Pricing analysis of Dong Wu Su Yuan Industry based on the pricing model of public REITs

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Abstract. Given that infrastructure public REITs in China are still in the early stage of development, this paper firstly reviews their current status from relevant sources and briefly describes their definitions, development status and main characteristics. The option-adjusted spread method based on Monte Carlo simulation is chosen as the pricing model. The term adjusted spread method needs to consider the interest rate term structure, so the CIR model is used as the interest rate term structure model for interest rate forecasting, and the three CIR parameter values obtained by fitting are brought into the CIR model using Monte Carlo method simulation to obtain 1000 forward interest rate paths, and the spot interest rate is obtained according to the forward interest rate curve path, and the spot interest rate is used to combine with the option adjusted spread OAS to discount the 1000 present values. The average value of the 1000 present values is the pricing result. Comparing the pricing result with the market value, it is found that the two are basically equal. This shows that the option-adjusted spread method based on Monte Carlo simulation can evaluate the value of public REITs more scientifically and reasonably.

Keywords: Public REITs; Option-adjusted spread model; Monte Carlo simulation; Pricing analysis.

1. Introduction

The price model of public infrastructure REITs is described in terms of pricing influencing factors, theoretical research on relevant pricing models and comparative analysis of existing REITs pricing models in the market, and then the option-adjusted spread method based on Monte Carlo simulation is selected based on the characteristics of public REITs themselves [1].

The option-adjusted spread method based on Monte Carlo simulation was used to analyze the pricing of the public REITs case-Dongwu Suyuan Industrial REIT for the selection of benchmark interest rate; to obtain the interest rate fluctuation path based on the interest rate term structure model - CIR model, in which 1000 forward interest rate paths were obtained by using Monte Carlo method simulation, and according to the forward interest rate curve path The spot rate is obtained, and the 1000 present values are obtained by combining the spot rate with the option-adjusted spread OAS[2]. The average value of the 1000 present values is the pricing result. Comparing the pricing result with the market value, it is found that the two are basically equal. This shows that the option-adjusted spread method based on Monte Carlo simulation can evaluate the value of public REITs more scientifically and reasonably.

Overall, based on the theoretical foundation of REITs and literature research, the paper outlines the situation of public REITs in China, compares the pricing models commonly used for REITs products in the market, and selects the option-adjusted spread method based on Monte Carlo simulation. Through empirical analysis, it is demonstrated that the pricing model proposed in this paper can be used for pricing public REITs, and corresponding policy recommendations are proposed from several perspectives, such as establishing a special REITs database, improving the tax preference system and laws and regulations, so as to promote the long-term and benign development of public REITs in China [3].

2. Pricing Model for Public REITs

2.1 Elements affecting the price

1. Interest rates

Changes in interest rates in the market can be caused by changes in the main international and domestic economic environment and economic developments. The value of a company is influenced by two factors: the discount rate and the cash flow. On the one hand, changes in interest rates will have a direct impact on the discount rate, and thus on the pricing valuation of REITs. The interest rate fluctuations, on the other hand, will also increase the chances of early loan repayment. In the case of a sharp drop in market interest rates, the issuer can compensate its inherent cash flow by issuing new bonds [4].

2. Early repayment

"Early repayment" means that the bond issuer pays full or partial interest to investors in advance of the bond's maturity. In times of declining market interest rates, bond issuers often choose to pay off their loans early, thereby reducing the cost of the loan and easing the burden of debt. Early repayment will have a direct impact on the uncertainty of future cash flows, which will cause price deviations. The longer the maturity of REITs, the more likely they are to be repaid early. Buying public REITs in the long term is equivalent to selling a callable option when you buy a security. So in summary, it is essential to consider this scenario.

2.2 A theoretical study of correlation pricing models

Currently, the following four pricing methods for REITs are commonly used by domestic and foreign scholars, each with its own advantages and shortcomings, and with significant differences in the applicable types [5].

1. Static discounted cash flow method (SCFY)

The static discounted cash flow method is one of the earliest methods and the simplest pricing model. This method has two assumptions: the interest rate remains constant and the borrower demonstrates a certain ability to repay early. The method uses a specific interest rate as a benchmark for predicting future cash flows in order to price them accurately. Usually, the Treasury yield is chosen as the discount rate. Its model pricing formula is.

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

Where, P denotes the theoretical price of the product, CF_i denotes the expected future cash flow in period i, r is the discount rate, and T is the number of periods at maturity. The biggest advantage of this method is the simplicity of operation, it does not take into account the early repayment rate and the volatility of interest rates in the actual calculation process, when there are fluctuations in market interest rates, the final product value will have a large estimation error, so the method does not truly reflect the risk faced by the product when pricing the product.

2. Static spread method (SS)

The static spread method is a static discounted cash flow method with the addition of interest rate risk and credit risk., it adds the static spread to the spot yield of treasury bonds as the discount rate for each period, and the model pricing formula is.

$$P = \sum_{i=1}^{T} \frac{CF_i}{(1+r+\Delta SS)^i} \tag{2}$$

3. Option Adjusted Spread Method (OAS)

In the asset securitization pricing process, the most commonly used is to choose the appropriate option-adjusted spread method, the essence of which is to assume future interest rate changes under various interest rate tracks based on changes in interest rates, and then use the option-adjusted spread and the sum of that interest rate to adjust so as to obtain a new future cash flow. On this basis, the option takes into account early repayment and interest rate risk to improve the static spread method, and the debtor tends to choose early repayment when future market interest rates fall. Lower financing costs result in higher early repayment rates [6]. Where default is a put option, early repayment is still seen as a call option. Multiple simulations of future interest rate changes are performed using Monte Carlo simulation methods, thus solving out the impact of different interest rate sensitivities on the flow of funds and weighting the cash flows under each channel to arrive at the theoretical value of the bond. Features of the option-adjusted spread approach. The first aspect is the study of the nature of the options included in asset-backed securities. The second is a comprehensive analysis of the different yield paths under the premise of duration, which is able to address the uncertainty of the impact of interest rate changes on future cash flows. The interest rate differential is obtained to ensure that the theoretical pricing obtained matches the true value in the market. By simulating a number of different interest rate trajectories, it is possible to better reflect the actual market conditions and is one of the relatively sound pricing methods at this stage. The corresponding pricing formula is as follows.

$$P = \frac{1}{n}\sum_{n=1}^{n}\sum_{t=1}^{t}\frac{CF_t^n}{(1+r_t^n+OAS)^t} \tag{3}$$

The model adequately reflects the role of interest rate fluctuations in the current market environment on the early repayment rate, but its disadvantage is that its operation process is tedious and requires some computer programming skills.

4. Monte Carlo simulation method

The Monte Carlo simulation method was first applied to the problem of stock pricing in the field of economics. Its pricing idea is to simulate the future stochastic interest rate by performing multiple high-frequency operations on various interest rate paths, so as to find out the flow of funds under different interest rate paths by making early repayment and different default risk adjustments, and using these methods to discount the different paths. The model is designed to obtain the market price for the different paths. The model is solved by simulating a large number of stochastic interest rate paths, taking into account the effects of both default and early repayment. However, the algorithm has a large path dependence. Without performing many simulations, it will affect the accuracy of the analysis [7]. In credit asset valuation, a Monte Carlo simulation method is used for assets with strong path dependence. The Monte Carlo simulation algorithm differs from the above algorithm in that it does not require precise assumptions about spreads, default rates, early repayment rates, etc., and omits the tedious steps of calculation, which can be implemented by computer. With sufficient data, more accurate pricing results can be obtained.

2.3 Pricing Model Select

Pricing methods have advantages and disadvantages and are suitable for pricing valuation of products with different characteristics. The option-adjusted spread method takes into account interest rate risk and thus adjusts future cash flows in a comprehensive manner. The option-adjusted spread method first needs to consider the term structure of interest rates, so the CIR model is used as the term structure model for interest rate forecasting [8]. 1000 forward interest rate paths are simulated in the CIR model using the Monte Carlo method, and the spot interest rate is obtained according to the path of the forward interest rate curve, and finally the spot interest rate is combined with the option-adjusted spread OAS to obtain 1000 present values. The average value of the 1000 present

values is the theoretical value of the pricing. The advantage of Monte Carlo simulation of interest rate paths is that a large number of forward interest rate paths can be simulated by computer, thus making the final pricing results more accurate. It is worth noting that since public REITs projects involve multiple interests, it is necessary to consider the factors affecting pricing in many ways. Therefore, considering the situation of China's infrastructure investment and financing market, and taking into account the characteristics of infrastructure REITs, the option-adjusted spread method based on Monte Carlo simulation is finally selected in this paper to be able to comprehensively and comprehensively consider the influencing factors, most importantly, the interest rate term structure model and the assumption of early payoff rate.

3. Pricing Analysis of Public REITs - Dongwu Suwon Industrial REIT

Product pricing is the most central part of the asset securitization process and is the key for the market to play an effective resource allocation. In this chapter, based on the theoretical pricing model in Chapter 2, we will choose a suitable model to explore in depth the theoretical pricing of public REITs based on the actual data of the public REITs project - Dongwu Suyuan Industrial REIT, in order to provide theoretical experience for future quantitative research of public REITs [9].

3.1 Option-adjusted spread model research theory

1. Interest rate term structure model study

In option-adjusted spreads, short-term interest rates must be simulated, and on this basis, an interest rate term structure model based on spot rates is given.

First, the term structure of interest rates in China is forecasted. From the previous section, it is known that both discount rate and cash flow are affected by interest rates. Theoretically, the analysis of interest rate maturity can be categorized into two types: static and dynamic. Among them, the typical ones are based on the spline analysis model and the NS model, which constructs a continuous interest rate curve by constructing the market quotation of a commodity on that day, and then tests it continuously to obtain an interest rate term that reflects the market conditions of that day. The non-arbitrage and equilibrium models assume a stochastic difference equation to obtain a theoretical structure of interest rates. The non-arbitrage model is based on expectations theory, such as the health-Jarrow-Morton model, while the equilibrium model is based on liquidity preference theory, which first presents the mean-reversion properties of interest rates and then uses the Vasicek model to investigate the mean-reversion properties of interest rates [10]. The Cox-Ingersoll-Ross (CIR) model, on the other hand, solves the problem of negative interest rate levels for the first two. The empirical results show that the CIR model is more consistent with the economic development of China. For this reason, we use a single-factor CIR interest rate model to analyze the term structure of interest rates in China.

2. Early payoff rate

So far, there is insufficient data related to the early repayment of public REITs in China. Given the high credit enhancement measures of public REITs projects, we do not include past repayment rates in this model in this paper, so we assume that the early repayment rate is 0%.

3.2 Option-adjusted spread pricing model construction steps and results

1. Selecting the benchmark interest rate

The choice of benchmark interest rate needs to take into account the indicator that is more representative of the risk-free rate, which is at the core of the overall interest rate formation mechanism and influences the formation of many types of interest rates in the market, and is usually used as the benchmark interest rate for financial assets with high creditworthiness, high liquidity, low risk and relatively stable. In this paper, the yield to maturity of the one-year Chinese government bond is used as the risk-free rate. The reasons for the selection are as follows: the government bond market is highly traded and liquid, and the government bond is a national credit, which is highly

creditworthy and has a very low probability of default, and is more accurate in reflecting the market interest rate. Therefore, this paper adopts the one-year Treasury yield to maturity as the benchmark interest rate, and simulates the interest rate path on this basis.

2. Interest rate fluctuation path based on CIR model

The CIR model is a short-term interest rate model established under the general equilibrium framework, which treats the term structure of interest rates as a kind of stochastic movement and can well describe the future trend of market interest rates. The model is characterized by the fact that interest rates revert to the mean at a rate that ensures the non-negativity of interest rate fluctuations. The stochastic differential equation of the CIR model is expressed as follows.

$$dr_t = \alpha(\mu - r_t)d_t + \sigma\sqrt{r_t}dW_t \tag{4}$$

In order to apply the CIR model to practical pricing, the parameters α, μ and σ need to be estimated first. The transfer density probability function of the CIR interest rate model is first given.

$$p\big(r(t)+\Delta t|r(t);\theta,\Delta t)\big) = ce^{-u-v}\left(\frac{u}{v}\right)^{\frac{2\alpha u-\sigma^2}{2\sigma^2}} I_q(2\sqrt{uv}) \tag{5}$$

Among them.$c = \frac{2\alpha}{\sigma^2(1-e^{-\alpha\Delta t})}$, $u = cr(t)e^{-\alpha\Delta t}$, $v = cr(t)+\Delta t$, $q = \frac{2\alpha R-\sigma^2}{\sigma^2}$, $I_q(2\sqrt{uv})$ is the q-order Besseli function.

Second, the interest rate time series likelihood function containing N observations is given.

$$L(\theta) = \prod_{i=1}^{N-1} p(r(t_{i+1})|r(t_i);\theta,\Delta t) \tag{6}$$

Taking the logarithm of the left and right sides of the above function, we get.

$$lnL(\theta) = \sum_{i=1}^{N-1} ln\, p(r(t_{i+1})|r(t_i);\theta,\Delta t) \tag{7}$$

Collating the above equations, the log-likelihood function of the CIR interest rate model can be obtained.

$$lnL(\theta) = (N-1)lnc + \sum_{i=1}^{N-1}\{-u(t_i) - v(t_{i+1}) + \frac{q}{2}ln\frac{v(t_{i+1})}{u(t_i)} + \ln\,[I_q(2\sqrt{u(t_i)v(t_{i+1})})]\} \tag{8}$$

Among them.$u(t_i) = cr(t_i)e^{-\alpha\Delta t}$, $v(t_i) = cr(t_i)$.

We can obtain the maximum likelihood estimate of θ.

$$\hat{\theta} \equiv (\hat{\alpha},\hat{\mu},\hat{\sigma}) = \arg\max_{\theta} lnL\,(\theta) \tag{9}$$

The initial parameter estimates need to be obtained first by fitting using the OLS method, and the discrete form of (4) is.

$$r_{t+\Delta t} - r_t = \alpha(\mu - r_t)\Delta t + \sigma\sqrt{r_t}\varepsilon_t \tag{10}$$

Where ε_t is a random number satisfying the standard normal distribution, i.e., white noise. The above equation is transformed into.

$$\frac{r_{t+\Delta t}-r_t}{\sqrt{r_t}} = \frac{\alpha\mu\Delta t}{\sqrt{r_t}} - \alpha\sqrt{r_t}\Delta t + \sigma\varepsilon_t \tag{11}$$

After a series of derivations, the expression for OLS parameter estimation is.

$$(\hat{\alpha},\hat{\mu}) = \arg\min_{\alpha,\mu} \sum_{i=1}^{N-1} \frac{r_{t+\Delta t}-r_t}{\sqrt{r_t}} - \frac{\alpha\mu\Delta t}{\sqrt{r_t}} + \alpha\sqrt{r_t}\Delta t \tag{12}$$

The initial parameter estimates obtained by the OLS method are brought into the objective function of the maximum likelihood estimation (ML) method (6), and the estimates of the ML method can be obtained using the parameter optimization algorithm (extremum).

The path of interest rate fluctuations is measured. In this paper, the daily data of one-year Treasury yield to maturity from May 20, 2020 to May 20, 2022 were selected from Wind database for short-term interest rate simulation, and the daily data trend is shown in Figure 1.

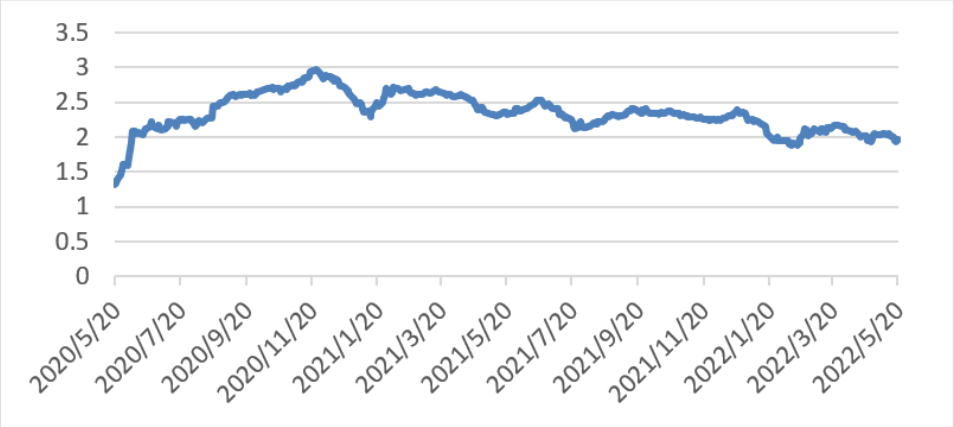


Figure 1. 2020-2022 One-Year Treasury Yield to Maturity Chart

The sample data were imported into Matlab software for fitting, and after discretizing the CIR model, the parameters were estimated using the least squares method and the great likelihood method, respectively, and the parameters were obtained as shown in Table 1.

Table 1. CIR model parameter estimation table

Estimation Method	α	μ	σ
Least Squares (OLS)	0.0228	0.0240	0.0197
Very Large Likelihood Method (ML)	0.0226	0.0240	0.0198

Data source: calculated from Matlab software

The parameters are brought into the CIR model to obtain the interest rate term structure formula as follows, the parameter estimation results are as expected, theoretically the great likelihood method is more accurate than the least squares method, the mean value of the interest rate estimated by the great likelihood method is 2.26% and the volatility is 1.98%.

$$d_{r_t} = 0.0226(0.0240 - r_t)d_t + 0.0198\sqrt{r_t}dW_t \tag{13}$$

3. Monte Carlo simulation of benchmark interest rates

(1) Forward interest rate simulation

The one-year Treasury yield on May 20, 2022 is 1.9565%, and this interest rate is used as the initial interest rate level. Based on the estimated parameters obtained above substituted into the CIR formula, the Monte Carlo simulation method is applied to simulate the stochastic fluctuation path of interest rate, according to the characteristics of stochastic simulation method, each interest rate path will generate different pseudo-random numbers, and this paper uses Matlab software to simulate the number of 1000 times, 1000 different interest rate paths are generated. According to the Monte Carlo

method to simulate the forward interest rate path for the next 10 periods, it can be seen that the larger the number of simulations, the more the forward interest rate curve will also tend to stabilize. Monte Carlo simulation to model the stochastic fluctuation path of interest rates is shown in Figure 2. Monte Carlo simulation of forward rates is shown in Table 2.

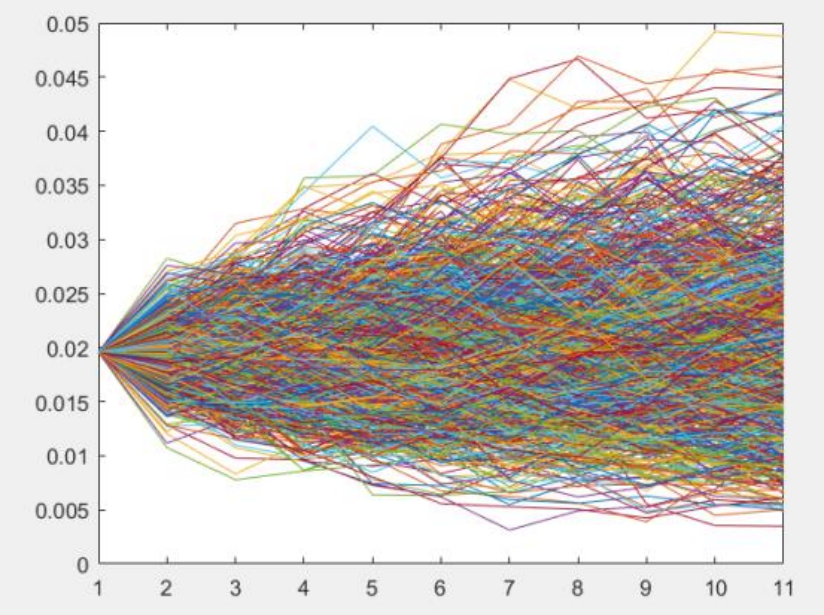


Figure 2. Monte Carlo simulation to model the stochastic fluctuation path of interest rates

Table 2. Monte Carlo simulation of forward rates

Year/Path	1	2	3	4	…	999	1000
1	0.0212	0.0247	0.0134	0.0221	…	0.0229	0.0165
2	0.0232	0.0226	0.0127	0.0201	…	0.0225	0.0174
3	0.0241	0.0263	0.0154	0.0192	…	0.0204	0.0169
4	0.0268	0.0273	0.0123	0.0236	…	0.0149	0.0137
5	0.0309	0.0304	0.0098	0.0230	…	0.0144	0.0170
6	0.0293	0.0283	0.0120	0.0231	…	0.0128	0.0161
7	0.0275	0.0304	0.0153	0.0185	…	0.0127	0.0171
8	0.0227	0.0269	0.0164	0.0183	…	0.0110	0.0141
9	0.0208	0.0259	0.0191	0.0169	…	0.0118	0.0115
10	0.0179	0.0274	0.0200	0.0205	…	0.0143	0.0120

(2) Simulation of spot rate

According to the relationship between the forward rate and spot rate, the spot rate can be obtained from the simulated forward rate, and their relationship is shown as follows. The Monte Carlo simulation of spot rates is shown in Table 3.

$$Z_T(t) = \left(\prod_{i=1}^{t} 1 + r_i\right)^{\frac{1}{t}} - 1 \tag{14}$$

Table 3. Monte Carlo simulation of spot rates

Year/Path	1	2	3	4	…	999	1000
1	0.0212	0.0247	0.0134	0.0221	…	0.0229	0.0165
2	0.0222	0.0237	0.0131	0.0211	…	0.0227	0.0170
3	0.0228	0.0245	0.0139	0.0205	…	0.0219	0.0169
4	0.0238	0.0252	0.0135	0.0212	…	0.0202	0.0161
5	0.0252	0.0263	0.0127	0.0216	…	0.0190	0.0163
6	0.0259	0.0266	0.0126	0.0218	…	0.0180	0.0163
7	0.0261	0.0271	0.0130	0.0214	…	0.0172	0.0164
8	0.0257	0.0271	0.0134	0.0210	…	0.0164	0.0161
9	0.0251	0.0270	0.0140	0.0205	…	0.0159	0.0156
10	0.0244	0.0270	0.0146	0.0205	…	0.0157	0.0152

4. Option-Adjusted Spread Method Pricing

The OAS (Option-Adjusted Spread) adjusts the cash flow of each period according to the future market interest rate situation. option. The option-adjusted spread method is based on an interest rate model that simulates the future interest rate path and adjusts future cash flows by predicting the likelihood of early repayment under different scenarios.

The option-adjusted spread essentially measures the extent to which the yield curve is shifted from the benchmark interest rate and represents a compensation for risk. This risk compensation value includes credit risk premium, liquidity premium and embedded option value. According to statistics, the weighted average cost of public REITs is 6%-7%, minus the spot yield of the benchmark interest rate to obtain the option-adjusted spread OAS=4%.

The future cash inflows are discounted according to the 1000 interest rate paths obtained in the previous section to obtain 1000 values, which are then averaged to obtain the theoretical price of the asset-backed special plan. The corresponding formula under the option-adjusted spread method is shown below.

$$P = \frac{1}{n}\sum_{s=1}^{n}\ \sum_{t=1}^{T}\frac{CF_t}{(1+r_{f(s,t)}+OAS)^t} + \frac{CF_T*(1+g)}{(r-g)/(1+r_{f(T)}+OAS)^T} \quad (15)$$

Based on the present value of cash flows for each period obtained after 1,000 simulations of the option-adjusted spread method, the results of 1,000 simulations are used as the pricing result of the option-adjusted spread method PV=4069.4133107 million. From this calculation, the price per unit share: ¥4.5216 per share, which is basically the same as the market price of ¥4.516 per share on May 22, 2022.

The average values of discounted cash flows for each period after discounting treatment are shown in Table 4.

Table 4. Present value of cash flows projected by option-adjusted spread method (Unit: 10000 yuan)

Number of periods	1000 times
1	8492.8645
2	7994.1788
3	7577.9543
4	7348.4460
5	6939.5261
6	6635.1190
7	6252.6072
8	5926.5817
9	5449.1705
10	5085.4221

5. Analysis of pricing results

This paper conducts an empirical study on the pricing of public REITs by using the option-adjusted spread method based on Monte Carlo simulation. After obtaining the theoretical price of asset-backed securities, this paper uses Monte Carlo simulation to establish 1,000 interest rate paths, combines the resulting spot rate of return and OAS to obtain the discount rate, and discounts 1,000 present values, and uses the results of 1,000 simulations as the pricing result of the option-adjusted spread method PV = 4069.41 million yuan, from which the unit share price is calculated: ¥4.5216 per copy, which is basically the same as the market price of ¥4.516 per copy on May 22, 2022. It illustrates that the option-adjusted spread method based on Monte Carlo simulation can evaluate and determine the value of public REITs in a more scientific and reasonable way. This paper argues that infrastructure, as a new underlying asset type of public REITs, is currently in the development stage, and with the continuous expansion of the business scale of public REITs in China and the acceleration of the interest rate marketization process in China, the option-adjusted spread method based on Monte Carlo simulation may be the main trend for the future development of China's financial market. It is expected to be further tested in the future research and lay the foundation for the price setting and adjustment of relevant public REITs.

4. Conclusion

The article analyzes the background, significance and characteristics of public REITs in China, and selects an appropriate pricing model in order to promote the healthy development of public REITs in China and improve the pricing of the market.

1. Build a special REITs database.

2. Improve the tax preference system.

3.Formulate and improve the relevant legal policy system.

The article conducts an in-depth study on the characteristics and development status of domestic public REITs by combining traditional pricing methods with its pricing model. Through the study of the pricing of public REITs project - Dong Wu Su Yuan Industrial REIT, it reveals the important influence of factors such as interest rate changes on the pricing results. Through the empirical analysis, this article argues the feasibility and reasonableness of the option-adjusted spread method based on Monte Carlo simulation in the pricing of public REITs in China. Based on the above induction, the following conclusions are summarized.

1. Public REITs projects are in the initial stage in China, and the pricing of public REITs has not yet formed a perfect industry standard. By comparing the pricing methods and applicability of four common types of asset securitization, combined with the actual situation of public REITs, the option-adjusted spread method based on Monte Carlo simulation is finally chosen as the research method of this paper. This method reduces the impact of unexpected events by taking into account the early

payoff rate and the term structure of interest rate. The pricing result is basically the same as the market value on May 22, 2022. It illustrates that this method can evaluate and determine the value of public REITs in a more scientific and reasonable way.

2. For the state, public REITs can make full use of China's infrastructure stock, thus reducing local liabilities, promoting local investment and financing efficiency in the context of China's new urbanization, and providing a pricing "anchor" for the infrastructure industry. For investors, actively promoting the reform of public REITs will help broaden the financing varieties in China's financial market, and promote the diversification of China's financial market.

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