Research on the Mechanism of Option Spread Design from a New Perspective Take Three Commodities for Example

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Abstract—This paper selects three commodity futures prices of CME in recent three years as samples, uses the Black Scholes option pricing model and Monte Carlo pricing method to price pig spread options, and obtains the option price of half-year spread options in the past two years. Then calculate the maturity value of breeding value options. Finally, the calculation results are compared and analyzed. The results show that although the breeding price spread fluctuates a lot, trading the breeding price spread options between feed raw materials and pigs can effectively avoid the risk of breeding price spread decline. Because some samples were selected at unstable prices, feed prices rose, and pork prices fell, resulting in negative farm income. The result of the call option is a net loss and the total loss of royalty. But compared with the loss of breeding profit, the loss of option speculation is limited. In general, the farm can hedge the risk of future breeding profit decline by selling call options and buying put options. On the other hand, investors in the futures market can also gain speculative benefits by selling call options or buying put options.

Keywords-spread option; Black-Scholes model; Monte Carlo; lean hog, corn, soybean meal

1 INTRODUCTION

In recent years, novel coronavirus pneumonia and the outbreak of African swine fever have caused uncertainty in the global pig market, and lean hog and feed prices have fluctuated considerably. In the turbulent period of the pig market, maintaining the profit of hog farms has become a key problem.

Based on the literature research of financial derivatives and spread options, we find that the current research on spread options is less than other financial derivatives. The research on spread options mainly focuses on empirical algorithm research. In the meantime, there is little research on product design. This paper uses pig, soybean, and corn as the research object. It is

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based on the Monte Carlo simulation option pricing method to design and study the potential application value of the breeding spread contract. The research results of this paper provide an application environment for the theoretical development of spread options in theory. They can also be considered as a reference for the design direction of spread options in practice.

Financial derivatives refer to a kind of financial contract whose value depends on one or more underlying assets or indexes. Financial derivatives also include mixed financial instruments with forward, futures, swap, and option characteristics. According to product types, financial derivatives can be divided into forward contracts with low liquidity, futures contracts with high liquidity, option contracts, and swap contracts [1]. Among them, the option contract is a kind of trading contract with financial derivatives as exercise products [2]; a Swap contract, also known as "swap contract", is a kind of contract signed by both sides of the transaction to exchange certain assets in a certain period in the future [3]. According to Wystup, a financial instrument, especially a financial contract, for an underlying, especially an asset or index, shall allow the trading, and therefore hedging, of the key features of the distribution of future underlying price [4]. This paper mainly discusses the option contract. Compared with the spread option designed in this paper, the existing financial derivatives have the following characteristics: 1. Zero-sum game: the profit and loss of both parties of the contract transaction (in the standardized contract, because it can be traded is uncertain) are completely negatively correlated, and the net profit and loss are zero, so it is called "zero sum" [5]. 2. High leverage: derivatives trading adopts a margin system. The minimum capital required for the transaction only needs to meet a certain percentage of the value of the underlying assets. Margin can be divided into the initial margin and maintains margin, and marked to the market system is adopted when trading in the exchange. If the margin ratio in the trading process is lower than the maintenance margin ratio, a margin call will be received. If investors do not add margin in time, they will be forced to close their positions [6]. It can be seen that derivatives trading has the characteristics of high risk and high yield. The role of financial derivatives is to avoid risk. Price discovery is a good way to hedge asset risk. However, everything has a good side and a bad side. If the risk is avoided, someone must take it. The high leverage of derivatives is to transfer the huge risk to the people who are willing to take it. This kind of trader is called a speculator. In contrast, the risk-averse party is called a hedger, and the other kind of trader is called an arbitrager. These three kinds of traders jointly maintain the above functions of the financial derivatives market [7].

The common option is to price the underlying assets, and the spread option is to price the spread between assets. Based on certain assumptions, the value of spread options can be approximately calculated by multiple integration and boundary estimation methods. The common pricing methods include the numerical method, upper and lower boundary estimation method, and approximation method. The numerical method needs a lot of calculation, and the time delay is large in practical application [8]; Boundary estimation methods include Carmona and Durrleman method [9], Li, Deng, and Zhou method [10]; The approximate methods include Kirk and Aron method [11], Bjerksund and Stensland method [12] and fast Fourier transform method [13].

Specifically, the spread option, as a new option form, has its unique application scenarios and natural advantages. The advantages are: 1. The maximum loss is controllable. Because it is an options transaction, the buyer cannot exercise the right when the market moves in an unfavorable direction, and the maximum loss is the option fee of the initial call option. When there is a price spread in futures trading, it is often a short jump or liquidity risk, which leads to the failure to close the position in time. In this case, the tail risk of futures trading is far greater than the risk of arbitrage trading using spread options [14]. 2. The withdrawal is relatively stable, and the net value fluctuates little. Since the fluctuation of the daily net value of the option buyer mainly reflects the passage of time value to a greater extent, the passage of time value of the option is actually relatively stable before the maturity date, so the impact on the trend of net value is relatively stable and predictable [15].

2 DATA AND METHOD

2.1 Data

The data in this article is from April 2, 2018, to March 31, 2021. Linear interpolation is used to fill in the missing data due to holidays. We use the closing prices of dominant corn futures, soybean meal futures, and lean hog futures from the Chicago Mercantile Exchange. The sample data comes from Yahoo Finance.

2.2 Method

2.2.1 Black-Scholes Pricing Model

The Black-Scholes formula (Black and Scholes, 1973) gives the exact value of a European call or put option [16]. The following assumptions must be made in order to use this model: (1) The option is European and can only be exercised at expiration. (2) There are no transaction costs in buying the option. (3) No dividends are paid out during the life of the option. (4) The underlying asset's price follows a geometric Brownian motion with constant drift and volatility. (5) The returns on the underlying asset are log-normally distributed.

The price of European call C and European put P on a non-dividend-paying asset with the underlying assets S_1 and S_2 can be calculated by the two-dimensional Black-Scholes formula as [17]:

$$P(S_1, S_2, T) = (S_2 + Ke^{-rT})N(-d_2) - S_1N(-d_1), \qquad (1)$$

$$C(S_1, S_2, T) = S_1N(d_1) - (S_2 + Ke^{-rT})N(d_2), \qquad (2)$$

with the final payoff condition

$$C(S_1, S_2, 0) = \max(S_1 - S_2 - K, 0), \qquad (3)$$

$$P(S_1, S_2, 0) = \max(K - (S_1 - S_2), 0), \qquad (4)$$

where

$$d_1 = (\ln(S_1) - \ln(S_2 + Ke^{-rT})) / \sigma\sqrt{T} + 1/2\ \sigma\sqrt{T}, \qquad (5)$$

$$d_2 = d_1 - \sigma\sqrt{T}, \qquad (6)$$

$$\sigma = [\sigma_1^2 - 2\rho\sigma_1\sigma_2 S_2/(S_2 + Ke^{-rT}) + \sigma_2^2 S_2^2/(S_2 + Ke^{-rT})^2]. \ (7)$$

N(d) is the cumulative normal distribution function for d [18], σ_1 and σ_2 are the volatilities of the two underlying, ρ is the correlation between them, K is the strike price, r is the risk-free interest rate, and T denotes the time-to-maturity.

2.2.2 Monte Carle Option Valuation Method:

Monte Carlo methods are a class of computational algorithms that are based on repeated computation and random sampling. Monte Carlo simulation is used in finance to value and analyze instruments, portfolios, and investments by simulating the sources of uncertainty that affect their value [19].

The idea of the Monte Carlo simulation method is: Assume the underlying asset price distribution function is defined. It is dividing the maturity of the option into small intervals. Then randomly sampling from a sample of distributions to simulate the shift of asset prices at each interval and many possible trajectories of the underlying asset. This calculates the final value of the option. The result can be considered a random sample of all possible final value sets, and more sample paths can generate more random samples.

Repeat these thousands of times to obtain a list of option values and then take their average to determine the expected return.

2.2.3 Volatility in Pricing Model

Since the spread option contract is not on the market, we cannot obtain the option price. To price the spread option, we use historical volatility to calculate the volatility of the underlying assets. Historical volatility is a statistical measure of the amplitude of past price changes. To calculate volatility, price movements are generally expressed as the compounded variation of daily price changes, i.e., $\ln(P_2/P_1)$ [20].

Here, we use the annual volatility converted from daily volatility during the one year before listing as the historical volatility in the pricing model.

3 RESULTS AND DISCUSSION

3.1 Breeding Price Spread Design

3.1.1 Breeding Profit

The cost of pig raising includes cash cost and sunk cost. Cash cost consists of the marginal cost of feed, medical treatment, water, and electricity. Depreciation, piglets, etc., are sunk costs. The cash cost describes that when the pig price is too low. For example, when the marginal length of pig meat can not cover the feed money, the farmers will take the initiative to reduce the pressure on the hurdles and reduce the pig's weight to re duce the loss. It will lead to the decrease of the industry's supply and push the pig price higher in the later period. This is strong support for short-term pig prices. Therefore, this paper mainly considers the impact of cash cost on pig price.

Feed raw materials determine the fluctuation of cash cost, and the main raw materials that affect feed price are corn and soybean meal. Therefore, we determined the price of corn and soybean meal as the cost. According to the USDA report [21] and the actual production situation, it takes about 7.875 bushels of corn and 171.04 pounds of soybean meal to raise a pig until 250 pounds are sold. The sum of the two kinds of feed cost accounts for about 85% of the feed cost. In pig breeding, feed cost accounts for about 50% of the total breeding cost. Therefore, 42.5% of the total breeding cost of a 250-pound pig comes from 441.04 pounds of corn and 171.04 pounds of soybean meal, i.e. we use 2.35 times two feed costs to represent the total breeding cost. According to this relationship, the breeding price spread is defined as $\text{breeding price spread} = 250 * \text{lean pig price} \quad 2.35 * (441.04 * \text{corn price} + 171.04 * \text{soybean meal price})$.

Here, all prices are in "USD / pound".

3.1.2 The volatility of Breeding Profit

First of all, we analyze the price volatility of three kinds of commodities and the volatility of breeding spread, preliminarily judge the potential application value of breeding spread contract from the relative size of commodity volatility, and lay the foundation for the follow-up research. Fig. 1 shows the variation of spread volatility.

Figure 1 Variation chart of spread volatility

3.2 Design of Breeding Spread Option

To study whether the spread option can meet the hedging requirements, the application value of the spread option contract is calculated. Firstly, it is assumed that all options are held to maturity, and the options are included in European options. Secondly, we use the following measurement methods to measure the hedging effect of spread options: calculate the half-year parity spread options' theoretical price and maturity value from April 2018 to October 2020. Also, consider the corresponding hedging operation and effect combined with the decline of spread.

3.2.1 Underlying Assets

CME's corn futures, soybean meal futures, and lean pig futures are selected as contract targets.

3.2.2 Variable Selection

The underlying asset price is determined by the monthly mean of the daily closing price of the futures in the month when the spread option is listed as S_1, S_2. The exercise price is replaced by the monthly average of the daily price spread of the lean pig futures and feed futures in the month when the options are listed, expressed by K. The correlation coefficient of the return on the underlying asset is replaced by the correlation coefficient of the return on the asset one year before the spread option is listed. The risk-free yield R is the yield to maturity of one-year treasury bonds.

3.2.3 Monte Carlo Simulation Pricing Method

According to the pricing method of spread option simulated by Monte Carlo, the theoretical price of breeding spread option contract and the premium of spot option are estimated. Table 1 shows the Contract Price of the Breeding Spread Option.

Table 1 the Contract Price of the Breeding Spread Option

Month	Call	Put
2020-10	2.61	16.05
2020-09	2.31	14.91
2020-08	1.94	13.76
2020-07	2.06	13.24
2020-06	2.25	12.79
2020-05	3.52	14.73
2020-04	3.61	10.71
2020-03	4.60	12.18
2020-02	4.94	11.99
2020-01	5.42	12.66
2019-12	5.45	12.61
2019-11	5.23	12.37
2019-10	5.16	13.32
2019-09	5.03	12.73
2019-08	5.56	12.61
2019-07	6.05	14.16
2019-06	6.19	14.16
2019-05	5.20	13.78
2019-04	4.45	15.02

3.2.4 Maturity Value

To measure the hedging effect of the breeding option contract, we need to measure its theoretical price and its maturity value. The calculation method of the maturity value of the half-year parity call breeding spread option contract is: the breeding spread at the end of half a year minus the breeding spread in the current month of the contract. Table 2 shows the maturity value of breeding spread options.

Table 2 Maturity Value of Breeding Spread Options

Date	Value
2020-10	1.75
2020-09	-23.58
2020-08	-14.15
2020-07	10.86
2020-06	16.84
2020-05	-10.22
2020-04	34.81
2020-03	-22.17
2020-02	-23.78
2020-01	-43.11
2019-12	-4.32
2019-11	-35.34
2019-10	-7.95
2019-09	-15.37

2019-08	-19.21
2019-07	-31.92
2019-06	-36.94
2019-05	-80.25
2019-04	-73.56

a positive number means that a contract is a call option, a negative number means a put option, and the absolute value of number means the maturity value of breeding spread options contract

3.3 The Hedging Performance of Options

Table 3 Profit from Buying Put Options

Date	Strike	Put	Value	Profit from buying put options	Profit on no option trading
2020-10	52.46	16.05	1.75	-16.05	13.85
2020-09	43.12	14.91	-23.58	-1.28	-13.63
2020-08	14.98	13.76	-14.15	-3.07	-10.69
2020-07	2.56	13.24	10.86	-13.24	11.45
2020-06	0.74	12.79	16.84	-12.79	17.01
2020-05	50.57	14.73	-10.22	-14.73	1.45
2020-04	-1.64	10.71	34.81	-10.71	35.51
2020-03	33.69	12.18	-22.17	2.21	-14.39
2020-02	25.75	11.99	-23.78	5.85	-17.84
2020-01	43.68	12.66	-43.11	20.37	-33.03
2019-12	43.22	12.61	-4.32	-12.61	5.65
2019-11	33.00	12.37	-35.34	15.36	-27.72
2019-10	33.86	13.32	-7.95	-13.18	-0.13
2019-09	35.18	12.73	-15.37	-5.47	-7.26
2019-08	52.81	12.61	-19.21	-5.59	-7.02
2019-07	65.16	14.16	-31.92	2.72	-16.88
2019-06	62.33	14.16	-36.94	8.40	-22.56
2019-05	106.30	13.78	-80.25	41.94	-55.72
2019-04	100.63	15.02	-73.56	35.32	-50.34

Table 4 Profit from Selling Call Options

Date	Strike	Call	Value	Profit from selling call options	Profit from no option trading
2020-10	52.46	2.61	1.75	0.86	13.85
2020-09	43.12	2.31	-23.58	14.91	-13.63
2020-08	14.98	1.94	-14.15	13.76	-10.69
2020-07	2.56	2.06	10.86	-8.81	11.45
2020-06	0.74	2.25	16.84	-14.59	17.01
2020-05	50.57	3.52	-10.22	13.73	1.45
2020-04	-1.64	3.61	34.81	-31.19	35.51
2020-03	33.69	4.60	-22.17	12.18	-14.39
2020-02	25.75	4.94	-23.78	11.99	-17.84
2020-01	43.68	5.42	-43.11	12.66	-33.03
2019-12	43.22	5.45	-4.32	9.77	5.65
2019-11	33.00	5.23	-35.34	12.37	-27.72
2019-10	33.86	5.16	-7.95	13.32	-0.13
2019-09	35.18	5.03	-15.37	12.73	-7.26
2019-08	52.81	5.56	-19.21	12.61	-7.02
2019-07	65.16	6.05	-31.92	14.16	-16.88
2019-06	62.33	6.19	-36.94	14.16	-22.56
2019-05	106.30	5.20	-80.25	13.78	-55.72
2019-04	100.63	4.45	-73.56	15.02	-50.34

Table 5 Three Kinds of Profit Statistics

	Profit from buying put options	***Profit from selling call options***	***profit from no option trading***
Standard deviation	16.80	12.47	22.58
Mean value	1.23	7.55	-10.12

From the income statistics of Table 3 to 5, we can see that the income under options trading is significantly higher than that without options trading. The yield of selling call options is higher than buying put options, and the stability is higher.

To sum up, according to the historical data of 2018-2021, the spread option contract can meet the hedging needs of pig enterprises.

4 CONCLUSION

This paper selects futures prices of three commodities of CME in recent three years as samples, uses Black Scholes option pricing model and Monte Carlo pricing method to price pig spread options, and obtains the option price of half-year spread options in the past two years. Then calculate the maturity value of breeding value options. Finally, the calculation results are compared and analyzed. The results show that although the breeding price spread fluctuates a lot, trading the breeding price spread options between feed raw materials and pigs can effectively avoid the risk of breeding price spread decline. Because some samples were selected in the period of unstable prices, feed prices rose, and pork prices fell, resulting in negative farm income. For highly value-added or impaired options, The Black-Scholes model has a large deviation in valuation. And Monte Carlo methods require large amount of computation. The result of a call option is a net loss and the total loss of royalty. But compared with the loss of breeding profit, the loss of option speculation is limited.

In general, the farm can hedge the risk of future breeding profit decline by selling call options and buying put options. On the other hand, investors in the futures market can also gain speculative benefits by selling call options or buying put options.

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