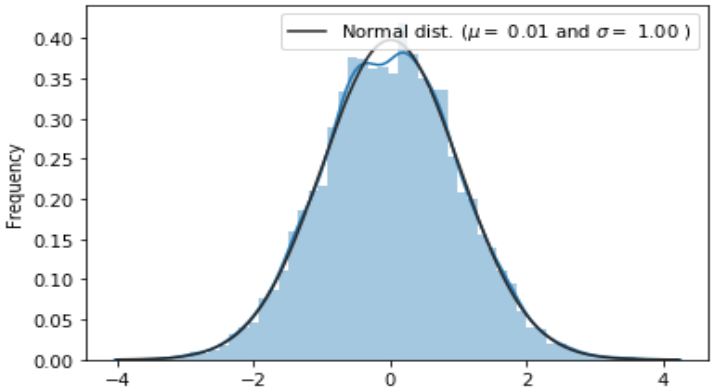

Fig 3. Standard Normal Distribution

3.2.2 Correlation

In this article, the correlation coefficient is used to represent the correlation. And the sensitivity analysis results of the correlation, as shown in Figure 3, reveals that the relationship between correlation coefficient and the rainbow option returns is negative. In order to explain the reasons in detail, this article elaborates the reasons through the single-exponential model.

Single-index model,

$$r_i = E(r_i) + \beta_i r_M + e_i \tag{7}$$

The correlation coefficient,

$$Corr(r_i,\ r_j) = Corr(r_i,\ r_M) \times Corr(r_j,\ r_M) \tag{8}$$

The results of the correlation coefficient of two different assets are shown in Table 4. If the correlation coefficient between individual stocks is positive, it means that the product of the correlation coefficient between the individual and the market is positive, indicating that both of the individual's volatility direction are consistent with the market volatility direction. There are many familiar market index such as the S&P 500 and the Nasdaq index et al.. According to formula 1, the rainbow option has the characteristics of obtaining the maximum positive return within the portfolio. Choosing two assets with negative correlation coefficients, such as META and NEM stocks, generally speaking, if the economic environment was down, the safe-haven asset NEM would rise and META would fall; if the economic environment was up, Meta would rise and NEM would fall, but there is still always an asset with a positive return, and the rainbow options could still get a positive return. Conversely, if the options correlation coefficient is positive, then the two assets' volatility will move in the same direction against the market volatility and the investor can only gain returns in one direction. This reduces the optional value of rainbow options. The correlation coefficient is therefore negatively correlated with options return.

Table 4. $Corr(r_j, r_j)$ matrix

	$Corr(r_j, r_M)$ *is postive*	$Corr(r_j, r_M)$ *is negative*
$Corr(r_i, r_M)$ *is postive*	POSTIVE	NEGATIVE
$Corr(r_i, r_M)$ *is negative*	NEGATIVE	POSTIVE

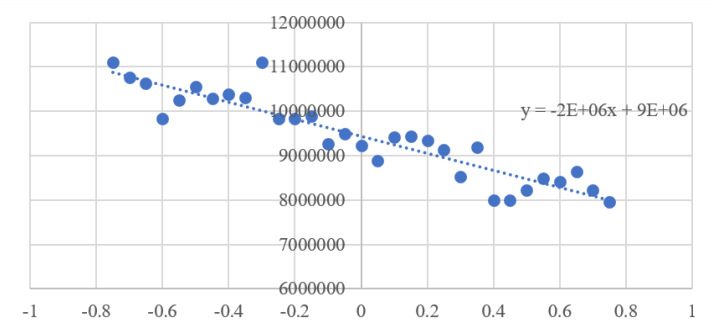

Fig 4. Correlation Sensitivity

3.2.3 Risk-free rate

The sensitivity results of risk-free rate are shown in Figure 5. There is a positive correlation between the risk-free rate and the return of the rainbow options. It can be explained mainly by two points:

Firstly, under the risk-neutral assumption, the expected return of stocks is equivalent to the remainder of the risk-free rate and the dividend rate. Hence the higher expected rate of return often companies with the increasing risk-free rate, which leads to the higher return of the rainbow options naturally under the condition that the dividend rate is fixed. Secondly, the higher the risk-free rate means the higher the discount rate so that the present value of the asset is lower. At the same time, the continuous rising risk-free interest also reveals that the Fed is now implementing a hawkish policy and the dollar is entering a strong period causing the economy away from the bullish side and people are pessimistic about investing the risky assets such as stocks and real estate and resulting in lower prices for those assets. The long position of call options means have the right to delay the time to buy underlying asset in the future and not happen at once, so extending the asset into the future could avoid interest rate risk caused by the Fed and losses caused by people's pessimism, so it is positively correlated.

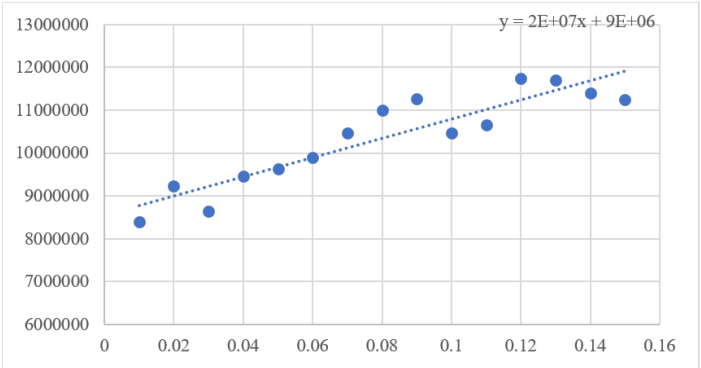

Fig 5. Risk-free rate sensitivity

3.2.4 Maturity

The maturity sensitivity results are shown in Figure 6. The relationship between rainbow options return and maturity is not a simple linear relationship, but a polynomial relationship. Gradually increase the polynomial coefficients and record the Goodness of fit, as shown in Table 5. R^2 is significantly improved when the highest term is increased from 2 to 3. After reaching 3 times, R^2 = 0.9813, which could already fit the curve well. Moreover, continuing to increase the highest order coefficient, R^2 is not significantly improved. Therefore, it is considered that i equals to 3. Because options value equals to the sum up of intrinsic value and time premium, in general, without other conditions changing, the time from expiration is longer leading to the greater time value. When the expiration date is 0, it is considered that the options has missed the exercise time and the holder has no value; however, focus on the options' return also needs to consider the present value of the option.

When the expiration is longer, the present value is lower for the reason that the risk-free is almost positive nowadays. What's even more, when the expiration date tends to infinity, the option is considered to lose the possibility of exercising, so the option does not have any value, hence the return is 0. And because the return is always positive and both of starting and ending are zero so that the figure6 presents an image of rising first and then falling as below.

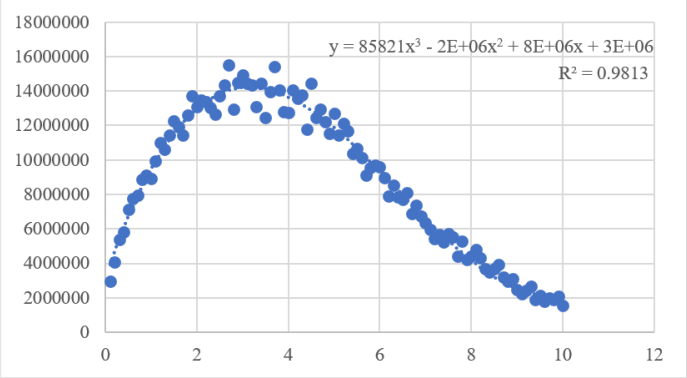

Fig 6. Maturity Sensitivity

Table 5. Highest-order coefficient and R^2 (Goodness of fit)

2	0.8359
3	0.9813
4	0.9824
5	0.9825
6	0.9831

4. Discussion

4.1 Pros

European rainbow call options on META and NEM stocks are a very suitable instrument for current investors. The main advantage is presented in two aspects. The first is the advantage of the options itself compared with buying stocks directly and the other derivatives like futures. Whatever futures and the stocks,the investors straightly get profit or loss due to the fluctuation of the underlying assets in financial market and suffer from the losses totally confronting the price dropping. In contrast with them, the long position of the options can control the loss for the maximum loss is just to pay the option fee and not exercise it which means the options could control the losses .Thus in the case of obtaining excess returns on individual stocks, the investors could get away from the risk to face the excess loss and even keep safe within the Black swan incidents. The second is that European rainbow call options have a price advantage over European vanilla call options, which are lower than the sum of the colors of European call options. In addition, it can be seen from the sensitivity analysis that when the correlation coefficient of the two underlying assets is negative, no matter which direction the market fluctuates, the European rainbow call option can obtain positive returns. It shows that the long position of the rainbow options can get the benefits brought by frequent market fluctuations.

4.2 Cons

It's of vital importance to concern that European rainbow call options don't always bring investors extra benefits compared with the cost. Although no matter how the market fluctuates, European rainbow call options could still get positive returns by transferring the portfolio's assets. However,

when investors could make clear predictions about the Business Cycle, or when investors are in a clear business cycle that most of the economic participants could make homogeneous expectations, rainbow options cannot not only magnify the benefits by predicting the economic cycle, but also show the cost advantage over single European call options if the invest just buys one. The distribution map drawn by python's pandas is shown in Figure 7. It can be seen that the European call rainbow option doesn't conform to the standard normal distribution. Skew and Kurtosis are calculated from stats. The SKEW is 2.66 denoting the distribution of rainbow options is positively skewed. Thus most points fall on the left side of the distribution; The kurtosis equals to 10.93, indicating that the distribution has the characteristics of sharp peak and fat tail causing that the more probabilities spreads out in the tails. The LSTM neural network is an algorithm commonly used to predict time series. The simulation result is shown in Figure 8 generated by LSTM. It can also be seen that the true value deviates far from the predicted value, which confirms figure 7 results. From the distribution, it can be seen that the European call rainbow options has the characteristics of positive skewed sharp peak and thick tail. Compared with the normal distribution, the probability of the distribution falling on the left side of the distribution is higher. Therefore, when investing, it cannot be regarded as an asset with stable returns (such as interest bonds, stable dividend stocks et al.), but as a special asset under frequent market fluctuations. If there are obvious signs in the market, or investors can make convincing and correct expectations about the future economic trend, the investors should not hold too much.

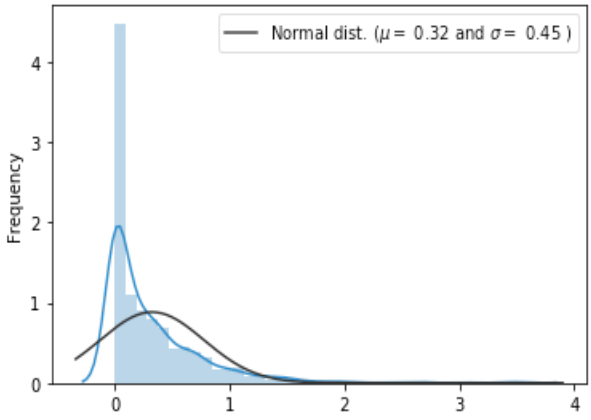

Fig 7. Distribution

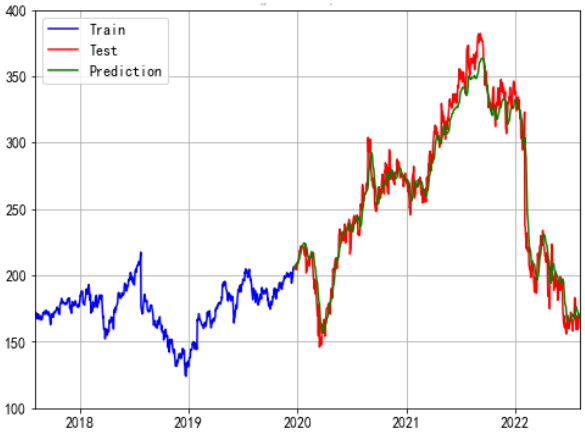

Fig 8. Meta Adj-Close LSTM Prediction

5. Conclusion

In this article, Monte Carlo simulation method is used to study the pricing problem of two-color European rainbow call options, and a sensitivity analysis is also made. In the meantime, at last the article also discusses the pros and cons of this instruments. The main findings include as follows.

Firstly, the price of European call rainbow options has cost advantages rather than to buy European call options which have the same underlying asset separately; Secondly, whether the economy is going up or down, adjusting the portfolio always brings up the positive returns; the third is that the distribution of European rainbow call options has the characteristics of sharp peaks and thick tails denoting that the options' investors wouldn't pursue stable income.

There are several implications in this article inspiring the investors. In today's complicate economic and political environment, constructing a European rainbow call options combining stocks of the metaverse and gold industry, could get always positive return in the case of controlling the maximum loss, no matter which directions the future economy would go. If the future economy improve, the metaverse sector rises and the economy deteriorates for instance the current global runaway inflation, the safe-haven assets such as the gold sector can get positive returns. In addition, rainbow options cannot make use of investors' expectations to amplify returns. However, since the financial market itself is a highly open market, any regional emergency will quickly reflect in the stock market and change the investors' expectation. What's more, it is irrational to predict an efficient market based on historical data. Therefore, here is a new approach for investors to manage their finances, that is, they could construct their own two-color European rainbow call options by changing the portfolio of individual stocks in the industry and obtain infinite positive returns with fixed cost. This instrument will be favored by investors who are looking for capital appreciation.

However, the article still exists some limitations. Firstly, the two-color European rainbow call options selected in this article may not be sufficiently dispersed for the unsystematic risk among assets; secondly, referring to Formula (1), the delivery price is the latest adj-close price and in fact the issuers can change the delivery price of the stock casually. In future research, Cholesky decomposition can be used to select more assets to build the options' portfolio, and it can also be improved in future research by changing the delivery price, using new simulation methods et al.

References

[1] Stokel-Walker, C. (2021). Facebook is now Meta–but why, and what even is the metaverse?. New Scientist, 252(3359), 12.

[2] Thomason, J. (2022). Metaverse, Token Economies, and Chronic Diseases. Global Health Journal.

[3] Wu, T. C., & Ho, C. T. B. (2022). A scoping review of metaverse in emergency medicine. Australasian emergency care.

[4] Hwang, G. J., & Chien, S. Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. Computers and Education: Artificial Intelligence, 100082.

[5] Pamucar, D., Deveci, M., Gokasar, I., Tavana, M., & Köppen, M. (2022). A metaverse assessment model for sustainable transportation using ordinal priority approach and Aczel-Alsina norms. Technological Forecasting and Social Change, 182, 121778.

[6] Alexander, C., Deng, J., & Zou, B. (2022). Hedging with Automatic Liquidation and Leverage Selection on Bitcoin Futures. European Journal of Operational Research.

[7] Boen, L. (2020). European rainbow option values under the two-asset Merton jump-diffusion model. Journal of Computational and Applied Mathematics, 364, 112344.

[8] Byström, H. N. (2002). Using simulated currency rainbow options to evaluate covariance matrix forecasts. Journal of International Financial Markets, Institutions and Money, 12(3), 216-230.

[9] Ahmadian, D., Ballestra, L. V., & Shokrollahi, F. (2022). A Monte-Carlo approach for pricing arithmetic Asian rainbow options under the mixed fractional Brownian motion. Chaos, Solitons & Fractals, 158, 112023.

[10] Stokel-Walker, C. (2022). Welcome to the metaverse. New Scientist, 253(3368), 39-43.

[11] Rubinstein, R. Y., & Kroese, D. P. (2016). Simulation and the Monte Carlo method. John Wiley & Sons.