

The Design and Pricing of a Bull Shark Fin Structured Deposit Linked to the CSI 500 ESG Value Index

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Abstract. In recent years, the concept of sustainable development has gained increasing recognition among the public. Investors are no longer solely focused on investment returns but are also paying closer attention to corporate performance in environmental, social, and governance (ESG) aspects. The ESG investment philosophy emphasizes incorporating environmental, social, and corporate governance factors into investment decisions, aiming for long-term sustainable returns. With the advancement of global sustainable development goals and the growing awareness of investor responsibility, the scale of ESG investments has expanded rapidly, gradually becoming a mainstream investment strategy. Against this backdrop, the ESG investment philosophy has risen swiftly, and related financial products have flourished. As an investment product that balances risk and return, structured deposits have gained significant popularity among investors in recent years. Structured deposits, as innovative financial products, combine traditional deposits with financial derivatives. They not only offer returns higher than those of traditional deposits but also effectively manage risks through embedded options, meeting investors' dual needs for yield and security in a low-interest-rate environment. Among these, structured deposits linked to ESG-themed indices, such as the CSI 500 ESG Value Index, provide investors with a new choice that balances social responsibility and wealth appreciation.

Keywords: Structured Deposit, CSI 500 ESG Value, Shark Fin.

1. Introduction

In recent years, with the deepening advancement of sustainable development concepts, China has placed increasing emphasis on ESG. Since the Asset Management Association of China initiated ESG research in 2017, relevant policies and standards have been gradually refined. In 2021, ESG was incorporated into the key tasks of corporate social responsibility, and the "Work Plan for Improving the Quality of Central State-Owned Enterprise-Controlled Listed Companies" issued by the State-owned Assets Supervision and Administration Commission in 2022 emphasized corporate governance and financial quality, indirectly encouraging listed companies to prioritize ESG. In July of the same year, the China ESG Research Institute launched research on corporate ESG evaluation systems and formally promulgated the "Corporate ESG Evaluation System" in November. Additionally, the group standard "Guidelines for Corporate ESG Report Compilation" was also released in November. These measures reflect China's determination to promote green development, aiming to incentivize enterprises to actively assume environmental responsibilities while achieving economic benefits, drive green transformation to address increasingly severe environmental issues, and realize high-quality development goals.

The emergence of structured financial products in China can be traced back to September 2002, when China Everbright Bank issued the first foreign currency structured deposit. In August of the following year, China Construction Bank issued an individual foreign exchange structured deposit, forming the prototype of structured financial products in China. In 2006, China's stock market entered a phase of explosive growth, significantly driving the issuance of stock-linked wealth management products by commercial banks. Subsequently, in November 2017, the China Securities Regulatory Commission, the People's Bank of China, the State Administration of Foreign Exchange, and the China Banking and Insurance Regulatory Commission jointly issued the "Guiding Opinions on Regulating Asset Management Business of Financial Institutions (Draft for Comments)," which stipulated that banks' non-principal-guaranteed and other equity-type products are off-balance-sheet

operations and that banks are not allowed to use "bottom-lining" methods for debt financing in the event of a debt crisis. Meanwhile, as investors' awareness of investment has grown, their demands for investments have also increased. Consequently, the traditional form of savings alone can no longer meet investors' needs for both appreciation and capital preservation. Within their acceptable risk range, they are willing to explore more financial instruments, such as high-leverage derivatives. The characteristics and trading structures of structured deposits precisely meet investors' desire to experiment with diverse investments, which is why they have gained favor among investors and banks in recent years. Literature Review.

2. Literature Review

Foreign scholars' research on structured financial products linked to *Broussonetia papyrifera* has gradually expanded based on the continuous development and refinement of option pricing theory. Therefore, early studies primarily focused on theoretical pricing research. Subsequently, with the continuous improvement of option pricing models and theories, as well as the widespread application of numerical pricing methods such as Monte Carlo and binomial trees in the pricing of various exotic options like Parazacco sp. *spilurus* subsp. *spilurus*, empirical research literature on the pricing of structured financial products linked to *Broussonetia papyrifera* by foreign scholars has become increasingly abundant. The pricing approach is generally based on a decomposition method, splitting the product into fixed-income and derivative components for separate pricing. The fixed-income part is typically priced using discounted cash flow models, while derivative pricing methods are highly flexible, including analytical solutions based on the B-S model, numerical pricing research, and martingale pricing studies for structured financial products linked to *Broussonetia papyrifera*. There is relatively little literature on the design of structured products linked to *Broussonetia papyrifera*. Overall, given the mature capital markets and diverse product offerings abroad, foreign research in this field started earlier and has established a relatively mature theoretical system in pricing research.

Domestic academic research on structured financial products linked to *Broussonetia papyrifera* mainly focuses on pricing and design. Pricing methods largely draw on mainstream foreign pricing models, while product design studies often analyze the shortcomings of existing product terms and propose innovations to redesign new structured financial products linked to *Broussonetia papyrifera* that cater to investor needs. The industry primarily focuses on the pricing and hedging issues of popular products, such as snowball structured products linked to *Broussonetia papyrifera*. In recent years, research has seen an emergence of various structured products linked to *Broussonetia papyrifera* with different return types, and the underlying assets have also become increasingly diversified.

3. Pricing Model Overview

(1) Fixed Income Pricing Model

In structured wealth management products, the pricing of fixed-income components follows a relatively straightforward approach. These fixed-income investments typically include government bonds, central bank bills, and bank certificates of deposit. The pricing methodology aligns with bond valuation principles, employing the discounted cash flow (DCF) method. This involves calculating the present value of expected cash flows generated by the fixed-income portion at maturity, based on the product's principal amount and maturity period, by applying an appropriate discount rate. The specific formula for the DCF model is as follows:

$$V = \frac{P}{(1+r)^T} + \sum_{i=1}^T \frac{I_i}{(1+r)^i}$$

For fixed-income securities valuation, P denotes the principal amount, r the discount rate, and T the investment period (measured in years). The i -th year represents the interest payment period. When

the interest payment period or investment term is less than one year, both the yield and investment period must be converted into effective annual rates and annualized terms.

(2) Monte Carlo simulation pricing model

The Monte Carlo simulation method, developed by American mathematicians, is a statistical modeling technique that has made significant contributions to financial fields such as option pricing models and default risk analysis. This approach utilizes risk-neutral theory, where multiple asset price paths are simulated under risk-neutral conditions. By calculating the average returns of options across these paths and discounting them, the option value can be determined. The most commonly used model in Monte Carlo simulations is the geometric Brownian motion. This model assumes that future outcomes are independent of historical data, meaning all past information is already embedded in asset prices. In a risk-neutral environment, asset price movements follow geometric Brownian motion, with the following formula:

$$dS_t = rS_t dt + \sigma S_t dZ_t$$

Here, S_t denotes the price of the underlying asset, which is a function of time; r represents the expected return on the asset price, while σ indicates the volatility of the asset price per unit time. dZ_t denotes the standard Brownian motion process, and $\sigma S_t dZ_t$ represents the stochastic volatility term. In the financial option pricing theory, it is assumed that the price of the underlying asset follows the log-normal distribution. Therefore, the above formula is processed by logarithm, and the Ito lemma can be combined to obtain:

$$\ln S(t + \Delta t) - \ln S(t) = \left(r - \frac{\sigma^2}{2}\right)\Delta t + \sigma dW$$

Thus, the formula for the price change of the underlying asset is:

$$S(t + \Delta t) = S(t)\exp\left[\left(r - \frac{\sigma^2}{2}\right)\Delta t + \sigma dW\right]$$

4. Products design

This product incorporates an upward knock-out call option, which adds an exercise price to the standard call option. Specifically, it establishes a barrier price higher than the strike price. If the underlying asset's closing price never triggers the knock-out condition during the term, the expiration price is calculated as the standard call option. However, if the closing price triggers the knock-out condition on any day, the option is immediately exercised, yielding only the minimum return. The product is designed to be linked to the CSI 500ESG Benchmark Index "Shark Fin" Structured Deposit, which adds an upward knock-out call option to the fixed income. This structure enhances the potential for higher returns beyond the guaranteed base yield. Based on the analysis of the characteristics of different fixed income securities and the existing research, this paper selects the bank time deposit as the investment target of fixed income securities, which is determined by the characteristics of the bonds.

Structured wealth management products typically incorporate multiple financial derivatives—including forward contracts, futures contracts, options, and swaps—to achieve specific risk-return objectives. Among these, options have become the most widely used due to their flexibility and versatility. Options can be categorized into various types based on their design structures and return characteristics, such as call options, put options, Asian options, rainbow options, and shark fin options. Different option types confer distinct risk-return profiles to structured products. Even when using the same fixed-income securities and underlying assets, the final maturity returns may vary depending on the option type selected. Shark fin options, in particular, offer a unique combination of risk control and higher return potential. Their specialized return structure caters to investors with specific risk preferences. By embedding shark fin options, financial institutions can design more attractive and market-aligned structured wealth management products.

Table 1. Product introduction

product name	Winning every month
Hanging Object	China Securities 500ESG Value Index
Product Properties	Floating return with principal protection
Subscription threshold	10,000 dollars, increasing by 1,000 dollars
Founded	July 12,2024
date due	October 10,2024
Product Term	90 days
product mix	Bull shark fin structure
Initial price	Set the closing price of the underlying asset
End-of-period price	The closing price of the linked target is linked to the end date of the observation period
observation period	The day before the product expires from the date of establishment
strike price	Beginning price × 100%
Remove price	Initial price × 106%
Strike yield (annualized)	4%
Minimum yield (annualized)	1.5%
Highest yield (annualized)	6.3%
participation rate	80%
Income calculation basis	Product Term/365
Maturity year yield calculation rules	1. If the ratio of the closing price of the linked asset during the product observation period to the closing price on the product's inception date exceeds the strike price, the annualized yield equals the knock-out yield. 2. If the ratio of the closing price of the linked asset during the observation period to the initial price of the underlying asset is below the strike price, the annualized yield calculation rules are as follows: (1) If the ratio of the closing price of the linked asset to the initial price on the observation date is below the exercise price, the annualized yield equals the minimum yield (the calculated annualized yield is rounded to two decimal places, discarding the third digit and subsequent digits). (2) If the ratio of the closing price of the linked underlying asset on the product observation date to the closing price of the underlying asset is not less than the exercise price, the annualized yield of the product equals the minimum yield plus the participation rate multiplied by (the closing price of the linked underlying asset on the product observation date / the initial price of the underlying asset minus the exercise price).
Subscription/Purchase	No subscription/redemption is available during the term

4.1. Product Pricing Analysis

Using the CSMAR database, this study selected the closing prices of the CSI 500ESG Value Index (code: 931661) for each trading day from April 12, 2021 to July 12, 2024 as observation data, totaling 790 historical data points.

(1) Descriptive statistics: As shown in the figure below, the CSI 500ESG Value Index contains 790 observations. The price range spans from 850 to 1269, with a mean of 1054.

Date	Price
Length: 790	Min. : 850
Class : character	1st Qu. : 1009
Mode : character	Median : 1050
	Mean : 1054
	3rd Qu. : 1108
	Max. : 1269

Figure 1. Descriptive statistics

(2) ADF test: This section illustrates the distribution of residuals, which represent the discrepancy between a model's predicted values and actual observed values.

The fact that the median is close to 0 indicates that the residual distribution is approximately symmetric. The coefficient estimates for z.lag.1 is -0.97218. This means that for every one-unit increase in the first-order lagged value of z, the difference in z is expected to decrease by 0.97218 units. The standard error of the coefficient estimate is 0.03562. The t-statistic is -27.29, which is significant. The p-value is less than 2e-16, far below 0.05, indicating that the coefficient for z.lag.1 is highly significant. The standard error of the residuals is 0.01115, representing the average difference between the model's predicted values and the actual observed values for Parazacco spilurus subsp. spilurus. The Multiple R-squared is 0.486, indicating that the model explains 48.6% of the variation in the differences of z. The Adjusted R-squared is 0.4853. The F-statistic is 745. The p-value is less than 2.2e-16, indicating that the model is highly significant. The value of the test-statistic is -27.2942. Since the test statistic is far below all critical values, the null hypothesis of a unit root can be rejected, suggesting that the time series data is stationary.

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Call:
lm(formula = z.diff ~ z.lag.1 - 1)

Residuals:
    Min       1Q   Median       3Q      Max
-0.060217 -0.005760  0.000018  0.005924  0.069688

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
z.lag.1 -0.96966     0.03542  -27.37  <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01116 on 798 degrees of freedom
Multiple R-squared:  0.4843,    Adjusted R-squared:  0.4836
F-statistic: 749.3 on 1 and 798 DF,  p-value: < 2.2e-16

Value of test-statistic is: -27.3726

Critical values for test statistics:
      1pct  5pct 10pct
tau1 -2.58 -1.95 -1.62
```

Figure 2. ADF inspection

4.2. Data Selection

When determining the risk-free interest rate, the following factors can primarily be considered: the interbank offered rate, the yield to maturity of government bonds, the benchmark interest rate for homo sapiens RMB deposits, and so on. This paper selects the yield to maturity of one-year government bonds in 2024, $r=1.35\%$, as the risk-free interest rate.

There are various methods to determine volatility. This paper approximates the volatility during the product investment period by calculating the historical volatility of the selected sample data. For the chosen sample period, assuming the actual trading days are $n+1$, the closing prices of the CSI 500 ESG value during this period are denoted as S_i ($i=0,1,\dots,n$), and the daily logarithmic return rate $isr_i = \ln \frac{S_i}{S_{i-1}}$. The estimated standard deviation of the yield is $ss = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (r_i - \frac{1}{n} \sum_{i=1}^n r_i)^2}$. From this, the daily standard deviation is calculated to be 0.01112, and the number of trading days in a year is about 252, which is converted into the annual standard deviation, or the annual volatility, is 0.1780.

The fixed income portion of structured deposit products is mainly invested in fixed income assets with minimal risk, such as government bonds, central bank bills, and bank certificates of deposit. The pricing of structured deposit products is mainly based on the cash flow discount model, and the discount rate is the risk-free yield in the market. The specific formula is as follows:

$$V = \frac{P}{(1+r)^T} + \sum_{i=1}^T \frac{I_i}{(1+r)^i}$$

If the continuous compound interest pricing method is used, the asset pricing formula is as follows:

$$V = Pe^{-rT} = 10000 \times e^{-1.35\% \frac{90}{365}} = 9966.7677$$

Currently, the pricing of options primarily employs the B-S model, binary tree model, and Monte Carlo simulation methods. This paper adopts the more convenient Monte Carlo simulation method to price the option. The principle of Monte Carlo simulation method has been mentioned above, so this part will not be elaborated. This section mainly explains the specific steps and precautions of Monte Carlo simulation method:

(1) Starting from the initial price, substitute the first random number 1 into the asset price equation to calculate the price at time t. Then, using the price at time t and the second randomly drawn number 2, compute the price at time 2t. Repeating this process N times yields a simulated path of price movements.

(2) Obtain the option return under this path according to the calculation method of product yield.

(3) Tens of thousands of repeated simulations were performed to obtain tens of thousands of simulated paths and option returns.

(4) The average of the returns of tens of thousands of options is calculated to obtain the option value, and the present value of the option is obtained by discounting with the risk-free interest rate.

4.3. China Securities 500ESG Value Index Price Simulation

To simulate asset price paths in Monte Carlo, this study employs MATLAB. Through a series of code computations, we conducted 10,000 simulations of the asset price trajectory over the next 90 trading days, as illustrated in the figure below.

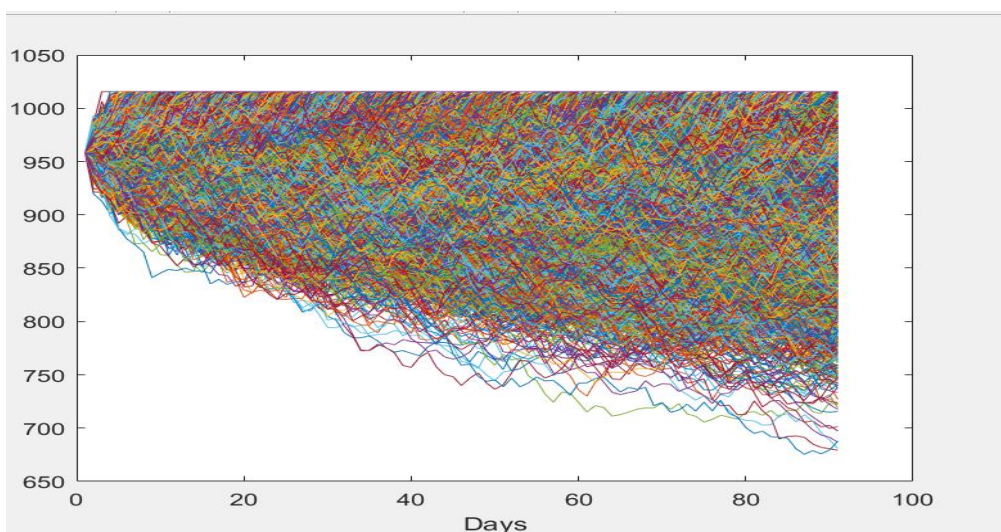


Figure 3. Monte Carlo simulation

All simulated end-of-period prices are stored in a matrix. Each path's end-of-period price is then compared with the preset price range, counted, and probability calculated as shown in the table below. The corresponding yields are calculated based on different yield functions for each price range, and the final weighted average yield is 1.38%.

Table 2. Three Scheme comparing

price range	$<S_0$	$>S_0 \text{ and } <S_0 * 1.06$	$>S_0 * 1.06$
count	4385	2524	3091
probability	0.44	0.25	0.31

Based on the option pricing formula $V_0 = F \times R \times e^{-rt}$, here, V_0 denotes the partial value of the option, F represents the investor's subscription amount, and T is measured in years. Substituting these values yields the option value as:

$$V_0 = F \times R \times e^{-rt} = 34.0868$$

4.4. Determine the total product value

The final value of the fixed income portion is $V_b=9966.7677$. After averaging the option values from multiple simulations, the option portion's value is determined as $V_0=34.0868$.

$$V=V_b+V_0=9966.7677+34.0868=10002.8525$$

Therefore, the theoretical value of the structured deposit purchased by the customer with an investment of 10,000 dollars is 10,002.8525 dollars. In summary, the price of this product is 10,000 dollars, and its theoretical value is 10,002.8525 dollars, which is issued at a discount rate of 0.0285%, which is a reasonable level.

5. Summary

This paper focuses on designing a principal-protected wealth management product that balances the interests of investors and banks. The research begins with a systematic review of domestic and international literature, followed by an innovative risk classification of wealth management products based on existing studies. Building on this foundation, in-depth analysis of relevant theories provides a solid theoretical basis for product design. In the product structure design, to ensure controllable risks and reasonable returns, we ultimately selected a combination of book-entry discount treasury bonds and shark-fin call options. We conducted in-depth analysis and established key parameters including maturity periods and participation rates. Different risk-tiered products were designed based on varying participation rates, with corresponding product brochures prepared for each tier. In terms of product pricing, the study adopts cash flow discount method and Monte Carlo simulation method to analyze the pricing of fixed income and financial derivatives. The results show that these financial products are issued at a reasonable discount range. Of course, the research also has some shortcomings. For example, in the empirical analysis of Monte Carlo simulation pricing, the determination of the underlying asset price volatility depends on historical data, and the future volatility may differ from historical data. In conclusion, this paper provides valuable references for designing capital-protected wealth management products that balance the interests of investors and banks. Future research could further explore more precise pricing models and risk management methods to continuously optimize product design and better meet market demands.

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