Research on Pricing of Automatic Redemption Structured Deposit Products Based on Monte Carlo Simulation

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Abstract: Structured deposit is one of the priorities today. It provides better options for investors and fills a gap in the market. However, due to his short development in the market, it lacks a unified understanding. Therefore, the topic of this paper is the pricing of structured deposit products. The research methods of this paper are as follows: First of all, the paper simulates the income of the product and introduces the basic information and income of a product to better explain the structured deposit product. Then, nine different market environments and various parameters are assumed, and the Monte Carlo method is used to simulate the price path of assets. According to the circumstances of nine different market environments, the annual expected return rate and annual volatility and estimated, and their sensitivity analysis is carried out. Finally, it is concluded which market environment has the highest product return, and the annual expected return is positively correlated with exercise price 1, and negatively correlated with exercise price 2, and the annual volatility has nothing to do with the exercise price.

1 INTRODUCTION

In 2002, China Everbright Bank launched a foreign currency structured deposit product. In 2005, it issued China's first structural deposit structure of RMB after becoming the first bank in China to be eligible to trade cross-currency derivatives of RMB (Zhang 2022 & Qin 2023). In April 2018, the People's Bank of China issued on its official website the "Guiding Opinions on Regulation the Asset Management Business of Financial Institutions" (referred to as the "New Regulations"), article 6 of which stipulated that financial institutions should pass on the of "seller is responsible, buyer is responsible" to investors, break the rigid payment, and guide financial products to realize the transformation to net worth products (Li 2023). This means that investors who are more inclined to capital-prot protection financial products will gradually withdraw from the market. Based on the characteristics of structural deposits, breaking through the interest rate ceiling to give investors higher benefits than general deposits are also in line with the reform requirements of relevant policies, which can fill the vacancy of capital protection products of commercial banks, and has a good market demand and market prospects.

Structured deposit refers to the deposit of RMB or foreign currency funds legally held by investors in banks, and the bank can embed financial derivatives (including but not limited to forwards, swaps, options or futures, etc.) based on ordinary deposits (Zhao 2022). Financial products with certain risks link investors' returns to interest rates, exchange rates, stock prices, commodity prices credit indices, and other financial or non-financial subjects (Zhao 2022). Structured deposits are not ordinary deposits and are different from bank wealth management. Structured deposits are embedded in financial derivatives based on deposits, and are linked to the fluctuations of interest rates, exchange rates, indices, etc., so that depositors can obtain higher returns based on bearing certain risks.

The pricing method is one of the important problems in the study of structured products, and also one of the difficulties in the study of structured products. Domestic scholars have adopted different research methods to analyze the pricing situation and influencing factors of products. In 2007, Li Chang selected two foreign currency range products issued by different banks, applied the GARCH model and Monte Carlo simulation, and studied the pricing methods, income characteristics, and the sources of price differences of the two products based on

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modern option pricing theory (Zhang 2022). In 2011, Liu Fengqin decomposed the value of structured foreign exchange deposits based on the combination decomposition principle of financial engineering and believed that the value of the ordinary interest-bearing part could be calculated by the Monte Carlo simulation method, while the part that could be redeemed in advance should be priced by the improved least squares Monte Carlo simulation method (Zhang 2023). In 2012, Ma Ying took a structured product of Everbright Bank as an example, conducted a pricing analysis with the Monte Carlo simulation method, found that it was issued at a premium, and concluded that the reason for this was caused by the procedure fees charged by the bank and the compensation charged to cover its risks (Wang 2023). In 2018, Chen Tingting et al. studied the pricing of exchange-linked structured deposits, used the principle of no arbitrage to construct a partial differential equation suitable for product value, and gave the pricing formula in the paper (Sang 2022). In 2020, Feng Ling et al. calculated the theoretical value of equity-linked products based on quantum field theory, and the results showed that the forward interest rate calculated by the quantum field theory model was closer to the Chinese financial market with better goodness-of-fit (Zhang 2022).

Due to the release of new regulations on capital management, capital protection financial products have gradually withdrawn from the market, while structured deposits can fill the gap in the market and meet the needs of investors. However, the development time of structural deposits in China is relatively short, and investors do not have a good understanding of structural deposits, and the income of structural deposits, which leads to blind investment.

This paper will study the pricing of a class of self-redemption structured deposits in a variety of market environments to give investors a more comprehensive perspective. The purpose of this paper is to provide some help for investors' deposit selection.

2 GUANGFA BANK ZZGYCAO1613 STRUCTURAL DEPOSIT DETAILS

2.1 Product Introduction

The product has two exercise prices, K_1 and K_2; There are three expected annualized returns, namely r_1, r_2 and r_3 ($r_1 > r_2 > r_3$); There are i observation days and the fixing price of the underlying object on observation day (i) is denoted as $i_1 - i_n$; The product principal is C. Structured deposit income is R. The actual term of structured deposits is t. There are two revenue scenarios for the product:

1. The structured deposit will automatically terminate and stop observation, and the structured deposit will in principle return the principal and the corresponding structured deposit income to the investor on the first early termination maturity date. The calculation is as follows:

$$R=C\times r_1\times t/365 \quad (1)$$

2. The structured deposit matures naturally, and in principle returns the principal and the corresponding structured deposit income to the investor on the maturity date of the structured deposit. The calculation is as follows:

$$i_{n+1} \geq K_2, R=C\times r_2\times t/365 \quad (2)$$

$$i_{n+1} < K_2, R=C\times r_3\times t/365 \quad (3)$$

2.2 Case Product Introduction

The selected case product is the bullish automatic redemption 276 days structured deposit ZZGYCAAO1613 product of Guangfa Bank. As shown in Table 1, the basic information of bullish automatic redemption 276 days structured deposit ZZGYCAAO1613 product of Guangfa Bank.

Table 1: Basic Product Information.

product name	"Guangyin Wealth creation" section D The 362 RMB structural deposit in 2023
hook mark	China Securities 500 Index
subscription	￥10,000.00, the amount above the subscription starting point should be an integral multiple of ￥1,000.00
earnings	It is linked to the price level of the CIS 500
expected annualized rate of return	0.5% or 2.7% or 3.9%
issuance size	The lower limit is ￥10，000，000.00 The upper limit is ￥100，000，000.00

subscription Period	2023.11.20-2023.11.26
launch day	2023.11.28
due day	2024.08.30
deposit term	276 days
structured deposit trading day	186 days
exercise prices 1	Opening price*100.01%
exercise prices 2	Opening price*97.0%
early termination triggers the condition	The fixing price of the underlying object on the observation date (i) ($i \leq 8$) is higher than or equal to the exercise prices 1
earnings are calculated on a basis	A/365

Data source: Guangfa Bank official website collation

As shown in Table 2, Guangfa Bank's call automatic redemption 276 days structured deposit ZZGYCAAO1613 product observation date and structured deposit trading day.

Table 2: Product Observation Date and Structured Deposit Trading Day.

i	observation date	trading day
1	2024.01.03	26
2	2024.01.30	45
3	2024.02.20	55
4	2024.03.19	75
5	2024.04.23	99
6	2024.05.21	116
7	2024.06.25	138
8	2024.07.29	162

As shown in Figure 1, the income information of the 276-day structured deposit ZZGYCAAO1613 of Guangfa Bank.

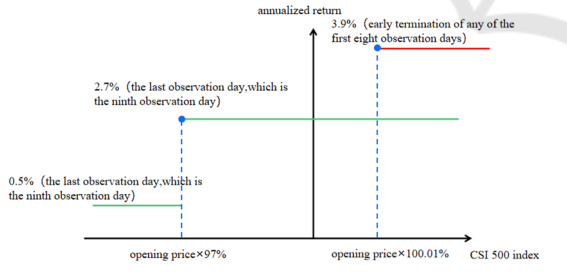

Figure 1: Product Revenue Information (Original).

The yield of this product is linked to the price of China Securities 500.

On the i (i = 1,2,3,4,5,6,7,8) observation day, if an early termination trigger event occurs, the structured deposit will automatically terminate and stop observation, in principle, the structured deposit will return the principal and corresponding structured deposit income to the investor on the i (l) early termination maturity date. Investors' return on structured deposits is calculated as follows:

Expected annualized returns = 3.9000%.

Revenue = principal × 3.9000% × the actual term of structured deposits / 365.

If no early termination trigger event occurs for the structured deposit, the structured deposit matures naturally, and in principle, the principal and the corresponding structured deposit income will be returned to the investor on the maturity date of the structured deposit. The calculation is as follows:

If on the product observation date (i = 9), the underlying closing price is greater than or equal to the exercise prices 2, expected annualized returns = 2.7000%.

If on the product observation date (i = 9), the underlying closing price is less than or equal to the exercise prices 2, expected annualized returns = 0.5000%.

Revenue = principal × 3.9000% × the actual term of structured deposits / 365.

3 MONTE CARLO SIMULATION

This paper will simulate nine different market environments in Monte Carlo. The parameters are:

μ is the expected annual return on the underlying asset, $\mu_1 = -2\%, \mu_2 = 0\%, \mu_3 = 2\%$;

σ is the annual volatility of the underlying asset, $\sigma_1 = 1\%, \sigma_2 = 5\%, \sigma_3 = 10\%$.

$S_0 = 100, K_1 = 110/100, K_2 = 90/100, r_1 = 4\%, r_2 = 3\%, r_3 = 0.5\%$.

A total of 250 days were simulated, with observation days 26, 46, 66, 86, 106, 126, 146, 166 and 186.

The main idea of Monte Carlo simulation is to classify the price movement of the underlying asset into different computation values ($S_1, S_2 ... S_T$). At time within the term, the underlying asset price at each time node is predicted by the following price formula (Li 2022):

$$S_{t+\Delta t} = S_t \exp[(\mu - \frac{\sigma^2}{2})\Delta t + \sigma\varepsilon_t\sqrt{\Delta t} \quad (4)$$

Using the Monte Carlo simulation method to simulate the underlying asset price steps are as follows:

1. Generate random numbers through Python software, and calculate the closing price of the second trading day according to the formula (4), and obtain the closing price of the second day. Based on this, the closing price of each trading day within the term of the product is obtained.

2. Repeat Step 1 for 10,000 times. According to the return determination method in the above part, the probability, annual expected return rate, and the annual volatility of the three scenarios are determined.

4 RESULT

4.1 Monte Carlo Simulation Result

Based on the methodology described above, the results obtained are shown in Table 3.

When μ remains the same and σ continues to rise, the expected annual rate of return will decline, but when $\mu = \mu_3$, the expected annual rate of return will first rise and the decline. The annual volatility decreases gradually, but when $\mu = \mu_1$, the annual volatility increases gradually.

When σ remains the same and μ continues to rise, the expected annual rate of return will first rise and then decline. the annual volatility also goes up and then down.

In these nine market environments, the annual expected annual rate of return is highest when $\mu = \mu_2 = 0\%$, $\sigma = \sigma_1 = 1\%$.

4.2 Sensitivity Analysis

By changing the values of K_1 and K_2, the annual expected rate of return and annual volatility are observed, and the sensitivity analysis is carried out. As shown in Figure 2, the annual expected return rate of K_1.

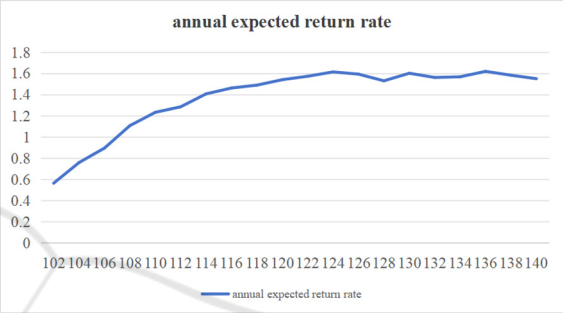

Figure 2: The annual expected return rate of K_1 (Original).

As shown in figure 3, the annual volatility of K_1.

Table 3: Simulation Result.

	μ_1, σ_1	μ_1, σ_2	μ_1, σ_3	μ_2, σ_1	μ_2, σ_2	μ_2, σ_3	μ_3, σ_1	μ_3, σ_2	μ_3, σ_3
The probability of early termination	0	7	28.4	49.6	77.5	75.1	100	100	99.9
The probability of a high yield on maturity	0	0	0	22.9	0.7	0	0	0	0
The probability of a low yield on maturity	100	93	71.6	27.5	21.8	24.9	0	0	0.1
Expected annual rate of return	0.3425	0.3262	0.2828	1.2311	0.4389	0.3175	0.0792	0.1098	0.1852
Expected annual rate of return upon early termination	nan	0.1096	0.1324	1.3436	0.4514	0.3092	0.0792	0.1098	0.1852
Expected annual rate of return for high yield at maturity	2.0548	2.0548	2.0548	2.0548	2.0548	2.0548	2.0548	2.0548	2.0548
Expected annual rate of return for low yield at maturity	0.3425	0.3425	0.3425	0.3425	0.3425	0.3425	0.3425	0.3425	0.3425
Annual volatility	0	0.0639	0.1276	0.8568	0.5397	0.4405	0.0272	0.0831	0.2327
Annual volatility upon early termination	nan	0.0888	0.1604	0.8464	0.5911	0.5081	0.0272	0.0831	0.2327

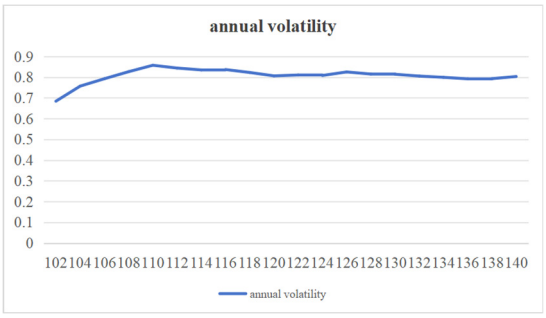

Figure 3: The annual expected return rate of K_2 (Original).

As shown in figure 4, the annual expected return rate of K_2.

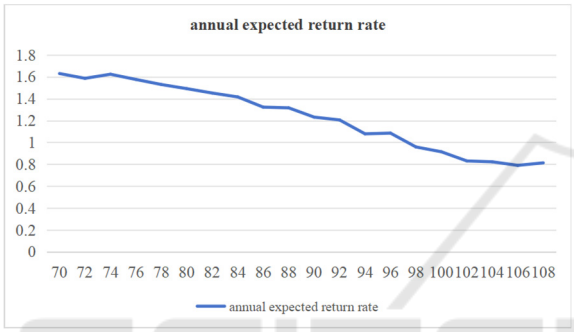

Figure 4: The annual expected return rate of K_2 (Original).

As shown in figure 5, the annual volatility of K_2.

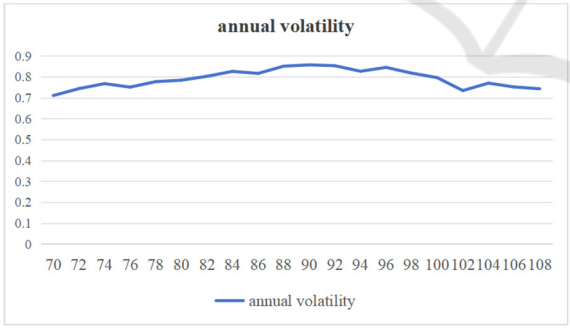

Figure 5: The annual volatility of K_2(Original).

The results show that the annual expected rate of return is positively correlated with K_1 and negatively correlated with K_2. and it have no significant impact on the annual volatility, indicating that K_1 and K_2 have no linear relationship with the annual volatility.

The sensitivity analysis of this paper is mainly to study how the annual expected rate of return and the annual volatility of structured deposit products are affected by single factor fluctuations. After a single factor sensitivity analysis, investors should pay special attention to certain factors when buying structured deposit products. In the above analysis of the return of structured deposit products, it can be seen that the exercise price 1 and exercise price 2 of the product are relatively analysis of this paper takes these two factors as research objects.

5 CONCLUSION

This paper selects nine different market environments, uses Monte Carlo method to simulate the structured deposit products in different market environments, and obtains its the annual rate of return and the annual volatility. The sensitivity analysis of exercise price 1 and exercise price 2 shows that exercise prices 1 is positively correlated to the annual expected rate of return, and exercise price 2 is negatively correlated to the annual expected rate of return, and the two are unrelated to the annual volatility. Therefore, both investors and banks need to pay more attention to the impact of the exercise price on the annual expected return. This paper first makes a brief introduction to the income methods of structured deposit products, so the investors can better understand structured deposit products. Secondly, results are obtained under different market conditions, and sensitivity analysis is carried out so that banks can refer to them when designing products. Finally, this study is only a single linked object, which can analyzed in different investment portfolios in the future, to obtain greater benefits.

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