Analysis of the Pricing of Structured Products Linked to China Securities Index 300 index

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Abstract. Under the situation that the actual return of residential deposits is low or even negative due to the current bank interest rate, structured products have gained the favor of the market by means of their fixed income part of capital preservation and low risk and financial derivatives part of pursuing income. In this paper, the structured deposits linked to China Securities Index (CSI) 300 index are selected for pricing, and the value of the products is divided into fixed income and option parts. Based on Monte Carlo simulation, the Geometric Brownian Motion (GBM) model is verified by Augmented Dickey-Fuller (ADF) test, log-return autocorrelation and normal distribution test, and Autoregressive Conditional Heteroskedasticity - Lagrange Multiplier (ARCH-LM) test for pricing analysis, and the average annualized return of the whole sample is 1.39%. The total present value of the option part is 2362.19 yuan, and the discounted present value of the principal is 997,557.66 yuan. The principal is preserved, and the product is sold at a discount of 80.15. The bank holds a conservative pricing strategy for it, with a higher expected income elasticity of the target and a higher cost performance of the income game, which can effectively replace time deposits. The pricing strategy in this paper can be used for banks' risk control and hedging, product architecture design, and consumer's rational investment decisions.

Keywords: Pricing of Structured Products, China Securities Index 300 Index, Monte Carlo Simulation.

1 Introduction

As China's economy steadily advances towards the stage of high-quality development, residents' wealth continues to accumulate. Against the macroeconomic backdrop of increasing global market volatility, persistent low domestic interest rates, and moderate inflation, the demand of ordinary residents for asset preservation and appreciation has become increasingly prominent. A variety of cumulative structured products, with their unique characteristics, can effectively meet part of the financial management needs in this context. Among them, products linked to the CSI 300 Index have emerged as the mainstream choice in the market.

In 2025, the interest rate for three-year time deposits in China was only 1.55%, while the growth rate of the consumer price index remained at around 3% during the same

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period. A comparative analysis shows that the real return on bank deposits was in a negative state. Under such circumstances, selecting an appropriate financial management method has become a prominent issue confronting current residents.

At present, the investment returns of structured products offered by commercial banks in China fluctuate significantly, and some investors have relatively weak awareness of investment risks, which further increases the uncertainty of investment returns. Against this backdrop, many residents adopt conservative investment strategies, adhere to the traditional perception that savings deposits carry low risks, and allocate most of their assets to bank deposits. Meanwhile, some groups turn to financial products such as stocks, funds, and bonds, implementing diversified asset allocation through portfolio investment in an attempt to balance risks and returns and achieve net asset growth. In recent years, the proportion of equity assets in residents' financial assets has risen to 15%, which proves that diversified investment conforms to the trend of the times. Among the structured products discussed in this paper, stock index-linked products have accounted for a large proportion in recent years. Among all stock index-linked products, the underlying target is usually the CSI 300 Index, while products linked to other assets account for a relatively small share. This paper chooses to conduct case study in theory, model the product and analyze the rationality and risk, and conduct pricing through Monte Carlo simulation. Starting from the observation frequency, barrier price and other factors, multi-angle risk analysis is beneficial to enrich the risk analysis system; In practice, it helps financial institutions improve product competitiveness, helps investors reduce information asymmetry, assists investment decisions, and provides reference for product supervision and market norms for government regulators [1].

2 Literature Review

In recent years, the pricing theory of structured products has broken through the limitations of traditional single-factor models, achieved breakthroughs in the direction of multi-dimensional integration, and significantly enhanced its adaptability to complex market environments. In terms of model framework optimization, some scholars have proposed a Bayesian Markov Chain Monte Carlo (MCMC) estimation scheme. Leveraging the flexibility of Bayesian probabilistic inference and the advantages of MCMC numerical simulation, this scheme has broken the parameter dependence of traditional models on specific portfolios, provided a unified modeling paradigm for various market anomalies such as volatility clustering and return skewness, and expanded the application scope of the theory. For the pricing of inflation-linked products, relevant studies have constructed a forward inflation index model with a multi-factor volatility structure, captured the volatility skewness characteristics through a leverage function, and calibrated the correlation among inflation indexes with different maturities, thereby making up for the deficiency of traditional models in describing dynamic volatility. In addition, the integration of artificial intelligence and pricing theory has gradually become a prominent trend. Sharma et al. established an integrated system for distributed reinforcement learning-based pricing and hedging of

multi-target note automatic redemption. Compared with the traditional Monte Carlo simulation method, this system significantly improves valuation efficiency; the optimized hedging portfolio also demonstrates greater advantages in tail risk prevention and control, realizing the simultaneous improvement of efficiency and risk control capabilities.

The development of pricing methods highlights the characteristics of differentiated and accurate adaptation to product structures, as well as the formulation of exclusive optimization schemes for the pain points of different types of products. For auto-callable products with strong path dependence and complex terms, scholars proposed an integrated pricing and hedging scheme based on the Continuous-Time Markov Chain (CTMC) [2]. This scheme can not only efficiently address complex dynamic characteristics such as local stochastic volatility but also provide systematic optimization ideas for dynamic hedging under scenarios involving transaction costs, thereby realizing the full-lifecycle valuation and risk control of products. The pricing of inflation-linked derivatives focuses on the quantification of time-delay effects and implicit costs.

Monte Carlo simulation remains the core method for pricing structured products, owing to its adaptability to complex path dependence and nonlinear characteristics. However, the focus of its optimization has shifted from traditional variance reduction techniques to the dual upgrading of efficiency improvement and intelligent empowerment. Traditional variance reduction methods continuously reduce simulation errors through iterative optimization via strategies such as path stratification and control variables. Path generation technology integrated with machine learning has emerged as a new research direction. By leveraging neural networks to explore the operational logic of asset prices, this technology can significantly reduce the number of simulation paths required to achieve standard accuracy and lower computational costs. Relevant studies have confirmed that such intelligent simulation methods exhibit excellent out-of-sample fitting performance in the pricing of complex derivatives, enabling efficiency improvement while ensuring valuation stability and providing technical support for the rapid pricing of highly complex products.

At present, the pricing research theory of structured products still faces three bottlenecks to be solved: first, the dynamic coupling of credit and market risk lacks a unified and efficient modeling framework, and it is difficult to accurately quantify and integrate multiple risks. Second, the risk accumulation mechanism of mainstream products such as snowball structure has not formed a transparent and quantifiable pricing evaluation system. Third, the "black box" problem of machine learning pricing model is prominent, and the interpretability and robustness in extreme markets still need to be strengthened. Future research needs to focus on multi-dimensional risk coupling mechanisms, risk analysis of complex products, interpretable design of Artificial Intelligence (AI) model, find a balance between valuation accuracy, computational efficiency and risk explanatory power, and provide theoretical and technical support for the steady development of structured product market.

3 Data Source and Preparation

A total of 729 closing price data of CSI 300(0003000.SH) from December 19, 2022, to December 19, 2025, are selected. The overall fluctuation and rise and fall trend of Shanghai CSI 300 index in the past 4 years can be analyzed from it, which is used to calculate the annualized volatility and determine whether the simulated index falls into the range to calculate the cumulative return of options. From the Oriental Wealth choice terminal, the index annualized dividend yield is 3.089%, which is used for Monte Carlo simulation. From the official website of the Ministry of Finance, PRC, the three-month yield of the MOF - China Treasury Bond yield curve on December 2, 2025, was 1.45%, which was used for the present value calculation of risk-free bonds and Monte Carlo simulation (Table 1). Tail volatility is the annualized volatility of 5% extreme returns up/down, and the tail volatility is 43.55% calculated from all closing prices of CSI 300 index in the past three years.

Table 1. Required variables for Monte Carlo simulation.

Name of variable	Name of variable	Numerical value
Principal amount	P	1000000
Term of product	T	62 (days)
Barrier price 1	L	3643.464
Barrier price 2	U	5465.196
Number of observations	N	44
Tail volatility	σ	43.55%
Index annualized dividend yield	q	3.089%
Current point of Shanghai-Shenzhen 300	S_0	4554.33
Risk-free interest rate (continuously compounded)	R_f	1.439%

The currency of China Merchants Bank Zhiying series aggressive two-way Shark fin 62-day structured deposits (product code: PE0483) selected in this paper is RMB, which is linked to the Shanghai-Shenzhen 300 index (0003000.SH), and its floating return is determined according to the price level of the linked Shanghai-Shenzhen 300 index. China Merchants Bank stipulates the return of this product as follows: When the index price is less than barrier price 1 or greater than barrier price 2 on any day of the observation period, the return to maturity of this product is 1.22% on an annualized basis. When all index prices in the observation period are greater than barrier price 1 and less than barrier price 2 and the ending price is greater than the strike price, then the yield to maturity is accurate to the second decimal point by rounding method. When

all index prices in the observation period are greater than barrier price 1 and less than barrier price 2 and the ending price is less than the strike price, at this time, the yield to maturity is accurate to the second decimal point by rounding method.

The specific pricing method of this paper is as follows: first, the structured products linked to the CSI 300 index are disaggregated into risk-free bonds and options, and the two parts are priced separately, and then the sum is added up. When pricing the risk-free bonds, the one-year yield of China's national debt is selected as the risk-free interest rate [2]. When pricing the options, Monte Carlo simulation is used to assume that the CSI 300 index follows geometric Brownian motion, and then ADF test, autocorrelation test, normality test and ARCH-LM test are carried out [3,4]. According to the verification results, volatility scaling is introduced, the price equation is derived, and 100000 paths are regenerated to simulate the index price. The Times of falling in the predetermined range are counted, and the option maturity return is calculated, and its mean value is then discounted [5-7]. Finally, the final pricing is obtained by summing the two parts of the risk-free bond and option pricing.

4 Empirical Analysis

In this paper, the product value is decomposed into two parts: risk-free bond and an option, and they are priced separately.

Calculate the present value P_v1 of the risk-free bond: (assume that the product is 100% break-even, and if part of the break-even is the break-even amount), discounted with continuous compound interest.

$$P_{v1} = P \times e^{-R_f \times T} \tag{1}$$

Firstly, it is assumed that the CSI 300 index follows geometric Brownian motion, and the ADF test is conducted on it (Table 2). The results are shown in the following table. It can be concluded that the logarithmic price series has unit root and is a non-stationary series, so the null hypothesis cannot be rejected ($p>0.05$). After the different treatment, the log price return series has no unit root and is a stationary series, which rejects the null hypothesis ($p<0.05$), so the ADF test passes [8].

Table 2. Statistical results of ADF test.

	The ADF statistic	ADF statistics	Critical value 1%	Critical value 5%	Critical value 10%
Logarithmic price series	-0.9448	0.7728	-3.4395	-2.8656	-2.5689
Log return series	-11.2197	0	-3.4395	-2.8656	-2.5689

After the autocorrelation test, the results are as follows: Ljung-Box test (lagged 20 orders) $p=0.1320>0.05$, there is no significant autocorrelation in the series, which meets the independence assumption [9]. Then, the normality test is carried out on the log-return series, and the skewness is 0.2499, the kurtosis is 14.7016, and the excess

gracefulness is 11.7016. The statistics obtained by Shapiro-Wilk and Kolmogorov-Smirnov tests are 0.8908 and 0.0752 respectively, and the p values are 0.0000 and 0.0005 respectively, indicating that the log return rate rejects the normal distribution. Secondly, the ARCH-LM test shows that the test statistics are 191.9161, the p-value is 0.0000, the F-statistics are 12.7737, the F-test p-value is 0.0000, and the original normal distribution is rejected [10]. Tail volatility is used instead of annualized volatility for the correction [11].

$$dS_t = S_t \times \left(R_f - q\right)dt + S_t \times \sigma W_t \tag{2}$$

Secondly, the continuous geometric Brownian motion is discretized,

$$S_i = S_{i-1} \times e^{\left[\frac{\left(R_{f-q-\frac{1}{2}\sigma^2}\right)}{N}+\sigma\times\sqrt{\frac{1}{N}}\times Z_i\right]} \tag{3}$$

(Z_i is the standard normal random number of step i, and each simulation needs to generate independent Z_1-Z_n)

Monte Carlo simulations are then carried out to generate M=10000 simulated paths and calculate returns in cycles, and for each simulation: 1 index price path with N observation days is generated $\{S_1,S_2,\ldots S_N\}$, Count the number C of times the index price falls in the interval $[L, U]$ in this path,Calculate the option maturity payoff P_k for this path [11]. Add up and average the returns. By calculating the present value of the option P_{v2},Get the final pricing P_v.

Finally, the average annualized return rate of the whole sample is 1.39%, the knockout path accounts for 0.76%, the total present value of the option part is 2362.19 yuan, and the discounted present value of the principal is 997,557.66 yuan. Among them, the extremely low ratio of knock out path indicates that the probability of triggering early redemption clause of the product is small, and the stability of customer income is strong. The discounted present value of principal is close to the initial principal, highlighting the high security of product principal.

5 Conclusion

Based on a series of quantitative analyses, including the ADF stationarity test, normality test, and ARCH-LM test, it is found that the log-price series of the CSI 300 Index fails to satisfy the normality assumption and exhibits typical leptokurtic and fat-tailed characteristics. Specifically, the probability of extreme returns is significantly higher than that predicted by the normal distribution, accompanied by an obvious volatility clustering phenomenon and a significant ARCH effect. Under such circumstances, the GBM model based on historical volatility cannot achieve accurate pricing, leading to substantial deviations.

Issuers selling products in the form of premium can achieve steady profits through stable pricing spread, and the overall risk at the customer level is controllable. In the

market environment with low interest rates and inflation, it can better meet the needs of some residents with conservative risk preferences and pursuit of steady returns and take into account their core needs of avoiding risks and moderate profits. Although the pricing model is modified by tail volatility, it is still affected by ARCH effect, and there is room for improvement in the accuracy of the existing correction methods. The further introduction of GARCH family models can dynamically capture the characteristics of time-varying volatility, more thoroughly eliminate the pricing bias caused by ARCH effect, make the model fit the real market volatility, and improve the pricing accuracy. The future pricing model can focus on real-time volatility monitoring and multi-dimensional risk quantification, adjust parameter Settings in combination with the market dynamics, enhance the timeliness and adaptation of the model, and more accurately match market changes and investor needs.

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