An option pricing model focus on spread based on the stock price of Eli Lilly and Novo Nordisk

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Abstract. Nowadays, the competition between Eli Lilly and Novo Nordisk is the epitome of the "two-man battle" in the global diet drug and diabetes treatment market. In this study, a European call spread option was designed to accurately capture the competitive dynamics between Eli Lilly and Company (LLY) and Novo Nordisk (NVO) in the GLP-1 diet drug market. By extending the Black-Scholes model and using Monte Carlo simulation, this paper quantifies the impact of spread volatility and correlation on the option value. The empirical results show that the model has flexible hedging and speculation functions in the high-volatility environment of the pharmaceutical industry, but it still needs to combine market expectations to deal with tail risks such as drug safety crises. At the same time, the model optimizes the calculation method of price spread and provides flexible hedging and speculation tools for investors. However, there are still limitations such as the failure to fully predict the disruptive changes of the market and the fact that the historical data may not fully reflect the future market trend.

1 Introduction

In today's financial market, as an important financial derivative instrument, option plays an irreplaceable role in risk management, investment strategy formulation and other aspects. Especially in the pharmaceutical industry, due to its stronger market volatility persistence and event sensitivity than some traditional industries, the demand for option pricing model is particularly urgent [1]. Spread options limit the risk exposure to a specific range through a portfolio strategy, and the return depends on the spread rather than the absolute price, so as to avoid the risk of single-direction bets. It is more suitable for the market with high volatility but uncertain direction, so as to carry out range trading or risk hedging under high volatility. This study focuses on the competitive dynamics between LLY and NVO in the GLP-1 diet drug market, and designs a European call spread option. The underlying asset of the option is the difference between the two stock prices, and the aim is to quantify the impact of the spread volatility and correlation on the option value by extending the Black-Scholes model and using Monte Carlo simulation.

Eli Lilly and Novo Nordisk are the global market leaders in diet drugs and diabetes treatment, and their core products are telpotide and semaglutide, respectively. Both drugs achieve weight loss and glucose reduction through the activation of the GLP-1 receptor, but

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telpootide additionally targets the GIP receptor, forming a dual-target mechanism that could theoretically enhance efficacy. This difference is reflected not only in the clinical performance of the products, but also in the performance of their stock prices. Therefore, it is of great significance to study the dynamic changes of the stock price difference between the two products, which helps investors better understand the market competition pattern and formulate corresponding investment strategies [2].

The significance of this study is to provide a new tool for capturing and quantifying the competitive dynamics between Eli Lilly and Novo Nordisk. By introducing the ratio of the initial price of the two companies, the price difference is defined as the LLY price minus the NVO price multiplied by the ratio of the initial price of the two companies. The empirical results show that this method can effectively narrow the price difference between the two companies and reduce the average, thus improving the accuracy of the simulation results. In addition, the study also highlights the flexible hedging and speculation function of the model in the high-volatility environment of the pharmaceutical industry, but also points out its limitation, that is, it cannot predict the disruptive changes in the market, such as the drug safety crisis. Therefore, investors still need to make comprehensive decisions based on market expectations.

This study aims to accurately capture the dynamic changes in the competition between LLY and NVO in the GLP-1 diet drug market by designing a European call spread option with the stock price difference of LLY and NVO as the underlying asset. In view of the existing problems that the option products in the pharmaceutical field do not match the stock price volatility characteristics well, and the large price difference will affect the accuracy of the simulation, this study designed a European type spread option, and introduced the initial price ratio to narrow the price difference, so as to fill the gap in the existing research. This model combines Black-Scholes option pricing theory with Monte Carlo simulation technology, which not only quantifies the impact of spread volatility and correlation on option value, but also provides a flexible hedging and speculation tool for investors. Especially in the high-volatility environment of the pharmaceutical industry, this model shows its unique advantages. However, tail risks such as drug safety crisis still need investors to make comprehensive decisions based on market expectations. The main innovation of this study is the treatment of the stock price difference between the two companies. The traditional spread calculation may be biased due to the large difference in the magnitude of the stock price between the two companies, which may affect the accuracy of the model. To This end, this paper introduces the concept of initial price ratio in the spread formula, that is, the spread is equal to the LLY price minus the NVO price times the ratio of the initial price of LLY and the initial price of NVO. The price difference between the two is shown in Figure 1, which shows that this improvement effectively reduces the difference between the two and significantly improves the accuracy of Monte Carlo simulation results. In addition, by extending the Black-Scholes model, this paper considers the comprehensive impact of stock price volatility and correlation on option value, which further enhances the practicability and forecasting ability of the model.

In the empirical analysis, this paper selects LLY and NVO as the research objects, conducts a detailed analysis based on historical data, and obtains the option prices and their confidence intervals through Monte Carlo simulation. The results show that this spread option can well reflect the competitive situation of the two companies in the GLP-1 diet drug market, providing investors with a new perspective and tool. At the same time, this paper also recognizes that the model has some limitations, such as the inability to fully predict market disruptive changes (such as drug safety crises), and the fact that historical data may not fully reflect future market trends. Therefore, in practical applications, investors still need to make comprehensive judgments based on market expectations and other information.
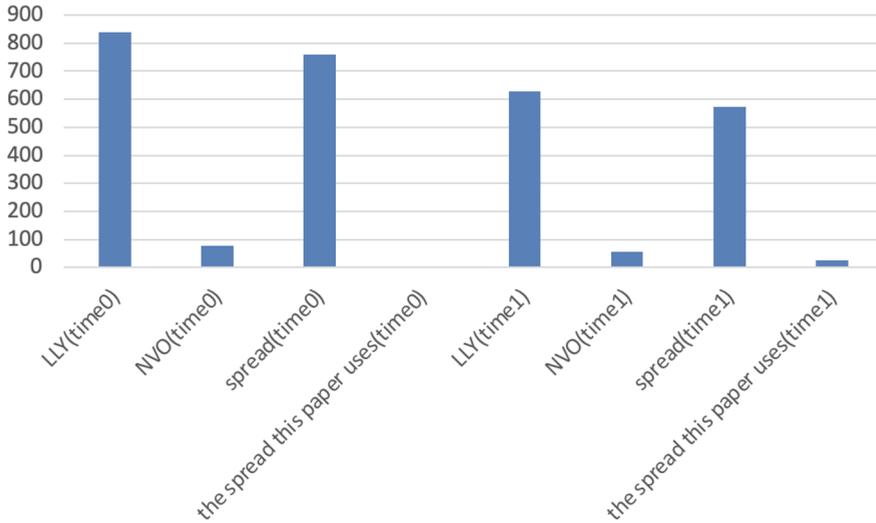
Fig. 1. the spread betwean LLY and NVO.

In the rest of the paper, Section 2 introduces the two companies, Section 3 describes the spread option, Section 4 describes the valuation and result analysis, Section 5, 6 and 7 respectively introduce the sensitivity analysis, suggestions for investors, and the extensions and limitations of the model. Finally, this paper concludes by describing the results and contributions.

2 Company description

2.1 Eli Lilly and Company (LLY) company profile

Eli Lilly and Company (LLY) is a world-class pharmaceutical company headquartered in Indiana, USA since 1876. As a long history company over 140 years, LLY aims to human health advance by providing innovative medicine; notably achieved in diabetes, cancer, immunology and neuroscience, etc. Over the past few decades, LLY has been a major player in global obesity medication and diabetes medicine fields with its leading-edge research in the GLP-1 receptor agonists. Its representative drug Tirzepatide simultaneously activates GLP-1 and GIP receptors, which constitutes a novel mechanism of the dual targeting mode and bring patients more efficacious solution for weight loss and glucose lowering. This technological advantage has helped LLY's share price have high potential to grow for several years and provides it a vital part in the world's pharmaceutical competitive market.

R&D strength is LLY's major influence factor of stock price. Over years, LLY's R&D expenses have occupied more than 20% of its entire sales revenue. Through their persistent R&D efforts, LLY has achieved continuous industry competitive new products and leadership in several drug areas. Besides, Lilly also pays attention to globalization strategy, and its drugs have spread to a lot of countries and region around the world, which further boosts the company's profitability and market influence. But with increased competition and potential risks of drug safety, drug purchasing and generic drugs problems, LLY's stock price is also relatively oscillatory, which makes its investors need to face an investment environment full of opportunities and challenges.

2.2 Novo Nordisk (NVO) company profile

Novo Nordisk (NVO) is a global biopharma leader developing solutions to treat and manage diabetes and other chronic diseases. Semaglutide is Novo Nordisk' main product which is a GLP-1 receptor agonist able to lower blood glucose levels and regulates body-weight by simulating the endogenous hormone GLP-1 produced by the intestines [3]. Semaglutide causes substantial weight loss in clinical trials, this is likely because DPP-IV inhibitors provide a protective mechanism for preventing semaglutide activity degradation, lengthening its half-life within vivo [4]. Furthermore, the DPP-IV inhibitor PF-00734200 was able to provacely increase GLP-1 levels nonlinearly, this provides support for the hypothesis of the activity of semaglutide.

Novo Nordisk's marketing strategy emphasizes on researching and marketing innovated drugs, and deep research on the diabetes area has made it as the market leader in the whole world, and gradually ventured into weight-reduction treatment. Nevertheless, Novo Nordisk is confronting unspeakable challenges, with the coming of Tirzepatide from LLY, Novo Nordisk may face competition at increasing level. Tirzepatide, in addition to be activated by the GLP-1 receptor, can activate GIP receptor in theory, to give a better weight loss effect. This competitive landscape is manifested in the two company's stock price changes directly, in the main junctions of new medicine development process or approval.

It is worth noting that despite the excellent performance of semaglutide in the market, the drug safety issue still needs to be closely monitored. For example, in the presence of near-complete inhibition of DPP-IV, GLP-1 levels instead decreased at night, suggesting the possibility of other degradation pathways or production limitations. This puts forward higher requirements for the stability of the drug for long-term use, and indirectly affects investors' expectations about the future growth potential of Novo Nordisk. Therefore, while maintaining its existing advantages, Novo Nordisk also needs to continuously optimize its product portfolio to cope with the increasingly fierce industry competition.

3 Spread options

While classical options are based on a single underlying asset, spread options can be viewed as a simple extension of classical options, whose value depends on the relationship between the two underlying assets. These two underlying assets can be any two indices, and the value of the spread option is derived from the difference between the prices of the two. For example, an investor may buy an oil call and sell a steel call. The difference between the two prices at maturity constitutes the value of the option.

Although the core logic of spread option is simple, its application form can be flexibly expanded and widely applied to solve real financial problems. In currency and fixed income markets, spread options can be expressed as derivatives based on the difference between two interest rates or the difference between two bond yields. In commodity markets, the subject may differ in the following dimensions: input and output prices of the same product in upstream and downstream production processes (processing spread), prices at different delivery points (calendar spread), prices in different geographical areas (location spread), or prices of products with different quality standards (quality spread).

In this work, two option contracts, with distinct underlying assets, are picked out, whose value is based on the price difference of the corresponding stock return. The return model is derived by the assumption of geometric Brownian motion, whose model parameters is calibrated by history data.

3.1 European call spread option design

As a derivative, the core of the spread option is to capture the relative performance between the underlying assets. In This study, this paper designs a European call spread option with the underlying stock price difference between Eli Lilly (LLY) and Novo Nordisk (NVO). This design is based on the competitive dynamics of the two companies in the GLP-1 weight-loss drug market, aiming to provide investors with a tool to accurately quantify the relative performance of the two companies [5]. Specifically, the value of the option depends on whether the difference between LLY and NVO stock price exceeds the set strike price K at the expiration date. By extending the Black-Scholes model with Monte Carlo simulation techniques, this paper is able to quantify the impact of spread volatility and correlation on the option value.

In order to achieve This goal, this paper assumes that the two underlying asset prices follow geometric Brownian motion and quantifies the volatility of stock prices by introducing random variables z_1 and z_2 [6]. Furthermore, this paper uses the ratio of the initial price of LLY to the initial price of NVO to adjust the calculation formula of the spread, so that the final spread is equal to the LLY price minus the NVO price multiplied by this scaling factor. This method effectively reduces the gap between the two original prices, thus improving the accuracy of the simulation results [7]. In addition, considering the high volatility and event sensitivity of the pharmaceutical industry, the model of This paper can not only reflect the price difference changes under normal market conditions, but also cope with the impact of tail risks such as drug safety crisis to a certain extent.

In the process of option design, this paper focuses on several key parameters: risk-free interest rate r, volatilities σ_1 and σ_2 corresponding to the annualized volatility of LLY and NVO, correlation ρ and strike price K, respectively. Together, these parameters determine the price level of the option and its sensitivity characteristics. For example, higher volatility generally increases the value of an option, while changes in correlation affect the shape of the spread distribution. By flexibly adjusting these parameters, investors can better understand the performance characteristics of options in different market environments.

3.2 Selection of underlying assets and dynamic analysis of competition

The choice of the underlying asset is crucial when designing a European call spread option. In this study, Eli Lilly (LLY) and Novo Nordisk (NVO) were selected as the underlying assets, and the core logic behind it lies in their competitive relationship in the GLP-1 diet drug market. Semaglutide of Novo Nordisk and telpotide of Eli Lilly are the core competitive products of the two companies, both of which achieve weight loss and glucose reduction by activating GLP-1 receptor. However, Lilly's telpootide additionally targets the GIP receptor, creating a dual-target mechanism that could theoretically enhance efficacy and thus positively affect stock price performance. Therefore, the stock price difference between LLY and NVO is selected as the underlying asset, which can effectively capture the dynamic changes of the two in the market.

The design of the spread option not only considers the absolute stock price difference between the two, but also introduces the concept of initial price ratio, that is, the spread is equal to LLY price - NVO price * (LLY initial price /NVO initial price). This innovative treatment significantly reduces the deviation caused by the absolute price difference between the two options, making the simulation results more accurate [8]. At the same time, considering the high volatility and event sensitivity of the pharmaceutical industry, investors need to make comprehensive decisions based on market expectations, especially in the face of tail risks [9].

Besides, the competitive relationship among LLY and NVO can also be identified in history data. Through analyzing the daily price (open, close, maximum and minimum), trading volume and derivative indicator of LLY and NVO, the volatility of stock price is 30% and 36% respectively, and the correlation coefficient is 0.5. These parameters can act as main input parameters for MC simulation which can ensure the model to be aligned with the actual status of the real market [10]. In conclusion, the determination of underlying asset and competitive behavior between them provide useful basis for the later valuation and result discussion.

4 Monte Carlo simulation pricing results

4.1 Extended application of Black-Scholes model

In This study, this paper extends the classical Black-Scholes model to accommodate European call spread option pricing based on the share price spread between Eli Lilly (LLY) and Novo Nordisk (NVO). The traditional Black-Scholes model is mainly used for the pricing of single-asset European options. Its core assumptions include that the underlying asset price follows geometric Brownian motion, the market is frictionless, and the risk-free interest rate is constant [11]. However, when dealing with spread options involving multiple assets, the model needs to be extended appropriately to take into account the correlation and volatility differences between assets. To This end, this paper expresses the price dynamics of two assets as geometric Brownian motion respectively, and quantifies the relationship between assets by introducing correlated random variables z1 and z2.

This paper collects the stock prices of 252 trading days in 2024 through Yahoo Finance and uses the following formula to calculate some key parameters, and the payoff obtained through simulation can be seen in Figure 2.

$$R_t = \frac{P_t}{P_{t-1}} - 1 \tag{1}$$

$$\sigma_{annual} = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(R_t - \overline{R})^2} * \sqrt{252} \tag{2}$$

$$\rho = \frac{Cov(R_{LLY}, R_{NVO})}{\sigma_{LLY}\sigma_{NVO}} \tag{3}$$

$$\mu_{annual} = (\frac{1}{N}\sum_{t=1}^{N} R_t) * 252 \tag{4}$$

$$z_2 = z_1 * \rho + \sqrt{1-\rho^2} * z \tag{5}$$

Where z1 and z2 are the relevant standard normal distributed random variables, and the correlation coefficient is ρ . In order to further optimize the calculation of the price difference, this paper introduces the ratio of the initial prices of the two companies, which not only effectively reduces the absolute value of the original price difference between the two companies, but also enhances the accuracy of the simulation results [12].
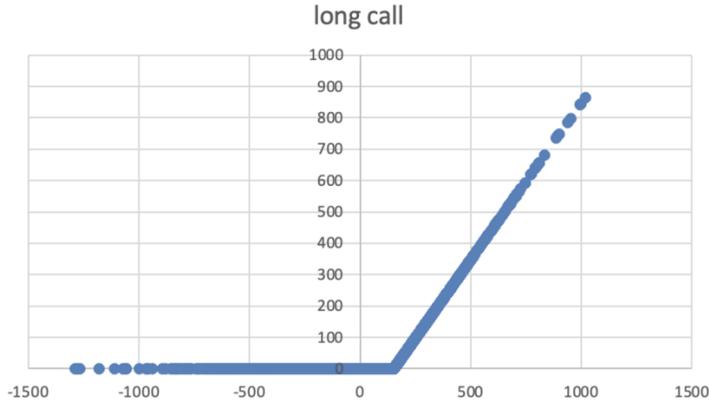
Fig. 2. payoff diagrams.

In addition, this paper model is combined with the monte carlo simulation technique, used to evaluate the option to pay expectations. The future stock price path is generated through multiple simulations, the option payment at maturity is calculated and averaged, and the option price is finally discounted at the risk-free interest rate. This method has significant advantages in dealing with high-dimensional problems, especially in the high-volatility environment of the pharmaceutical industry, where it can flexibly cope with complex risk structures [13].

It is worth noting that although the extended Black-Scholes model provides an accurate pricing framework in theory, its practical application is still limited by several assumptions. Model assumes, for example, volatility and correlation remains unchanged, while in reality these parameters may change over time. Therefore, in actual investment decisions, investors need to combine market expectations with other quantitative tools to assess potential risks more comprehensively [14].

4.2 Monte Carlo simulation pricing results

In this section, the results of the application of Monte Carlo simulation to pricing LLY versus NVO spread options are explored in detail. By setting the key parameters, such as the risk-free interest rate $r = 4.31\%$, volatility $\sigma 1 = 30\%$ (LLY) and $\sigma 2 = 36\%$ (NVO), correlation $\rho = 0.5$, and the strike price and expiration time $T = 1$, $K = 150$, extensive price path simulations were conducted. The initial price was set to $LLY = 837.57$ and $NVO = 76.86$ (assuming the price on March 21, 2025). The associated random variables $z1$ and $z2$ were generated based on the geometric Brownian motion model, the results obtained through Monte Carlo simulation can be seen in Figure 3.

From the simulation, the payoff of the option and spread of each path are computed. The spread is equal to the LLY price minus the NVO price minus the adjustment and the option payoff is equal to $(\max(\{spread\} - K, 0))$. An estimate of the price of the option is then computed by taking the average of several such simulations and discounting it at the risk free rate. We also provide standard errors which give a measure of the accuracy of the simulations and, consequently, of the margin of error.

In the empirical results we demonstrate that the model can provide a valid calibration of the effect of the spread volatily and correlation for the price of an option. More precisely, the option price varies when the volatility or the correlation changes and so, the model is able to catch their high sensibility. For instance, if the volatility goes upward or the correlation is falling, the prices of options go up, this is indicative of the market's anticipation of being

able to turn profit from a high volatility environment. We remark here that while Monte Carlo simulation is quite the effective tool, it has a few shortcomings.
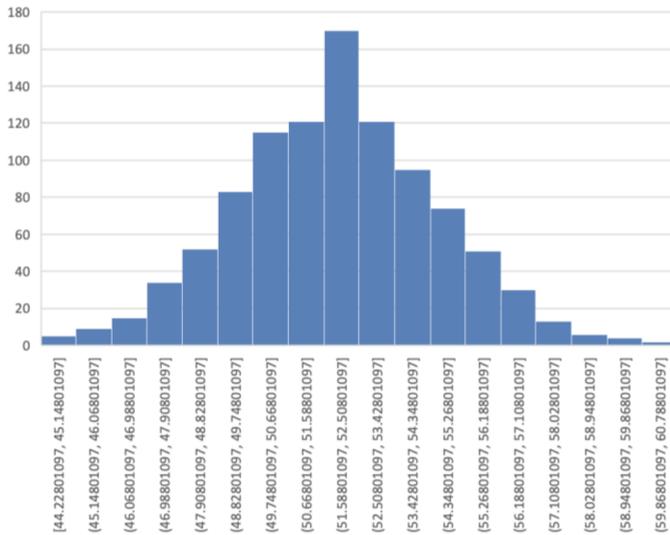

Fig. 3. Distribution of the average option value in day zero.

5 Sensitivity analysis

5.1 Impact of volatility on option value

Volatility is one of the important parameters affecting the value of options, especially in the spread options involving multiple assets, and its impact on the pricing model is more significant. According to the existing research results, the change of volatility will directly affect the probability distribution of option payment, thus changing the value of option. According to the calculated result shows that when a LLY or NVO volatility increases, the price to rise after falling, and the changes in option prices can be observed in Figure 4 and 5.
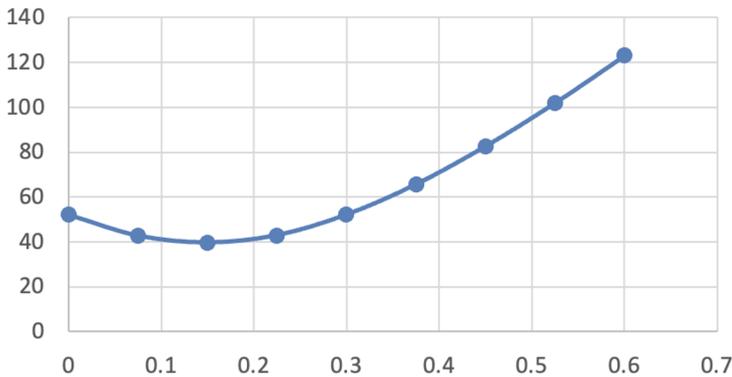

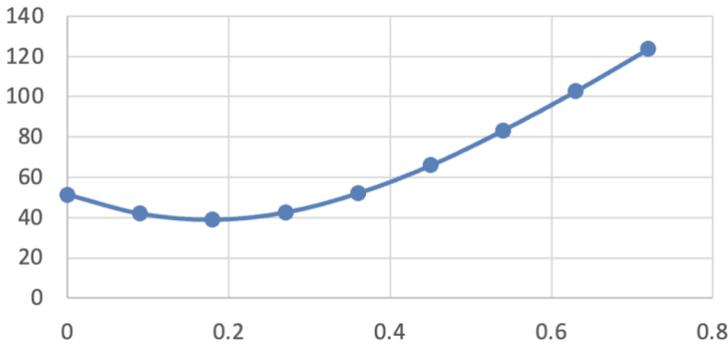
Fig. 4. Sensitivity analysis: volatility of LLY.

Fig. 5. Sensitivity analysis: volatility of NVO.

5.2 Role of correlation changes on option prices

Correlation is a key factor in the pricing of spread options, and its changes have a significant impact on option prices. In this study, the correlation coefficient ρ between LLY and NVO stock prices is adjusted to observe its effect on option prices. When the correlation increases, the common volatility of the two stocks increases, which means that the uncertainty of the spread decreases, thus leading to a decrease in the option value. Conversely, lower correlation means that the price movements of the two stocks are more independent, which increases the volatility of the spread and therefore increases the value of the option. The changes in option prices can be observed in Figure 6.

As correlation is also an input factor that impacts price of the spread option, and its dynamics vary by specific market condition and model definition. Estimation of correlation and correlation dynamics is of key importance to price in highly volatile industries such as pharmaceutical.
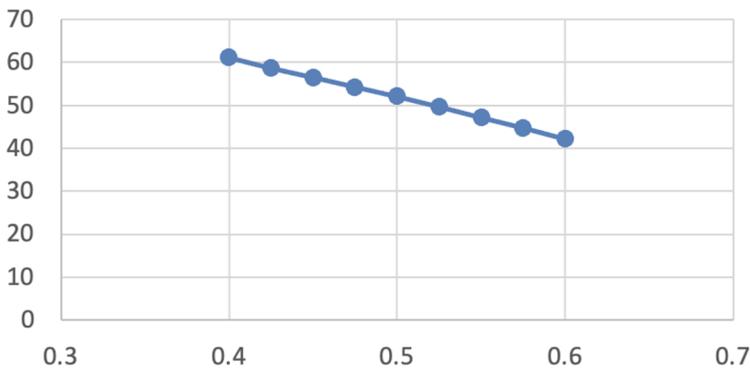

Fig. 6. Sensitivity analysis: correlation.

5.3 Impact of strike price on option value

The strike price defines the "threshold" of the spread and directly impacts the intrinsic value of the option: the higher the strike price, the unlikely it is for the spread to exceed K and consequently the lower the value of the option. The time value is maximized if K is as close as possible to the expected value of the spread and the option is close to its mean. There

exists a clear downward linear relationship between the strike price and the value of the option. The changes in option prices can be observed in Figure 7.
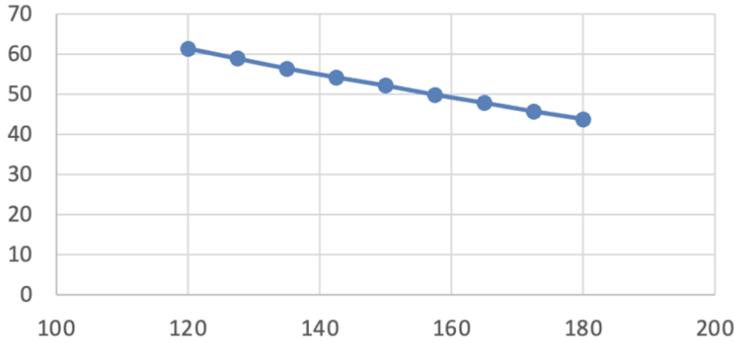

Fig. 7. Sensitivity analysis: strike price.

5.4 Impact of time to expiration on option value

The longer the time (T increases), the greater the volatility space of the underlying asset, the spread may widen or narrow significantly, the time value of the option (the potential gain from volatility) rises, and the value of the option increases. There is an upwards linear correlation between T and the value of an option. The changes in option prices can be observed in Figure 8.
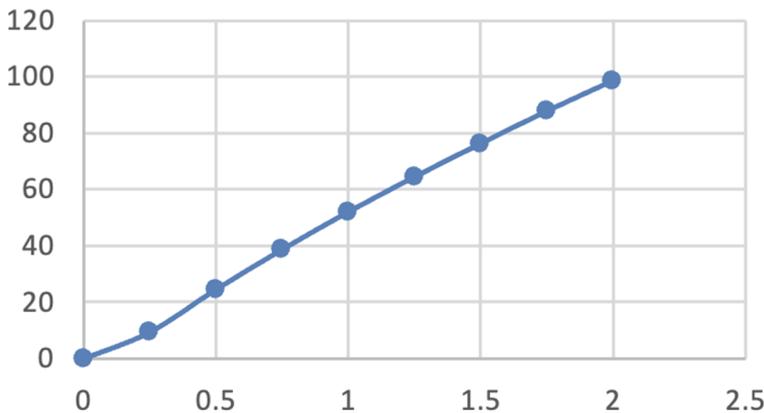

Fig. 8. Sensitivity analysis: maturity.

6 Advice for investors

6.1 Investment strategy and risk management

Considering the high volatility of the pharmaceutical industry, investors must also flexibly employ option tools to avoid risks and make profits as much as possible. According to the European call spread option which we have designed above, based on the difference of the prices of two companies Eli Lilly (LLY) and Novo Nordisk (NVO) is the underlying asset, the investor can design a set of highly effective investment strategies. First, the spread option allows the investor to grasp the competitive situation of the two in the GLP-1 diet drug market.

Then, investors are more able to judge the influence of the fluctuation in the market for option value by measuring the spread volatility and the correlation. This helps them to revise their portfolio.

Specifically, investors can achieve different investment objectives by setting a reasonable strike price K. For example, when Eli Lilly's telpotide is expected to show a stronger competitive advantage in the market, a higher strike price K can be selected to obtain greater potential gains. Conversely, if the market expects Novo Nordisk's semaglutide to continue to dominate, a lower strike price K can be selected to reduce risk [15]. In addition, investors can also use the monte carlo simulation, the result of the combination of historical data and market expectations, further improve the investment decision-making.

However, it is worth noting that although the model has strong flexibility and practicality in theory, it still needs to consider the impact of tail risk in practice. Some unforeseen events may lead to sharp stock price fluctuations, which in turn affect the option value [16]. Therefore, investors should adopt diversified investment strategies based on market expectations to diversify risks. For example, a certain proportion of other asset classes, such as bonds or commodities, can be allocated while holding spread options to balance the risk-return characteristics of the overall portfolio.

Furthermore, risk management is also one of investment strategies. It can manage risk with dynamically adjusting the size of position and setting stop-loss points. Such as when volatility of market increases or counter-trending signals occur, liquidate or shrink the position on time to prevent the loss further widens; meanwhile, always review and make adjustments to the investment strategy to guarantee the investment strategy is always consistent with the current market environment and risk tolerance.

6.2 Decision making method based on market expectations

In the highly turbulent pharmaceuticals sector, investors are forced to integrate market expectation to handle tail risk like drug safety crisis. The European call spread option constructed in this paper gives investors the correct opportunity to grasp the stock price competition dynamics between Eli Lilly (LLY) and Novo Nordisk (NVO).But the option price provided by model itself cannot comprehensively cover all complexity of market, and investors have to take multiple factors of the market into account to enhance the development of an effective investment strategy [17].

First, investors can through the analysis of historical data to predict future trends. For example, in the study of This paper, by using Monte Carlo simulation method, it is possible to quantify the impact of spread volatility and correlation on option value. However, historical data may not fully reflect future market changes, especially in the face of disruptive events, such as policy adjustments or drug safety crises or. These unforeseen factors may significantly affect stock price movements and thus the value of options [18].

Secondly, investors can focus on changes to the competitive landscape in the GLP-1 diet drugs market. Novo Nordisk's semaglutide and Eli Lilly's telpotide serve as the two main competing products and changes to their market share could manifest directly in the stock price performance of both. For instance, if Lilly's dual-target mechanism proves to be more successful then it is likely their stock price will increase, subsequently impacting the value of the spread option.Besides, market sentiment, policy environment, macroeconomic should also be considered.

Finally, to cope with uncertainty, investors can adopt a phased investment strategy. For example, you can gradually increase or decrease your position based on market expectations, while hedging your risk using options instruments. This will not only reduce the overall risk of the investment, but also allow you to take advantage of market fluctuations. In short, although this study provides the spread option model provides an effective analysis

framework for investors, but still need to be combined with market expectations in the practical application and other related information, in order to achieve a better return on investment.

7 Extensions and limitations

7.1 Expansion direction of the model

In the direction of model expansion, the current spread option pricing model can be further optimized by introducing more dynamic factors and market parameters. Firstly, the stochastic interest rate can be incorporated into the model framework. Existing models assume that the risk-free interest rate r is constant, but in real financial markets, interest rates tend to fluctuate with macroeconomic environment and policy changes. By combining with stochastic interest rate models such as Hull-White or CIR, the impact of interest rate on option value can be more truly reflected, thus improving the applicability and accuracy of the models.

Second, consider the high volatilities and event sensitivity characteristic of the pharma industry, one may extend the model with a jump diffusion process. In the conventional Black-Scholes framework, stock prices are assumed to follow the geometric Brownian motions, which are inadequate to accommodate potential prices jumps induced from breaking news, drug safety issues, regulatory policy changes and so forth. Thus, such tail risk effects to option prices cannot be accurately depicted simply in a diffusion framework without Merton's jump-diffusion model or other models [19].

Moreover, if taking into account of competitive relationship between LLY and NVO in the GLP-1 weight-loss drug market, more sophisticated multi-factor models should be investigated in future. For instance, company's financial information (i.e., R&D cost and market share) could be added as an auxiliary variable for further enrichment in correlation analyzing of underlying assets. It also could have the timelines of the drug R&D progress of two companies, which can predict the stock price of two companies. That method not only helps explain the hidden competition relationship of two companies, but also offers investors a richer decision-support.

At last, with advances in artificial intelligence technology, we can also apply machine learning methods to option pricing models. LSTM neural networks are a kind of deep learning model, which have been used for financial times series forecasting successfully, and it has strong nonlinear fitting power which helps it well process the complicated volatility structures. The application of such methods on enhancing GARCH model's prediction capabilities will aid constructing a stronger and more flexible option price system.

7.2 Analysis of limitations of the current model

The current model shows some innovation in capturing the stock price spread dynamics of Eli Lilly (LLY) and Novo Nordisk (NVO), but its limitations cannot be ignored. First of all, the model assumes that the underlying asset price follows Geometric Brownian Motion (GBM), which is widely used in the Black-Scholes framework, but may not be fully applicable in the actual market [20]. This is especially true in the pharmaceutical industry, where stock price fluctuations often show non-normal distribution characteristics, such as peak fat-tail phenomenon or jump behavior, due to the influence of drug development progress, regulatory policy changes and market competition. This complexity may lead to models underestimating the risk of extreme events, thus affecting pricing accuracy.

Secondly, the correlation parameter (ρ) in the model is a fixed value estimated based on historical data, while in reality the correlation between two assets may change over time. For

example, when market uncertainty increases, the correlation may rise significantly, while it is relatively low during periods of market stability. Failure to dynamically adjust correlation may lead to misjudgment of option value. In addition, the initial price ratio is introduced in the spread calculation to narrow the gap between the two options. Although this method improves the accuracy of the simulation results, its rationality depends on the assumption that the proportion of the two companies' stock prices will remain stable in the future. However, this assumption may be biased in view of the rapid evolution of the competitive landscape in the GLP-1 market.

Furthermore, such a model cannot capture fully the influence of external events on stock prices. For instance, we may observe sudden rise or fall in the price of a stock due to unforeseeable events including, but not limited to, a drug safety crisis or a drug trial failure, which however cannot be captured by classical statistical models due to the presence of tail risks.Even though Monte Carlo simulation produces a substantial number of random paths, model accuracy is still controlled by input choice, and the quality of random number generator. Thus, in reality investors have to work along with market expectation, in addition to other qualitative analysis tools to supplement the limitations of the model.

Last, the model assumes the risk-free interest rate is fixed for the whole life of an option. In this case, the assumption might not be suitable for the option pricing with long-term maturity, as the interest rates affect not only the discount factor, but also the underlying asset price through altering the cost of funds. In short, while the model offers a useful flexible tool to investors, its result should be interpreted with the caution and that it should be added to other complementary means for high volatility environments decision making.

8 Conclusion

In this study, a European call spread option was designed to accurately capture the competitive dynamics of Eli Lilly (LLY) and Novo Nordisk (NVO) in the GLP-1 diet drug market. By extending the Black-Scholes model and Monte Carlo simulation method, this paper quantifies the impact of spread volatility, correlation and market parameters on the option value. The results show that the model has flexible hedging and speculation functions in the high-volatility environment of the pharmaceutical industry.

Specifically, we find that the value of the spread option is not only dependent on the volatility of the underlying asset, but also significantly affected by the price correlation between them. When the correlation between the two increases, the price of the spread option will decrease, otherwise it will increase. In addition, the adjustment of the risk-free interest rate also affects the price of the option, and its mechanism is consistent with the classical option pricing theory. The empirical results of this paper show that the model can effectively reflect the dynamic changes in the competition between LLY and NVO in the GLP-1 market, and provide a flexible risk management tool for investors.

Although there are some theoretical merits in the model, there are also some practical limitations. First, the geometric Brownian motion assumption might not fit the real dynamics of the stock prices, particularly when the real time is faced with extreme events, such as the crisis of drugs safety, then the predictive power of the model might be under a questioning. Second, the parameter estimates driven by the historical data are not reliable, particularly when the market environment is fluctuating very quickly. Thus, with this model, investors still must also join the market expectation and other qualitative analysis for an overall decision.

Summing up, the innovation of this paper is proposing a European call spread option pricing model for LLY and NVO stock price spreads, which optimizes the spread structure and enhances the accuracy of the simulation results by adding the initial price ratio. And the application scene of the model is mainly concentrated in the high-volatility market of the

pharmaceutical industry, and the model meets the hedging and speculation needs. More future research is also needed about the applicability of the model to other industries or asset portfolios, as well as how to handle the tail risk problems better.

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