Barrier Option Pricing and Sensitivity Analysis Based on Facebook

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ABSTRACT

This article studies the up-and-in-barrier option pricing research based on Facebook. With the economic development, more and more people are willing to invest in the stock market or financial products. Among them, barrier option is a very common barrier option. The paper first introduces the characteristics of the barrier option and why the up and in barrier option was chosen. According to the features of the up and in barrier option, Facebook was selected as the target. Afterward, the Black-Scholes pricing model is used to price the barrier option. The simulation was be used for sensitivity analysis. The article shows directly that with the increase in volatility, the price of stocks is also rising. Also, when the strike price became higher, the option price became lower. Besides, the spot price also has a positive effect on the option price.

Keywords: *Barrier option, Facebook, Black-Scholes.*

1. INTRODUCTION

There are a lot of financial products and financial derivatives, including futures, options, and options of some nature. Among them, barrier options are very popular and characteristic financial derivatives. This article focuses on exploring barrier options, as well as the pricing and sensitivity of barrier options.
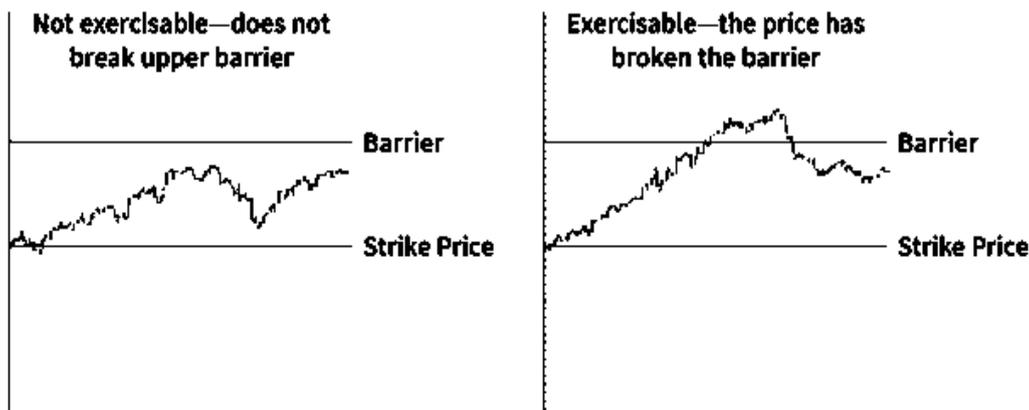

Figure 1. Barrier option model.

The barrier option is a branch of option. Set a value based on the ordinary option. When the target value touches this value, the barrier option will be triggered, and this value is the barrier value. There are two categories of barrier options.

(1) Knock-in barrier option: A knock-in option is an option effective automatically when the target asset price touches the barrier. The knock-in option can be divided into the down-and-in option and up-and-in option.

(2) Knock-out barrier option: A knock-out option is a knock-out barrier option, when the target asset

price touches the barrier, the option is automatically scrapped. The option with this feature was called a knock-out barrier option. The knock-out barrier option can be divided into a down-and-out option and an up-and-out option.

Since the up and in barrier option is the current mainstream barrier option and it is very popular in the market, this article will focus on the up and in barrier option. For the up and in barrier option, the definition is as follows.

Up-and-in options are a type of exotic option that is often made available through specialized brokers to high-end clients in the OTC markets. The option features both a strike price and a barrier level. As the name suggests, the buyer of the option will benefit once the price of the underlying rises high enough to reach (knock-in) the designated barrier price level. Otherwise, the option will expire worthlessly.

Many stocks continue to rise in the stock market, and consumers generally have a bullish attitude towards them. The up-and-in-barrier option is to set a barrier based on the strike price, which is greater than the strike price. When the stock price touches the barrier, consumers can trade a certain number of stocks at the strike price. If the stock price does not touch the barrier, the barrier option is invalidated.

There is much literature considering option pricing. Yao et al., establish a model to forecast the option prices of Nikkei 225 index futures which are carried out using backpropagation neural networks [1]. Diltz and Kim conduct an empirical study indicating that stock price changes adjust to lagged option price changes over two trading days [2-3]. Besides, other works also show the option price could be affected by strike price, the interest rate, and so on [4-7].

This article establishes facebook's option model based on the Barrier Option framework. A series of sensitivity analyses are also conducted to identify the different impacts to give investors essential investment suggestions. The remainder of the article is organized as follows. Section 2 presents the background of Facebook. In Section 3, we offer the model of the pricing barrier option. Section 4 introduces the sensitivity analysis based on different factors. Finally, we conclude the article in Section 5.

2. THE BACKGROUND OF FACEBOOK

Facebook is currently the world's largest social networking site. It was created by Mark Zuckerberg when he was studying at Harvard University in 2004 [8]. The original idea was to develop a website for college students to facilitate communication and contact. In 2006, anyone could take part in Facebook when they are over 13 years old and have a valid email address. Facebook hopes that users can contact their relatives and friends at any time, and users can learn about what is happening in the world through Facebook and strengthen their connection with the world [9].

Compared with the previous mailbox, Facebook provides users with greater openness and immediacy. Users can share the content they are interested in and their lives at the moment, and more people will see it. On the basis of providing communication, Facebook can bring more exciting openness to users. And though the user's friend list, Facebook will help users find their mutual friends, which can help users build a circle of friends faster and improve Facebook's sociality.

Facebook makes money predominantly by showing ads from advertisers within its Facebook and Instagram (Instagram is a subsidiary of Facebook, and Facebook completed the acquisition of Instagram on April 10, 2012). Advertising represented 98% of Facebook's $86bn revenue in 2020. The remaining 2% of revenue came mainly from selling Oculus and Portal devices and also payment fees from developers.

The historical data in the past two years of Facebook can be seen in Figure 2.

We find that the fakebook's stock price increases from Sep 2020 to Oct 2021. Although, there is a shock in the Oct 2021. Due to the stock price's risk, it is essential to make an option to hedge risk.

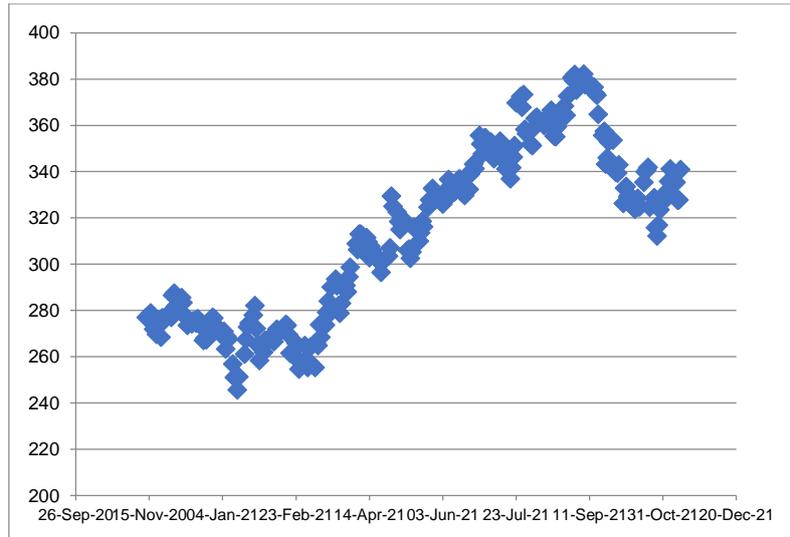According to the feature of the line chart of Facebook, it is suitable to make a barrier option.

Figure 2. Facebook's historical data

3. PRICING BARRIER OPTION

According to the Facebook stock data in the previous two years, the stock price has risen from 193 yuan to 340 yuan [10]. According to the nature of Facebook's company and the graph, I am bullish on Facebook's future stock price. So next, I plan to simulate a barrier option that knocks up and price it.

Table 1. The data description of the option price

standard deviation	0.01798944
correlation	0.55463497
annual volatility	0.28557356
volatility	0.28557356

According to the date of Facebook last year, It can be calculated the standard deviation is 0.01799. The correlation is 0.55463. The annual volatility is 0.2856. I set the strike price is 340 because the stock price of Facebook is 340.89. I made a simulation of the payoff 1000 times. And Average payoff is 35.957. And the normal average payoff is 38.924.

A digital simulation is needed to try to price barrier options.

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

Black-Scholes is a pricing model used to determine the fair price or theoretical value for a call or a put option based on six variables: volatility, type of option, underlying stock price, time, strike price, and the risk-free rate. When pricing barrier options, I chose the Black-Scholes option pricing model.

At first, I set the barrier value as 400, and the strike price as 340. Risk-free rate as 0.01%. Throw this formula, and the option price is 39.89.

4. THE SENSITIVITY ANALYSIS

4.1. Sensitivity about barrier price

Then, I wanted to find out what option price is related, so I made a simulation with different barriers from 340 to 830. Throw the simulation, and it can be found out that when the barrier price became higher, the option price became lower.
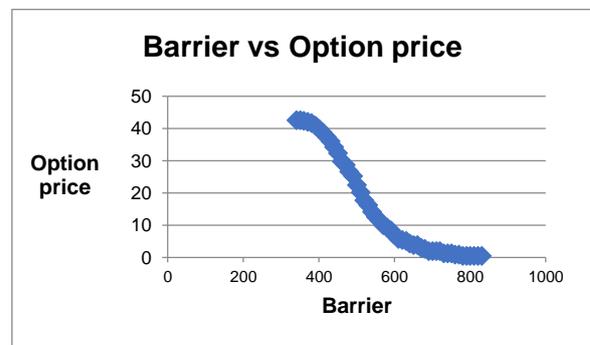

Figure 3. Barrier vs. Option price

4.2. Sensitivity about strike price

I want to find out the impact of strike price on the option price. I made a simulation that I made strike price from 290 to 485. It is clear to see from the chart below that when the strike price became higher. The option price became lower. Thus, we find that there is a negative impact between the option price and the strike price.
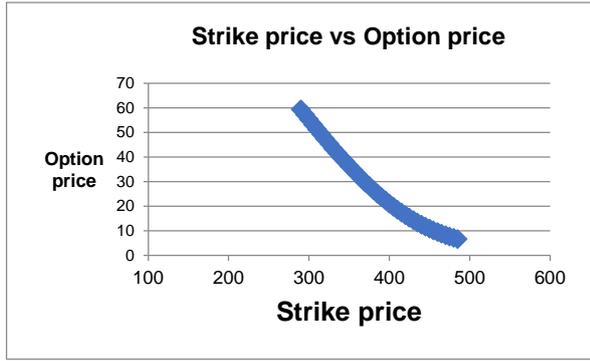
Figure 4. Strike price vs. Option price

This result can also be explained very well through logic. Through Facebook's historical data, it can be known that Facebook's stock has been rising all the time, so when consumers buy options, the smaller the strike price, the greater the profit it brings to consumers. Accordingly, the price of barrier options is also Higher. The barrier represents the difficulty with which the option can be exercised. When the price of the barrier is higher, the difficulty for the exercise of the barrier option is also more serious, so the price of the barrier option is also lower. The above digital simulation can prove this point well.

4.3. Sensitivity about option price

Due to the nature of barrier options, as long as the price of the stock hits the barrier before the trading day, the option can take effect. Therefore, I think volatility is also a very important factor affecting prices, I also conduct different volatility Digital simulations.
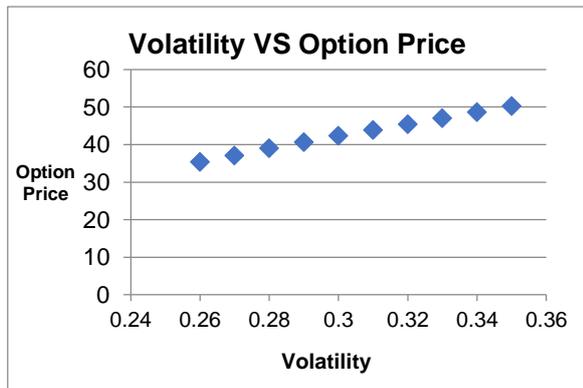

Figure 5. Volatility vs. Option price

As can be seen directly from the above picture, with the increase in volatility, the price of stocks is also rising. I think the higher the volatility, the greater the probability that the price of the stock will touch the barrier, and the more likely the barrier option will take effect. So the price of barrier options is higher

4.4. Sensitivity about spot price

Figure 6. Volatility vs. Option price

I did a digital simulation to understand the impact of spot price on the option price. It can be seen from the figure above, as the spot price rises, the option price is also rising.

5. CONCLUSION

This experiment can help understand the principle of barrier option and how to use Black-Scholes to price barrier option. Using digital simulation to calculate the sensitivity analysis of barrier options and barrier, strike price, volatility, and spot price can help understand the pricing method of barrier options. Lots of sensitivity analyses are researched in the article.

We identify the optimal option price of Facebook based on a barrier option. We find that volatility is also an essential factor affecting prices, which would improve the option's price. Moreover, when the spot price rises, the option price is also growing. These findings would give investors suggestions on how to make an investment decision.

The article's limitation includes that we do not consider the market index as the basic item for the option model. In the future, we would consider the S&P index to conduct research.

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