Are Convertible Bonds Efficiently Priced in the Chinese Market? Insights from a Simulation-Based Pricing Model

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Abstract

This study investigates the pricing efficiency of Chinese convertible bonds and presents evidence of systematic mispricing. To support this analysis, we develop a pricing framework based on the Least Squares Monte Carlo (LSM) method, tailored to reflect contractual features unique to the Chinese market. Using this model, we simulate fair values over the full lifespan of 154 convertible bonds issued between 2015 and 2019 and compare them to observed market prices. The model-predicted price curves generally align well with observed price patterns, demonstrating the robustness and practical value of our approach. However, we also find that trading prices occasionally deviate from model-implied values by more than 10%, with these deviations exhibiting consistent patterns rather than random fluctuations. Furthermore, we demonstrate that simple trading strategies—both at the individual bond level and at the portfolio level—can exploit these discrepancies to generate substantial excess returns. These findings suggest that the Chinese convertible bond market is only partially efficient and highlight persistent arbitrage opportunities, underscoring the importance of market-specific valuation models in emerging financial markets.

Keywords: Convertible Bonds; Monte Carlo Simulation; Least Squares Regression; Embedded Options; Chinese Market; Pricing Model; Stock Volatility; Trading Strategy

1 Introduction

1.1 Convertible bonds and their pricing

Convertible bonds are hybrid financial instruments that blend debt and equity characteristics, offering issuers flexible financing options and providing investors with a unique risk-return profile. Unlike traditional bonds, they give holders the option to convert their bonds into the issuer's stock under specific conditions, enabling participation in potential stock price gains. Convertible bonds also include features like call and put options, with the addition of a unique reset clause in the Chinese market. These embedded options increase the bond's flexibility, making convertible bonds a balanced solution that combines the income stability of bonds with the growth potential of equities, ultimately meeting the strategic needs of both issuers and investors.

Convertible bonds, with their combination of debt and equity features, are complex to price due to embedded options and varied contractual terms. Pricing convertible bonds requires a comprehensive approach that considers both the bond and option components and their interactions. Different convertible bonds may contain unique features, necessitating distinct parameters or even entirely different pricing methods. Generally, pricing methods can be divided into two main categories: component-based and holistic approaches.

The component-based approach separates the convertible bond into bond and option parts. While the bond component is relatively straightforward to price, the option component can be valued using traditional pricing theories, such as the Black-Scholes model [1], binomial trees, and Monte Carlo simulation. Although the Black-Scholes model is foundational, its assumptions of frictionless markets and absence of default risk limit its applicability to convertible bonds. Ingersoll (1977) [2] incorporated default risk into the model, while Lewis (1991) [3] extended it to more complex capital structures. Although classical models are simple to compute, they overlook interactions among convertible bond clauses, making them less effective for pricing bonds with complex embedded options.

The holistic approach treats the convertible bond as a single entity for pricing. Since closed-form solutions are typically unattainable, numerical methods like binomial trees, finite difference methods, and Monte Carlo simulations are often used. The binomial model introduced by Cox, Ross, and Rubinstein [4] and the finite difference method by Brennan and Schwartz [5] address option pricing in discrete time. Monte Carlo methods were first applied by Boyle (1977) for valuing complex financial instruments. The Least Squares Monte Carlo (LSM) method by Longstaff and Schwartz [8] optimizes early exercise decisions for American options, making it suitable for convertible bonds with call and conversion features. The barrier Monte Carlo method by Cheuk and Vorst [9] and the credit risk model by Tsiveriotis and Fernandes [7] further enhance convertible bond pricing for instruments with complex clauses and default risk.

1.2 Chinese convertible bond market

Clauses of Chinese convertible bonds

In the Chinese market, convertible bonds typically include four main clauses: the conversion clause, the redemption clause, the put provision, and the reset clause. Among these, the reset clause is unique to China. Next, we briefly introduce them with examples illustrating their features and implications.

The conversion clause defines the period when investors can convert bonds into the issuer's stock at a predetermined price, starting a few months after issuance and lasting until maturity. For example, the Everbright Convertible Bond (`113011.SH`), listed on May 5, 2017, allowed investors to begin converting their bonds into stock at a conversion price of 4.36 yuan per share starting from September 18, 2017. This means each bond with a face value of 100 yuan could be converted into approximately

$100/4.36 \approx 22.94$ shares. Investors do not always convert when the stock price exceeds the conversion price, as further stock appreciation is possible. Additionally, the bond's market price may hold a premium due to remaining bond value and embedded options, leading investors to sell in the secondary market instead.

The put clause provides investors the right to sell bonds back to the issuer at a preset price if adverse conditions occur, such as a substantial stock price decline, thus reducing downside risk. For example, the Aviation Information Convertible Bond (`110031.SH`) stipulates that if the company's stock closes below 70% of the current conversion price for any 30 consecutive trading days during the last two interest-bearing years, bondholders have the right to sell all or part of their bonds back to the issuer at the face value plus accrued interest. Issuers generally prefer to avoid early redemption under the put provision, as it requires repaying the debt early, conflicting with the goal of converting debt into equity without cash outflows. The reset clause addresses this concern.

The reset clause allows issuers to lower the conversion price if the stock falls below a certain level, making conversion more appealing and potentially avoiding the put option. For instance, the Aviation Information Convertible Bond (`110031.SH`) includes a reset provision that permits the company's board of directors to propose a downward adjustment of the conversion price if the stock's closing price is below 90% of the current conversion price for 10 out of any 20 consecutive trading days during the bond's life. The adjustment requires approval at a general shareholders meeting, and it is at the issuer's discretion. Although reset conditions are often triggered, the adjustment may not always be implemented. Modeling this clause requires adding a variable to account for the issuer's discretion.

Table 1 summarizes the key terms of these clauses. Together, the conversion, redemption, put, and reset clauses embed options into the convertible bond, adding complexity to its valuation. Since terms vary across bonds, pricing models must

Clause	Main Content
Conversion Clause	Specifies the period during which investors can convert their convertible bonds into shares of the issuing company's stock at a predetermined conversion price.
Redemption Clause	Allows the issuer to redeem the convertible bonds before maturity under certain conditions, typically when the stock price has appreciated significantly, by paying bondholders the face value plus accrued interest.
Put Provision	Grants investors the right to sell the bonds back to the issuer at a predetermined price under specific adverse conditions, such as a significant decline in the stock price, providing downside protection.
Reset Clause	Permits the issuer to adjust the conversion price downward under certain conditions, usually when the stock price has fallen below a specified threshold, to make conversion more attractive and discourage investors from exercising the put provision; unique to the Chinese market.

Table 1 Key clauses commonly found in Chinese convertible bonds, including the distinctive reset clause that permits issuers to lower the conversion price following sustained stock price declines, thereby reducing the value of the conversion option for investors.

adapt to each bond's unique features, necessitating a flexible approach to capture the interactions between options and cash flows.

Pricing Chinese convertible bonds

Since the issuance of the first convertible corporate bond (hereinafter referred to as "convertible bond") in 1992, the Chinese convertible bond market has experienced more than 20 years of development. From 2019 to 2022, the financing scale of listed companies through convertible bonds exceeded 200 billion yuan annually ([18]), and convertible bonds have now replaced additional equity issuance as the primary financing option for listed companies. The pricing of Chinese convertible bonds has its particularities. Compared to capital markets such as the United States, Chinese convertible bonds generally have reset clauses, which means that pricing models used in other countries cannot be directly applied to Chinese convertible bonds.

To address these challenges, Wang Yintian and Wen Zhiying (2018) [17] investigated the influence of reset clauses on pricing accuracy, revealing that incorporating these clauses into models significantly reduces pricing errors and mitigates premium phenomena. Further advancing this research, Li (2023) [19] applied the Black-Scholes model to a sample of 20 listed Chinese convertible bonds, performing a regression analysis between theoretical and market prices. The findings demonstrated that the model's theoretical prices align closely with actual market prices, suggesting that this model offers valuable explanatory power for Chinese convertible bond prices. Similarly, Xie Dejie (2016) [16], leveraging the Least-Squares Monte Carlo (LSM) simulation by Longstaff and Schwartz (2001) [8], adapted the model by incorporating clauses unique to the Chinese market to validate its applicability. Collectively, these studies underscore the substantial impact of reset clauses on the pricing of Chinese convertible bonds. However, they also reveal limitations in current research, which often relies on small samples and short time frames. For instance, Xie Dejie's (2016) [16] study was restricted to 13 convertible bonds over just 16 trading days. Additionally, these studies lack a standardized, objective benchmark for assessing pricing model accuracy. Therefore, current research still leaves one question unanswered: Is the pricing of convertible bonds in the Chinese market truly accurate? Or, put differently, does price volatility in convertible bonds create ongoing profit opportunities?

To address this issue, this paper employs a modified Least-Squares Monte Carlo (LSM) model to value 154 convertible bonds over their entire listing periods. By constructing trading strategies based on the model's valuations and actual trading prices, we investigate the accuracy of convertible bond pricing in the Chinese market.

1.3 Structure and Contribution of this Paper

The structure of this paper is as follows: Chapter One introduces the concept of convertible bonds and the common methods used for their pricing as well as an overview of the convertible bond market in China, with a focus on its unique features. Chapter Two explains the construction of the pricing model based on the Monte Carlo method. Chapter Three presents the empirical analysis and the corresponding results. Lastly, Chapter FOUR concludes with a summary of findings and suggestions for future research.

This paper makes the following contributions: First, it proposes a novel calculation approach that incorporates the unique characteristics of the Chinese convertible bond market. Specifically, Formula 2 and Algorithm 2 are designed to account for the distinct contractual terms and pricing dynamics in this market. Second, it conducts a comprehensive computational experiment using a large dataset of real Chinese market data. The results reveal systematic mispricing in Chinese convertible bonds, highlighting arbitrage opportunities. This finding underscores market inefficiencies and provides empirical evidence that deviations from theoretical values can be exploited for excess returns.

2 LSM Monte Carlo Simulation for Convertible Bonds Pricing

We begin by discussing the pricing of traditional bonds, which lays the foundation for extending the discussion to the pricing of convertible bonds. Traditional bonds are financial instruments that represent a loan from the investor to the issuer, typically offering fixed periodic payments (coupons) and a repayment of the principal amount at maturity. The pricing of a bond reflects the present value of these future cash flows, discounted at the appropriate rate to account for the time value of money and the credit risk associated with the bond. The price of a bond (V_{bond}) is calculated using the following formula:

$$V_{\text{bond}} = \sum_{t=1}^{T} C_t e^{-r_t t} + N e^{-r_T T}, \tag{1}$$

where:

- V_{bond}: The price of the bond, which is the present value of its expected future cash flows.

- C_t: The coupon payment at time t, typically a fixed percentage of the bond's face value.
- r_t: The discount rate at time t, incorporating the bond's credit risk and the time value of money.
- $e^{-r_t t}$: The discount factor for the cash flow at time t.
- T: The maturity of the bond, representing the final time period when the principal is repaid.
- N: The principal (or face value) of the bond, repaid by the issuer at the bond's maturity.
- $e^{-r_T T}$: The discount factor for the principal repayment at maturity (T).

Convertible bonds are traditional bonds with embedded options that allow the bondholder or issuer to modify the cash flow structure by holding the bond, converting it to equity, or exercising other options. These options create uncertainty in valuation by affecting both the bond's maturity (T) and future cash flows. Before exercising these options, convertible bonds behave like traditional bonds with periodic coupon payments and principal repayment. Once exercised, the cash flow structure adjusts to reflect the specific payoff, adding complexity to their valuation.

The future cash flows of a convertible bond are uncertain. To determine its value, we calculate the expected present value of its cash flows under different scenarios, weighted by their probabilities. Thus, based on the traditional bond pricing formula (1), the pricing formula for a convertible bond at time t (V_t) can be written as follows:

$$V_t = E\left[\sum_{i=1}^{t^*(t)} C_i e^{-r_i i} + \text{Payoff}(t^*(t), S_{t^*(t)}, \text{Conv}_{t^*(t)}, V'_{t^*(t)}, Action_{t^*(t)}) e^{-r_{t^*(t)} t^*(t)}\right], \tag{2}$$

where, in addition to the variables already defined in Equation (1), the remaining variables are defined as follows, and the whole process of calculation of $\mathit{Payoff}(t^*(t), S_{t^*(t)}, \mathit{Conv}_{t^*(t)}, V'_{t^*(t)}, \mathit{Action}_{t^*(t)})$ is concluded in Algorithm 1:

- $t^*(t)$: The optimal stopping time, determined by the exercise of embedded options. We will discuss the determination of the optimal stopping time in subsection 2.1.
- $S_{t^*(t)}$: The stock price at the optimal stopping time $t^*(t)$.
- $\mathit{Conv}_{t^*(t)}$: The conversion price at $t^*(t)$, which is the price per share that must be paid when converting a convertible bond into company stock. It determines the cost at which investors acquire the shares, and we will discuss how the conversion price determined in section 2.3.2.
- $E[\cdot]$: Under different stock paths $\{S_i\}_{i=t+1,\ldots,T}$, which will be discussed in 2.3.1, there will be varying payoffs and stopping times $(t^*(t))$, resulting in different present values of cash flows. This expectation value represents the average of these present values across all possible stock price paths. Note that $t^*(t)$, $\mathit{Conv}_{t^*(t)}$, $\mathit{Action}_{t^*(t)}$, $V'_{t^*(t)}$, and $\mathit{Action}_{t^*(t)}$ are all determined by the stock price paths $\{S_i\}_{i=t+1,\ldots,T}$.
- $\mathit{Action}_{t^*(t)}$: A variable indicating whether any embedded options—call, put, or convert—have been exercised from the bond's issuance up to time $t^*(t)$. If any option is exercised, the bond terminates immediately, and $\mathit{Action}_{t^*(t)} = 1$; otherwise, $\mathit{Action}_{t^*(t)} = 0$. We will discuss how to determine $\mathit{Action}_{t^*(t)}$ in section 2.2.
- $\mathit{Payoff}(t^*(t), S_{t^*(t)}, \mathit{Conv}_{t^*(t)}, V'_{t^*(t)}, \mathit{Action}_{t^*(t)})$: The cash flow at the optimal stopping time $t^*(t)$. We will later discuss the calculation methods for payoffs under different scenarios in subsection 2.2.
- $V'_{t^*(t)}$: Continuation value, the present value of the expected future cash flows from holding the bond. We will discuss this variable in detail in subsection 2.3.

Thus, the pricing formula for convertible bonds can be seen as a modification of the traditional bond pricing formula, incorporating the impact of embedded options and their associated uncertainties. The remainder of this section details a simulation-based calculation of the quantities involved in Formula (2) and demonstrates its application in pricing a convertible bond.

2.1 Determination of the Optimal Stopping Time $t^*(t)$

As shown in Table 1, the embedded options in a convertible bond may be exercised under specific conditions when the stock price $S_{t^*(t)}$ and the conversion price $\mathrm{Conv}_{t^*(t)}$ meet certain criteria. These options include the call option, conversion, and put option. The exercise of these options implies that the convertible bond will not be held until maturity ($t^*(t) < T$). Therefore, the determination of $t^*(t)$ depends on the time at which one of these options is exercised. In a Monte Carlo simulation, we identify the exercise times for all embedded options and select the earliest of these times as $t^*(t)$. The payoff of a convertible bond is fundamentally influenced by the timing and execution of its embedded options by both investors and issuers.

Investors aim to maximize their returns. During the holding period of a convertible bond, if the conditions for exercising an option, such as conversion or put, are met, they must decide whether to exercise the option or continue holding the bond. To make this decision, we define the continuation value ($V_t^{'}$) at time t as the present value of the expected future cash flows from holding the bond.

Similarly, for issuers, their objective is to minimize the cash flows they are required to pay. To make this decision, the issuer will decide to exercise an option (such as a call) at time t when the continuation value ($V_t^{'}$) exceeds the cash flow resulting from exercising the option at t, provided the conditions for exercising the option are met.

The optimal stopping time $t^*(t)$ is determined by both the investor's and the issuer's decisions. Specifically, $t^*(t)$ is the earliest time when either the investor chooses to exercise their option (e.g., conversion or put) or the issuer exercises their option (e.g., call), provided the respective conditions for exercising the option are met. Mathematically, this can be expressed as:

$$t^*(t) = \min \left\{ \arg \max_{t_i \in \mathcal{T}_{\text{investor}}} \left\{ t_i \,|\, \text{Payoff}(t_i, S_{t_i}, \text{Conv}_{t_i}, V^{'}_{t_i}, Action_{t_i}) \geq V^{'}_{t_i} \right\}, \right. \\ \left. \arg \min_{t_c \in \mathcal{T}_{\text{call}}} \left\{ t_c \,|\, \text{Payoff}(t_c, S_{t_c}, \text{Conv}_{t_c}, V^{'}_{t_c}, Action_{t_c}) \leq V^{'}_{t_c} \right\} \right\}, \quad (3)$$

where:

- The set $\mathcal{T}_{\text{investor}} = \mathcal{T}_{\text{put}} \cup \mathcal{T}_{\text{conv}}$ indicates when the investor can exercise their options. $\mathcal{T}_{\text{put}}$ is for exercising the put option to sell the bond back, while $\mathcal{T}_{\text{conv}}$ is for converting the bond into equity.
- $\mathcal{T}_{\text{call}}$ is for exercising the call option to redempt the bond back from investor.

2.2 Definition of the Payoff function

We will now define the Payoff function, which can take on one of seven possible values based on four potential outcomes for a convertible bond: redemption (call), repurchase (put), conversion, or holding the bond until maturity, along with their corresponding payoffs. Table 2 shows the detailed definition of the Payoff function, which involves the following notations:

- Call Price: Redemption price, representing the amount the issuer pays to redeem the bond.
- Put Price: Put price, representing the amount investors receive when selling the bond back to the issuer.
- Conv_t: Conversion price at time t, determining the number of shares investors receive upon conversion. In the Chinese convertible bond market, Conv_t is a time-series variable because of the presence of reset clauses. When these clauses are triggered—typically due to stock price declines—the conversion price may be adjusted

Outcome	**Condition**	**Payoff**$(t, S_t, \text{Conv}_t, V_t^{'}, \text{Action}_t)$
Redemption (Call) or Voluntary Conversion	1. $t \in \mathcal{T}_{\text{conv}} \cap \mathcal{T}_{\text{call}}$ 2. $V_t^{'} > \text{Call}$ 3. $\text{Action}_t = 0$ 4. Redemption clauses satisfied	$\max\{n_t S_t, \text{Call Price}\}$
Redemption (Call)	1. $t \in \mathcal{T}_{\text{call}}$ and $t \notin \mathcal{T}_{\text{conv}}$ 2. $V_t^{'} > \text{Call}$ 3. $\text{Action}_t = 0$ 4. Redemption clauses satisfied	Call Price
Repurchase (Put)	1. $t \in \mathcal{T}_{\text{put}}$ 2. $V_t^{'} \leq \text{Put}$ 3. $\text{Atrion}_t = 0$ 4. Repurchase clauses satisfied	Put Price
Voluntary Conversion	1. $t \in \mathcal{T}_{\text{conv}}$ 2. $n_t S_t > V_t'$ 3. $\text{Action}_t = 0$ 4. Redemption clauses not satisfied	$n_t S_t = \frac{100}{\text{Conv}_t} S_t$
Holding to Maturity	1. $t = T$ 2. $\text{Action}_t = 0$	$\sum_{t=1}^{T} C_t e^{-r_t t} + \alpha N e^{-r_T T}$
Continue Holding	1. $t < T$ 2. $\text{Action}_t = 0$ 3. Redemption and repurchase clauses not satisfied	0
Option Exercised, Bond Terminated	1. $\text{Action}_t = 1$	0

Table 2 Payoff Calculation Formulas and Trigger Conditions for Convertible Bond Outcomes. Each row corresponds to a possible outcome for a convertible bond, with associated trigger conditions and the formula used to calculate the resulting payoff.

downward, making Conv_t time-dependent. The Conv_t is determined by stock path $\{S_i\}_{i=t+1,\ldots,T}$ which will be discussed in section 2.3.2

- $n_t = \frac{100}{\text{Conv}_t}$: Conversion quantity at time t, representing the number of shares obtained for each bond.

In convertible bonds, the exercise of any embedded option—call, put, or convert—results in the immediate termination of the bond. Therefore, when determining the payoffs for these outcomes, it is crucial to ensure that no option has been exercised prior to the occurrence of a specific outcome. If an option has already been exercised, the bond ceases to be active, and the corresponding payoff is set to zero.

Next, we provide a detailed explanation of above equation.

Redemption (Call)

Redemption occurs when the issuer exercises the call option during the call period ($\mathcal{T}_{\text{call}}$). Before announcing the redemption decision, the issuer evaluates the continuation value V_t' and the redemption price Call. If the continuation value V_t' exceeds the redemption price Call, the issuer announces its intention to redeem the convertible bonds at Call. Otherwise, the issuer will choose not to redeem the bonds.

If the issuer announces its decision to redeem the bonds and the current time t also falls within the investor's conversion period ($t \in \mathcal{T}_{\text{conv}}$), investors face two choices: either wait for the issuer to redeem the bonds at the announced redemption price Call or actively convert the bonds into stock at the current conversion price Conv_t, obtaining $n_t = \frac{100}{\text{Conv}_t}$ shares. The decision depends on the relationship between the value of conversion $n_t S_t$, where S_t is the stock price at time t, and the redemption price Call. If $n_t S_t > \text{Call}$, investors will choose to convert the bonds into stock, as the value of conversion exceeds the redemption price. Otherwise, they will opt to wait for the issuer to redeem the bonds at Call.

Resell (Put)

Resell occurs when investors exercise the put option during the put period ($\mathcal{T}_{\text{put}}$). The decision to exercise the put option depends on the relationship between the put price Put_t, the continuation value V_t', and the immediate conversion value $n_t S_t$. However, the trigger condition for the put option is often that the current stock price remains below a certain percentage of the conversion price for several consecutive trading days. Therefore, in this context, the possibility of investors converting the bonds into stock can be disregarded. So if $V_t' \leq \text{Put}$, investors will exercise the put option.

However, it should be noted that when the stock price remains consistently below the conversion price, in addition to the put option potentially being triggered, the issuer's option to reset the conversion price may also be activated. In this case, the conversion price Conv_t is no longer constant, which could prevent the put option from being triggered.

Voluntary Conversion by Investors

Similarly, voluntary conversion occurs when investors decide to convert their bonds into shares during the conversion period ($\mathcal{T}_{\text{conv}}$). The decision to convert is based on the comparison between the immediate conversion value $n_t S_t$ and the continuation value V_t'.

Holding to Maturity

If none of the aforementioned scenarios occur during the life of the bond, the bond will be held to maturity. At maturity, investors will receive the maturity value, which consists of the principal amount N and any compensatory payments represented by αN, where α is a multiplier greater than one. In this case, αN will replace the N in Equation (1).

This outcome reflects a situation where neither the issuer nor the investors find it optimal to exercise any embedded options, and the bondholder receives the contractual payoff at maturity.

We elaborate on the detailed calculation process of the Payoff function in Algorithm 2.

2.3 Calculation of Continuation Value V_t' Based on LSM

The continuation value V_t' represents the expected present value of future cash flows if the convertible bond is held beyond a given time t. It serves as a benchmark for determining whether to exercise an embedded option or to continue holding the bond. So V_t' is calculated as:

$$V_t' = \mathbb{E}\left[e^{-r_f \Delta t} V_{t+\Delta t} \,|\, S_t, Conv_t\right], \tag{4}$$

where:

- r_f is the risk-free interest rate, observed data,
- Δt is the time step,
- $V_{t+\Delta t}$ is the value of the convertible bond at the next time step,
- S_t is the stock price at time t,
- $Conv_t$ is the convert price at time t,
- $\mathbb{E}[\cdot]$: This represents the conditional expectation of the future discounted payoff $V_{t+\Delta t}$, averaged across all possible paths of simulated stock prices and convert price.

Building upon the framework introduced by Longstaff and Schwartz (2001) [8], we employ an enhanced version of the Least Squares Monte Carlo (LSM) method. This approach leverages Monte Carlo simulations to generate multiple stock price paths and utilizes regression analysis to approximate the conditional expectation $\mathbb{E}[\cdot]$.

2.3.1 Stock Price Paths Generation

The stock price S_t is modeled using geometric Brownian motion (GBM), governed by the stochastic differential equation (SDE):

$$dS_t = r_f S_t dt + \sigma S_t dW_t, \tag{5}$$

where:

- σ is the volatility of the stock,
- W_t is a Wiener process, with $W_t \sim \mathcal{N}(0, t)$, representing random fluctuations.

The solution to this SDE provides the stock price at a future time t:

$$S_t = S_0 \exp\left(\left(r_f - \frac{1}{2}\sigma^2\right) t + \sigma W_t\right), \tag{6}$$

where:

- S_0 is the initial stock price at the start of the simulation,

- σ is the volatility of the stock's return. In this paper, σ is estimated using the historical volatility of stock returns.

indicating that S_t follows a log-normal distribution. To capture the stochastic behavior of the stock price, multiple stock price paths $\{S_i\}_{(i=t+1,\dots,T),(j=1,2,\dots)}$ are simulated over discrete time steps Δt. These simulated stock price paths represent potential future scenarios and form the foundation for subsequent calculations.

2.3.2 Conversion Price Sequence Generation

The conversion price sequence $\mathrm{Conv}_{t,j}$ is calculated based on these simulated stock price paths. At the time of issuance, the company specifies an initial conversion price Conv_0. If the stock price $S_{t,j}$ continues to decline and meets certain reset conditions specified in the bond's contractual terms, a reset clause may be triggered. When this occurs, the conversion price may be adjusted downward with a probability p[1]. The conversion price at time t is updated using the following formula:

$$\mathrm{Conv}_t = \mathrm{Conv}_{t-1} \cdot [1 - \delta \cdot \mathbb{I}(\text{Reset conditions are met}) \cdot \mathbb{B}(p)], \tag{7}$$

where:

- δ is the reset adjustment factor which is embedded in bond clauses,
- $\mathbb{I}(\cdot)$ is an indicator function that equals 1 if the reset conditions are met and 0 otherwise. The determination of whether the reset conditions are met is based on the stock price path $\{S_i\}_{i=t+1,\dots,T}$. Each convertible bond has its own specific rules that define the stock price conditions under which the reset clause will be triggered.
- $\mathbb{B}(p)$ is a Bernoulli random variable with success probability p, representing whether the reset occurs when conditions are met.

[1] In this paper, p is set to 0.4 based on historical data, which indicates the proportion of cases where companies chose to reset the conversion price after the reset clause was triggered. Readers may adopt different values or models for p depending on changes in market conditions.

2.3.3 Backward Deduction for V_t' Calculation

The estimation of the continuation value V_t' follows a backward deduction approach, which involves iterating over all simulated stock price paths in reverse order, starting from the maturity date ($t = T$) and moving backward to the initial time ($t = 0$).

First, we need to define the intrinsic value of a convertible bond: the immediate realizable value based on its conversion or other options. So, the intrinsic value is:

$$IV_{t,j} = \begin{cases} \max(n_{T,j}S_{T,j}, N), & t = T, \\ \\ \max\left(n_{t,j}S_{t,j}, \text{Put Price}, \text{Call Price}\right), & t < T. \end{cases} \tag{8}$$

The bond value $V_{t,j}$ is the maximum of the intrinsic value and the continuation value, representing the greater value between immediately realizing the bond's worth or the value of continue holding it . The formula for calculating the bond value is:

$$V_{t,j} = \max(IV_{t,j}, V_{t,j}'), t = 0, \ldots, T \tag{9}$$

Finally, based on the above definitions, the value V_t' at each time point t can be calculated through iterative steps.

STEP 1 Initialization at Maturity ($t = T$)

At maturity, the bondholder does not have the option to hold the bond further. The bond value V_T is therefore equal to the intrinsic value IV_T. So, the initial continue value at time T is defined as:

$$V_{T,j}' = \max(n_{T,j}S_{T,j}, N)$$

.

Then, substituting $V_{T,j}'$ into equations (8) and (9), we obtain the initial values at time T:

$$V_{T,j} = IV_{T,j} = \max(n_{T,j} S_{T,j}, N), \tag{10}$$

STEP 2 Iteration for Previous Time Steps (Using data at time $t + \Delta t$ to calculate values at t)

Given $V_{t+\Delta t,j}$, $S_{t,j}$, and $\text{Conv}_{t,j}$ for all j, we iteratively calculate $V'_{t,j}$, $IV_{t,j}$, and $V_{t,j}$ for each t. At each time point $t = 1, 2, 3, \ldots$, we estimate V'_t using the regression model:

$$V'_t = \alpha_t + \beta_{1,t} S_t + \beta_{2,t} \text{Conv}_t + \epsilon_t, \tag{11}$$

The purpose is to obtain α_t, $\beta_{1,t}$, and $\beta_{2,t}$, which can then be used to estimate V'_T for future data.

1. **Calculation of Continuation Value for a Single Path:** For any given simulated stock price path j, the continuation value at time t, denoted as $V'_{t,j}$, is calculated by discounting the convertible bond's value at the next time step $t+\Delta t$, denoted as $V_{t+\Delta t,j}$, back to the present. This approach incorporates the time value of money and is expressed as:

   $$V'_{t,j} = e^{-r_f \Delta t} V_{t+\Delta t,j},$$

   where:

   - $V_{t+\Delta t,j}$ represents the convertible bond's value at $t + \Delta t$ for the jth stock path, obtained through backward deduction,
   - Δt is the length of the time step.

   Discounting ensures that all future cash flows are valued in terms of their present value at time t. This creates a consistent basis for comparing the continuation value and intrinsic value.

2. **Regression-Based Continuation Value Estimation Model:** To estimate V'_t, we leverage the simulated stock price paths $S_{t,j}$ and corresponding conversion

prices $\text{Conv}_{t,j}$ for each path $j = 1, 2, \ldots$, generating a comprehensive dataset. In this dataset, $V'_{t,j}$ serves as the dependent variable, while $S_{t,j}$ and $\text{Conv}_{t,j}$ act as independent variables. A regression model is then constructed to approximate the continuation value at time t. The model is expressed in equations (11).

3. **Update Bond Value:** After obtaining the regression model, the bond value at time t, denoted as $V_{t,j}$, is updated by comparing the continuation value $V'_{t,j}$ with the intrinsic value $IV_{t,j}$. The intrinsic value reflects the immediate payoff of exercising the convertible bond options and is calculated as:

$$IV_{t,j} = \max\big(n_{t,j}S_{t,j}, \text{Put Price}, \text{Call Price}\big),$$

where:

- $n_t S_{t,j}$ is the value obtained from converting the bond into shares,
- Put Price and Call Price are the bond's put and call values as defined in the contract.

And the continuation value $V'_{t,j}$ is calculated by fit the regression model using the j-th path data $S_{t,j}, Conv_{t,j}$ at time t:

$$V'_{t,j} = \hat{\alpha} + \hat{\beta}_1 S_{t,j} + \hat{\beta}_2 Conv_{t,j}.$$

Where $\hat{\alpha}, \hat{\beta}_1, \hat{\beta}_2$ are calculated by equations (11). The bond value is then updated as:

$$V_{t,j} = \max(IV_{t,j}, V'_{t,j}),$$

ensuring that the bondholder always selects the option yielding the highest value.

STEP 3 Repeat Until All Time Steps t Are Covered

This process is repeated for all time steps, working backward from $t = T$ to $t = 0$. At each time step t, the continuation value V'_t is estimated as a regression model based on the simulated stock price S_t and conversion price Conv_t. After completing this backward induction process, we obtain a set of regression models for V_t' across all time steps t. These models allow us to calculate the continuation value at any time t based on the current stock price S_t and conversion price Conv_t.

These continuation value models are essential for determining the optimal decision at any time t. With real-time stock price S_t and conversion price Conv_t, we can directly compute an accurate estimate of the continuation value and make informed decisions regarding whether to hold or exercise embedded options. The whole process is concluded in algorithm 1.

Algorithm 1 Calculation of Continuation Value V_t' Using LSM

Require: Simulated M stock price paths $\{S_{t,j}\}$ and conversion prices $\{\mathrm{Conv}_{t,j}\}$ for $j = 1, 2, \ldots, M$, time steps $t = 0, \Delta t, 2\Delta t, \ldots, T$, risk-free rate r_f.

Ensure: Regression models V_t' for all time steps t.

1: **Initialize at maturity $t = T$:**

2: **for** each path $j = 1, 2, \ldots, M$ **do**

3: Compute intrinsic value at $t = T$:

$$V_{T,j} = \max\big(n_T S_{T,j}, N\big),$$

4: **end for**

5: **Backward deduction with step size Δt:**

6: **for** each time step $t = T - \Delta t, T - 2\Delta t, \ldots, 0$ **do**

7: **for** each path $j = 1, 2, \ldots, M$ **do**

8: Discount the bond value at the next time step $t + \Delta t$:

$$V_{t,j}' = e^{-r_f \Delta t} V_{t+\Delta t,j}.$$

9: **end for**

10: Construct a regression dataset:

$$\{(V_{t,j}', S_{t,j}, \mathrm{Conv}_{t,j}) : j = 1, 2, \ldots, M\}.$$

11: Fit a regression model to estimate V_t':

$$V_t' = \alpha + \beta_1 S_t + \beta_2 Conv_t \ + \epsilon_t.$$

12: **for** each path $j = 1, 2, \ldots, M$ **do**

13: Compute the intrinsic value at t:

$$IV_{t,j} = \max\big(n_t S_{t,j}, \text{Put Price}, \text{Call Price}\big).$$

14: Update $V_{t,j}'$ using regression model which share information across all stock paths:

$$V_{t,j}' = \hat{\alpha} + \hat{\beta}_1 S_{t,j} + \hat{\beta}_2 Conv_{t,j}.$$

where $(\hat{\alpha}, \hat{\beta}_1, \hat{\beta}_2)$ are fitted coefficients from regression model from Step 11.

15: Update the bond value at t, which will be used in step 8 in next iteration:

$$V_{t,j} = max(IV_{t,j}, V_{t,j}')$$

Algorithm 2 Convertible Bond Valuation at time t, i.e. Calculating V_t

Require: $\{S_u\}_{u<t}$, S_t, Conv_t, r_f, bond terms (C_t, call/put prices, conversion rules, reset clauses, maturity value N, reset factor δ, simulation number M, and multiplier α. Where $\{S_u\}_{u<t}$ represents the stock prices over a past period before t. The length of this period can be adjusted based on the model's requirements.

Ensure: V_t

Step 1: Simulate Stock and Conversion Price Paths

for each path $j = 1, \ldots, M$ **do**

  Generate $\{S_{i,j}\}_{i=t+1,\ldots,T}$ based on $\{S_u\}_{u<t}$, S_t, r_f and equation (6)

  Compute $\{\text{Conv}_{t,j}\}_{i=t+1,\ldots,T}$ using equation (7) for each simulated stock price path

end for

Step 2: Get V′ obtained from Algorithm (1)

Step 3: Compute t_j^* for each path using Equation (3)

Step 4: Compute Payoff

for each path j, and each corresponding time k from t to T **do**

  Determine the payoff according to Table 2 **return** Corresponding payoff value

end for

Step 5: Compute Present Value of Convertible Bond for each path

$$V_{t,j} = \sum_{i=1}^{t_j^*} C_i e^{-r_i i} + \text{Payoff}(t_j^*, S_{t_j^*,j}, \text{Conv}_{t_j^*,j}, V'_{t_j^*,j}, \text{Action}_{t_j^*,j}) e^{-r_{t_j^*} t_j^*}$$

Step 6: Estimate Convertible Bond Value at time t

Compute the expected value of V_t by averaging the present values $V_{t,j}$ obtained from all M simulated paths:

$$V_t = \frac{1}{M} \sum_{j=1}^{M} V_{t,j}$$

Output: V_t

3 Data

This section describes the dataset used in our empirical analysis. All data in this study are obtained from the Wind database [20].

3.1 Convertible Bonds and Stock Data

The objective of this paper is to develop a convertible bond pricing model that can accurately estimate the theoretical value of convertible bonds. By leveraging the model's calculated values, the study aims to explore whether mispricing in the Chinese convertible bond market creates opportunities for profit. To achieve this, it is first essential to demonstrate that the model's calculated values closely approximate the bonds' true theoretical values.

Since the true theoretical value of an asset is unknown, market trading prices are expected to fluctuate around this value. This paper argues that if a model can consistently and accurately price assets over the long term, the trading prices should align closely with the model's calculated values and fluctuate around the theoretical value. Conversely, in an efficiently priced market, trading prices should not exhibit significant or persistent deviations from the theoretical values. Therefore, if a trading strategy can generate consistent profits by exploiting discrepancies between the model's calculated values and actual trading prices, it would suggest potential inefficiencies in market pricing.

To achieve the stated objective, we exclude convertible bonds with particularly short maturities and focus on the gap between the model price and the trading price for each bond 30 trading days after its listing. Specifically, we selected all convertible bonds with a maturity of more than two years and a listing date between January 1, 2015, and December 31, 2019, resulting in a total of 154 bonds. Additionally, we collected the corresponding price series for the underlying stocks associated with these convertible bonds. The decision to focus on bonds issued before 2020 stems from the

Table 3 Summary of Conditions and Payoffs for Convertible Bonds

bond id	**Call**			**Put**			**Reset**	
	Price	Trigger	Period	Price	Trigger	Period	Trigger	Period
110033	100	130	30	100.0	70.0	30.0	90	30
110034	100	130	30	103.0	70.0	30.0	85	20
110038	100	125	30	100.0	50.0	30.0	80	30
110041	100	130	30	100.0	70.0	30.0	90	30
110043	100	130	30	na	na	na	80	30
...	...	...	...	...	...	...	...	...
128091	100	130	30	100.0	70.0	30.0	90	20

Table 3 presents the key contractual terms embedded in example convertible bonds, specifically focusing on the call, put, and reset clauses. For example, in the case of bond 110033, if during the 30-day Call Period, the stock price exceeds the Call Trigger (130) for a number of consecutive trading days as specified in the bond contract, the issuer has the right to redeem the bond at the Call Price (100). Similarly, if during the 30-day Put Period, the stock price below the Put Trigger (70) for a number of consecutive trading days as specified in the bond contract, the investor has the right to resell the bond at the Put Price (100) to issuer. In the case of the reset clause, if during the 30-day Reset Period, the stock price below the Reset Trigger (90) for a number of consecutive trading days as specified in the bond contract, the issuer has the right to reset the convert price. Some bonds (e.g. 110043) do not include put or reset clauses, in which case the corresponding entries are marked as `na`.

typical six-year listing duration of Chinese convertible bonds. By selecting bonds listed before 2020, we ensure that the vast majority of our sample has completed its full listing cycle by the time of this study, providing a comprehensive dataset for analysis.

After obtaining the convertible bond sample, we analyze the additional clauses embedded in these convertible bonds. Table 3 presents the embedded additional clauses for 15 convertible bonds as examples. c_p represents the call price, which is usually the face value of the bond plus the accrued interest. c_m indicates the evaluation period for determining whether the call clause is triggered. c_t represents the condition under which the call clause is triggered. Similarly, p_p represents the put price, p_t represents the condition under which the put clause is triggered, and p_m is the evaluation period for determining whether the put clause should be triggered. In this sample, all convertible bonds have call clauses, as call clauses are favorable to the bond issuer, i.e., the company. However, not all convertible bonds have put clauses, such as the convertible bond 110043. Therefore, when modeling and estimating the price of convertible bonds, we need to take this factor into consideration.

Compared to call and put clauses, which are predetermined when the bond is issued, the reset clause carries more uncertainty. r_t represents the condition under which the reset clause is triggered. For example, if $r_t = 90$, it means that if the stock price (or average price) falls below r_t of the convert price during the evaluation period, the reset clause is triggered. r_m represents the evaluation period for determining whether the reset clause is triggered. When the reset clause is triggered, the company can choose to adjust the convert price or not, so we cannot be certain whether the company will definitely adjust the convert price, which means the model requires parameter adjustments. Even if the company chooses to adjust the convert price, it has the discretion to decide the magnitude of the price adjustment within a certain range. To simplify the analysis, based on recent years' assumptions, we assume that once the reset clause is triggered, the probability that the company will choose to adjust the convert price is 0.4. If the company chooses to reset convert price, the convert price will be reduced to the proportion of r_t.

3.2 Interest Rate and Credit Rates of Underlying Stock of Convertible Bonds

The interest rates involved in this paper include two aspects: one is the risk-free rate, for which we use the yield of Chinese government bonds. The other is the yield to maturity (YTM) corresponding to the risk of each bond. We identify the market prices of pure bonds issued by each convertible bond's issuing company and then deduce the YTM of each bond as the yield to maturity incorporating default risk for the convertible bonds. Moreover, we need to calculate the data for both the risk-free rate and the bond's YTM for each trading day.

The risk-free rate is used to construct the stock volatility model in this paper, while the bond's yield to maturity is used as the discount rate for discounting future cash flows in the pricing of convertible bonds. Figure1 shows the distribution of maturity and credit rating among our sample.

It can be observed that the credit ratings of the companies associated with the convertible bonds in the sample are all A+ or above. This is due to the fact that in the Chinese market, companies issuing convertible bonds are required to meet certain profitability criteria, making convertible bonds a low-risk asset. At the same time, they offer the potential for capital gains if the stock price rises. Therefore, for investors who are optimistic about the company's stock price but do not want to bear the risk of unexpected stock price declines, convertible bonds are a good investment option.

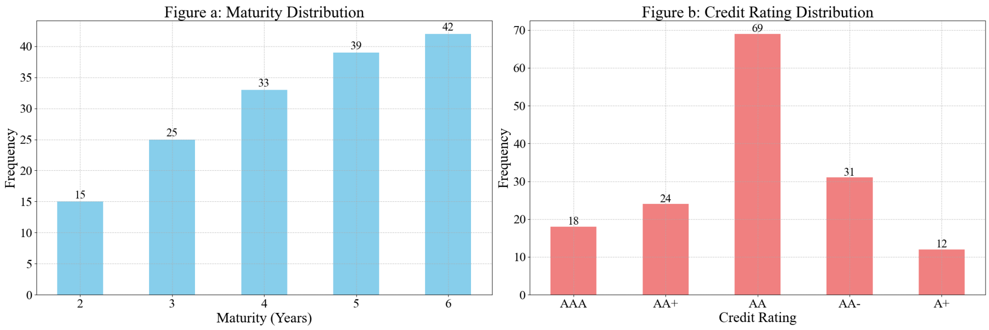

Fig. 1 Distributions of Maturity and Credit Ratings of Chinese Convertible Bonds. (a) Distribution of issuance durations for the convertible bonds analyzed. Durations range from two to six years; bonds with shorter durations were excluded due to insufficient data, and none exceeded six years. (b) Distribution of credit ratings. All bonds are rated between A+ and AAA, reflecting the stringent requirements for issuing convertible bonds in China. The vertical axis (Frequency) represents the number of bonds (out of 154 total) that fall into each category.

4 Empirical Analysis

To test whether Chinese convertible bonds are priced efficiently, we conduct empirical analysis on historical market data introduced in the last section, and compare our model's theoretical valuations to observed trading prices. Drawing on the Efficient

Market Hypothesis (EMH), we assume that any systematic, profit-generating deviations from fair value would indicate partial market inefficiency [21]. If a given pricing method can systematically generate positive excess returns, it suggests some degree of market inefficiency [22]. Conversely, if no persistent excess returns can be obtained, the market is considered efficient [23]. Our empirical investigation proceeds in two stages: analyzing 154 individual bonds and then constructing portfolios to detect broader patterns of mispricing.

4.1 Individual Convertible Bond Example

In this experiment, individual refers to the fact that our pricing and strategy simulations are conducted at the level of an individual convertible bond (instead of a portfolio of multiple bonds). In this subsection, all results presented and performance evaluations are based on the aggregated results from these 154 bonds.

To assess the pricing efficiency of the Chinese convertible bond market, we first examine whether the trading prices of convertible bonds align with the theoretical prices generated by our model at specific time points. This comparison allows us to quantify the extent of deviation between market prices and model-implied values. Figure 2 illustrates the distribution of price deviations, computed as:

$$\text{Difference Rate} = (\text{Simulated Price} - \text{Trading Price})/\text{Trading Price} \tag{12}$$

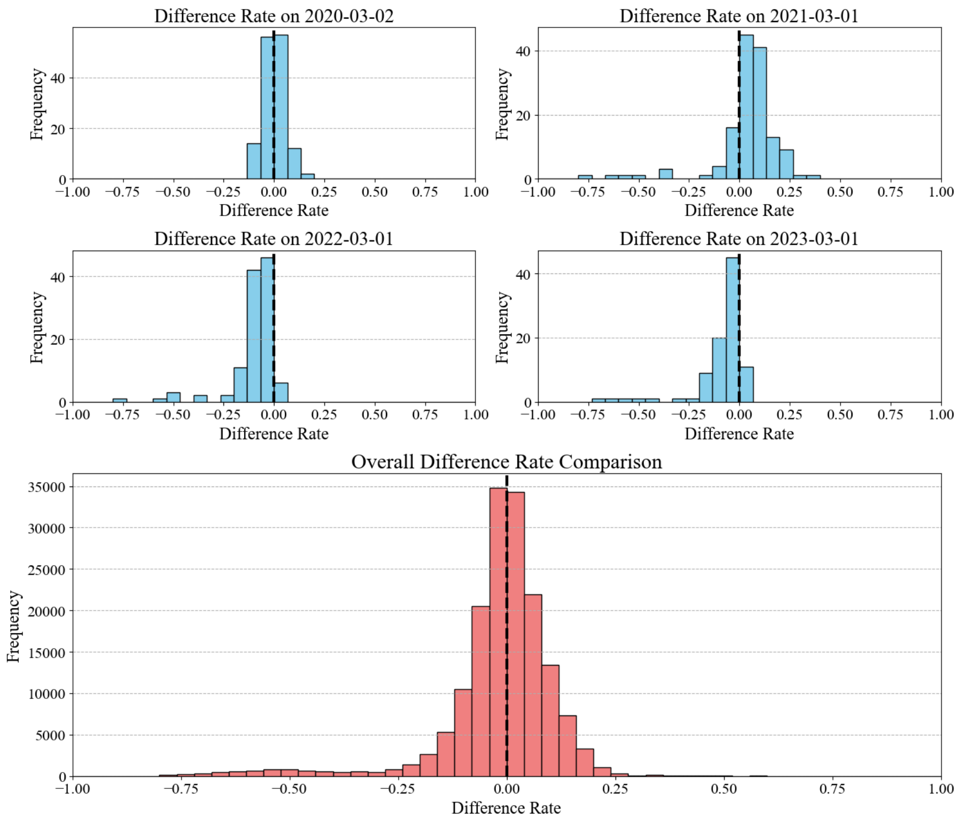

Fig. 2 Distribution of differences between simulated prices and market trading prices on four selected trading days, as well as across all time points. While deviations are generally within 10%, the overall distribution is slightly left-skewed, suggesting that market prices tend to be marginally higher than simulated prices on average. However, on individual trading days, deviations can be substantially larger in either direction. The vertical axis (Frequency) indicates the number of convertible bonds that fall into each deviation bin. For the first four subplots, the distribution reflects all convertible bonds on each respective trading day. The final subplot aggregates all available Difference Rate values for all sample convertible bonds across the entire sample period, and hence has much higher frequencies.

The first four panels in Figure 2 show the distribution of price deviations for all convertible bonds on early March trading days in each year from 2020 to 2023 (specifically, '2020-03-02', '2021-03-01', '2022-03-01', and '2023-03-01'). These dates represent typical patterns observed throughout the sample period, with similar distributions found on many other trading days. The fifth panel presents the aggregated distribution across all trading days in the dataset. The results reveal that significant deviations exist between theoretical and market prices, with trading prices deviating by up to 10% in most cases. On average, market prices are 1.58% higher than model-implied values, with a variance of 1.88%.

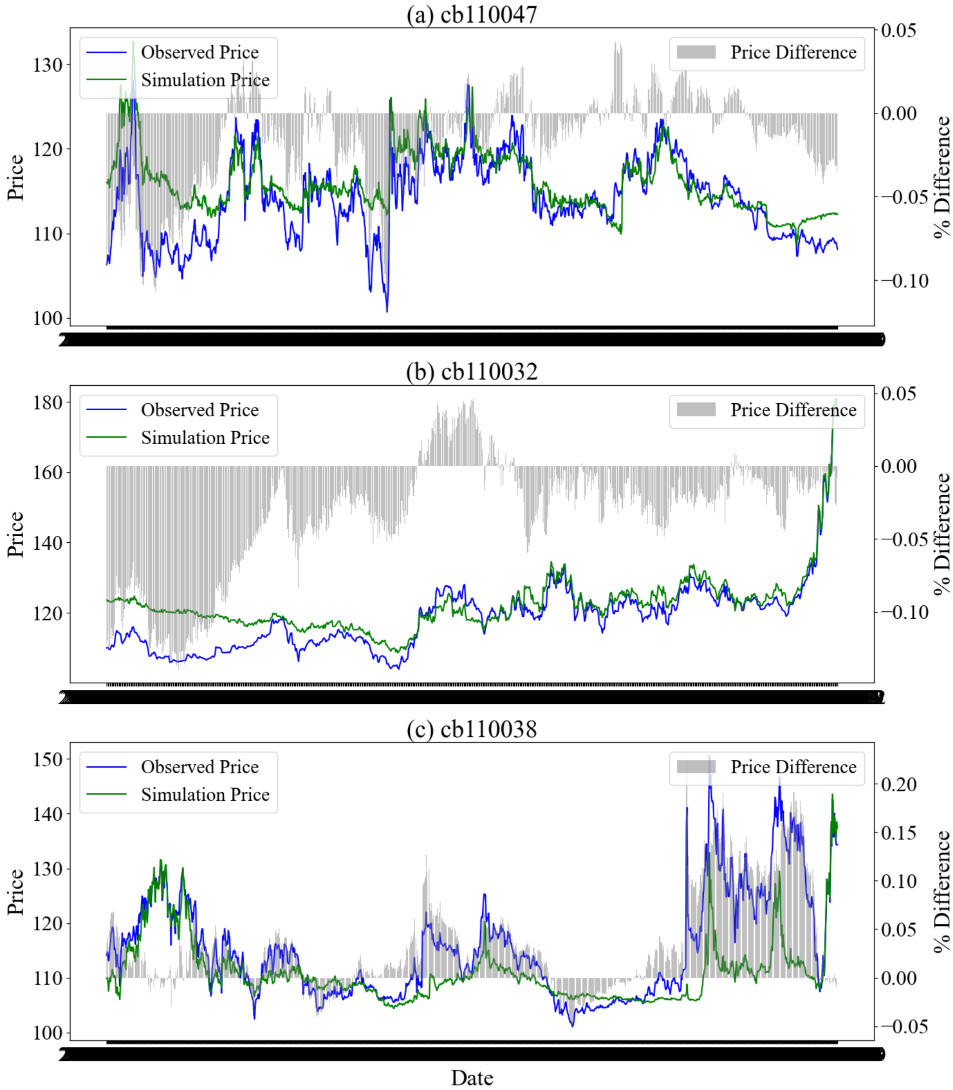

Fig. 3 Price Difference. Comparison between simulated and observed prices for four convertible bonds. (a) shows early-stage volatility post-issuance with eventual convergence to model values. (b) captures a price surge driven by stock rally. (c) illustrate model robustness during high volatility or downward trends.

Figure 3 presents the differences between the simulated prices and the observed market prices for three representative convertible bonds. In Figure 3 (a), the bond exhibits high price volatility shortly after issuance, while the model remains stable—highlighting its ability to capture intrinsic value without being influenced by short-term market noise. Over time, the market price gradually converges toward the model price. Figure 3 (b) illustrates a case where a sharp rally in the underlying stock causes a surge in the convertible bond price, which is accurately reflected by the model. Figure 3 (c) shows scenarios characterized by pronounced stock price fluctuations or downward trends, where the model continues to provide consistent pricing.

A comparison of the model-predicted price curves and the observed bond price curves in Figure 3 suggests that, while the overall trends are similar—demonstrating the robustness and accuracy of our pricing framework—there are periods with notable deviations.Such deviations are likely driven by short-term market inefficiencies, such as fluctuations in supply and demand. These pricing discrepancies prompt an important question: can they be systematically exploited to generate excess returns through arbitrage strategies?

To investigate whether observed deviations can be systematically exploited, we propose a straightforward "buy-low-sell-high" trading strategy. Specifically, we introduce two thresholds, α and β, where we buy when the trading price falls below $1-\alpha$ times the simulated price, and sell when the trading price exceeds $1+\beta$ times the simulated price. This strategy is applied individually to each convertible bond in our data. In this study, we use 3 different settings of (α,β) at (4%,2%), (6%,3%) and (8%,4%).

Figure 4 summarizes the performance of the trading strategy based on the proposed pricing model, applied independently to 154 individual convertible bonds. The figure illustrates the distributions of annualized returns (left column), win rates (middle column), and number of trades (right column) under three parameter configurations, each defined by a distinct combination of entry and exit thresholds α and β. Across all parameter settings, the strategy demonstrates strong and consistent performance: the mean and median annualized returns range from 8.5% to 10.7%, while win rates consistently exceed 78%, indicating a high proportion of profitable trades. The number of trades per bond remains moderate, typically between 6 and 11, reflecting a relatively low trading frequency. These results suggest that even a simple rule-based strategy can systematically capture excess returns, highlighting the pricing model's effectiveness in identifying and exploiting mispricing opportunities in the convertible bond market.

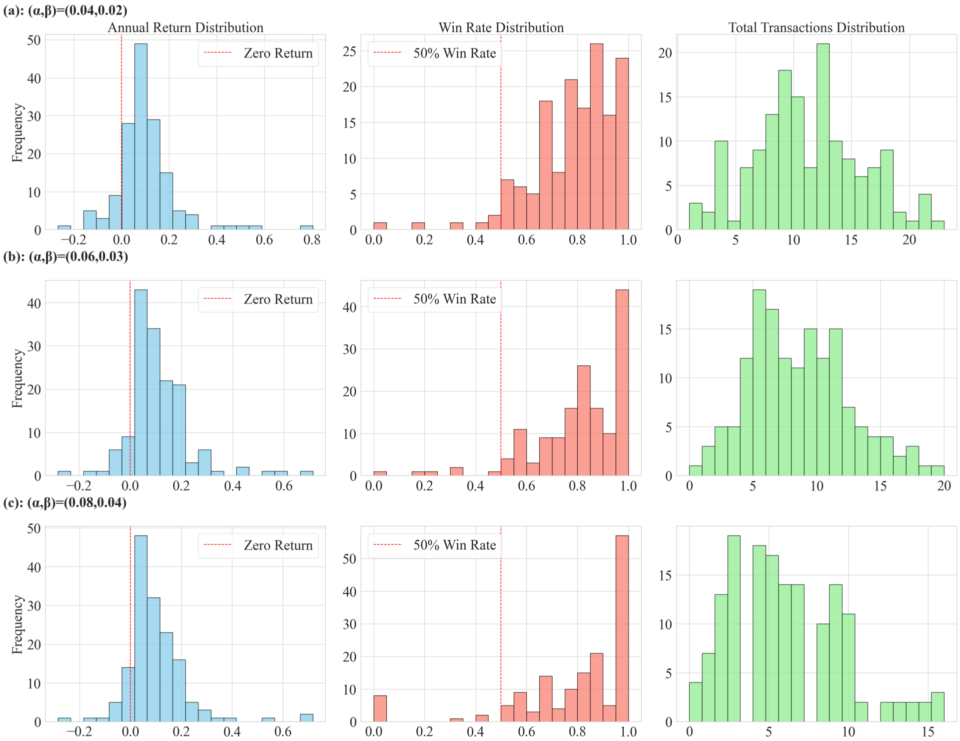

Fig. 4 Performance of the trading strategy based on the proposed pricing model applied to 154 individual convertible bonds. This figure displays the distribution of annualized returns (left column), win rates (middle column), and number of trades (right column) for a trading strategy applied to 154 individual convertible bonds, evaluated under three different combinations of trading decision parameters (entry threshold α and exit threshold β), shown across rows. The strategy was applied independently to each bond, and the distributions summarize outcomes across all bonds. The results demonstrate robust performance across parameter settings, with most annual returns being positive, win rates exceeding 0.5 in most cases, and a relatively low number of trades.

4.2 Portfolio-Based Evidence of Arbitrage Opportunities

Beyond individual trade-based strategies, we also evaluate the model's effectiveness using a portfolio-based approach. Over the entire sample period, we implement a 20-working-day cycle. In each investment cycle, we construct portfolios based on the difference rate between the model-implied price and the market trading price of each convertible bond. Specifically, at the beginning of each cycle, we calculate the difference rate for all eligible convertible bonds in our sample using the formula defined earlier. We then rank the bonds based on their difference rates and divide them into three equal-sized groups: the Low Difference Group (lowest third), the Median Difference Group (middle third), and the High Difference Group (highest third).

The Low Difference Group contains bonds that are relatively undervalued by the market compared to the model, while the High Difference Group includes those that appear relatively overvalued. For each group, we construct an equally weighted portfolio and hold it throughout the investment cycle. Additionally, we form a long-short portfolio by taking a long position in the Low Difference Group and a short position in the High Difference Group, each with equal dollar amounts to ensure market neutrality. This long-short strategy is designed to capture the excess returns arising from mispricing, while minimizing market-wide risk exposure. At the end of the cycle, we rebalance the portfolios by repeating the above steps based on the updated difference rates.

Figure 5 presents the performance metrics of these portfolios. The results reveal a clear and significant monotonic relationship between the difference rate and portfolio returns. The Low Difference Group achieves an annualized return of 7.28%, with volatility and maximum drawdown of 14.82% and -16.62%, respectively. The Median Difference Group records an annualized return of 3.71%, with volatility of 17.37% and a maximum drawdown of -25.37%. Meanwhile, the High Difference Group incurs a negative annualized return of -3.17%, with higher volatility (21.04%) and a deeper maximum drawdown (-30.69%). These findings indicate that convertible bonds with lower difference rates tend to be relatively undervalued by the market, while those with higher difference rates are relatively overvalued. As a result, a trading strategy that goes long on undervalued (low difference rate) bonds and short on overvalued (high difference rate) bonds can generate significant excess returns. Notably, the long-short portfolio outperforms all individual groups, delivering an annualized return of 9.2%, with volatility of 15.36% and a maximum drawdown of -12.41%.

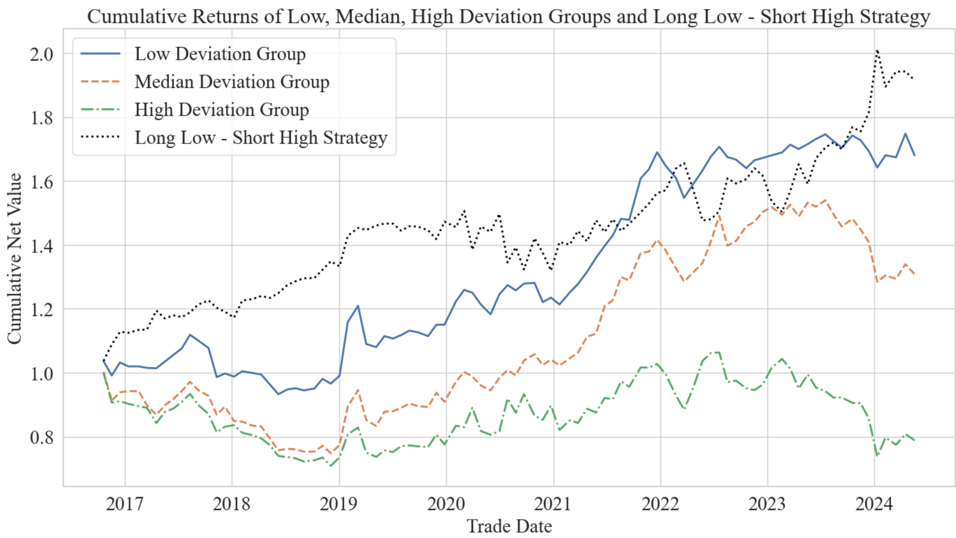

Fig. 5 Cumulative Returns of Low, Median, High Deviation Groups and Long Low - Short High Strategy.This figure shows the cumulative returns of three deviation groups (Low, Median, High) and the long-short strategy. Convertible bonds are re-ranked every 20 days based on price deviation, and portfolios are updated accordingly. The long-short strategy, going long on Low Deviation Group and short on High Deviation Group, demonstrates the model's effectiveness in portfolio construction.

These results provide compelling evidence that price deviations in the Chinese convertible bond market can be systematically exploited for arbitrage. The model not only offers stable and accurate pricing but also enables the construction of profitable portfolios that leverage valuation discrepancies. This highlights its potential in generating significant excess returns while offering deeper insights into the efficiency of market pricing.

5 Conclusion

This paper presents a comprehensive analysis of Chinese convertible bond pricing, based on all 154 bonds issued between 2015 and 2019. We find that market prices broadly align with theoretical values, yet notable and systematic mispricings persist—revealing exploitable inefficiencies in the market. To support this analysis, we develop a novel pricing model based on the Least Squares Monte Carlo (LSM) method, incorporating key contractual features specific to the Chinese market, including reset clauses, call provisions, and put options. While the model successfully replicates overall pricing patterns, the remaining price gaps suggest that investors may overlook or misvalue key contractual elements. For instance, reset triggers—unique to the Chinese convertible bond market—are rarely addressed in the existing literature, leaving limited guidance on how to properly incorporate them into pricing models. Moreover, the relatively small scale of the Chinese convertible bond market makes it more susceptible to speculative capital. This study also finds that convertible bond prices in China frequently exhibit extreme volatility, including sudden surges and sharp declines.

Our empirical analysis confirms that a simple buy–sell strategy keyed to these pricing deviations consistently outperforms baseline returns, revealing partial market inefficiency. Additionally, a long-short approach across multiple bonds shows that relative mispricing can be systematically harnessed for enhanced gains. Consequently, this study provides a roadmap for understanding and quantifying embedded-option complexity in an emerging financial market context. Looking ahead, more advanced calibrations of credit risk, volatility behavior, and issuer decision-making could reduce pricing uncertainty and possibly dampen these arbitrage opportunities. Ultimately, the findings encourage market participants to adopt more comprehensive valuation practices and promote continuing efforts by regulators to foster transparency and liquidity in the Chinese convertible bond sphere.

Declaration

Availability of data and material

All data in this study are obtained from the Wind database available at: https://www.wind.com.cn/portal/zh/WDS/index.html. Accessed: March 2025.

Competing interests

The author declares that they have no competing interests.

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Authors' contributions

S.L. and X.Z. jointly conceived the study; X.Z. supervised the research, while S.L. performed all computer experiments and prepared the initial manuscript draft. All author(s) read and approved the final manuscript.

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References

[1] Black, F., Scholes, M. (1973). The pricing of options and corporate liabilities. *Journal of Political Economy*, **81**(3), 637–654.

[2] Ingersoll Jr J E. (1977). A contingent-claims valuation of convertible securities[J]. *Journal of Financial Economics*, **4**(3), 289-321.

[3] Lewis, C. M. (1991). Convertible debt: Valuation and conversion in complex capital structures. *Journal of Financial Economics*, **30**(2), 289-321.

[4] Cox, J. C., Ross, S. A., Rubinstein, M. (1979). Option pricing: A simplified approach. *Journal of financial Economics*, **7**(3), 229-263.

[5] Brennan, M. J., Schwartz, E. S. (1977). Convertible bonds: Valuation and optimal strategies for call and conversion. *The Journal of Finance*, **32**(5), 1699-1715.

[6] Jarrow, R. A., Turnbull, S. M. (1995). Pricing derivatives on financial securities subject to credit risk. *The journal of finance*, **50**(1), 53-85.

[7] Tsiveriotis, K., Fernandes, C. (1998). Valuing convertible bonds with credit risk. *The Journal of Fixed Income*, **8**(2), 95.

[8] Longstaff, F. A., Schwartz, E. S. (2001). Valuing American options by simulation: a simple least-squares approach. *The review of financial studies*, **14**(1), 113-147.

[9] Cheuk, T. H., Vorst, T. C. (1997). Currency lookback options and observation frequency: a binomial approach. *Journal of International Money and Finance*, **16**(2), 173-187.

[10] Fleming, J. (1998). The quality of market volatility forecasts implied by SP 100 index option prices. *Journal of empirical finance*, **5**(4), 317-345.

[11] Meng, Y. (2023). Research on Pricing Model of Chinese Convertible Bonds: Based on The Nature of Convertible Bonds Themselves. *Frontiers in Business, Economics and Management*, **11**(3), 80-84.

[12] Luo, X., Zhang, J. (2019). Pricing Chinese convertible bonds with default intensity by Monte Carlo method. *Discrete Dynamics in Nature and Society*, **2019**(1), https://doi.org/10.1155/2019/8610126.

[13] Li, P., Song, J. (2014). Pricing Chinese convertible bonds with dynamic credit risk. *Discrete Dynamics in Nature and Society*, **2014**(1), https://doi.org/10.1155/2014/492134.

[14] Ammann, M., Kind, A., Wilde, C. (2003). Are convertible bonds underpriced? An analysis of the French market. *Journal of Banking and Finance*, **27**(4), 635-653.

[15] Engle, R. F. (1982). Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. *Econometrica: Journal of the econometric society*, 987-1007.

[16] Xie, D. J. (2012). Application research of Monte Carlo simulation method in convertible bond pricing [D]. Guangxi University. DOI:10.7666/d.y2161408.

[17] Wang, Y. T., & Wen, Z. Y. (2018). The impact of downward adjustment clauses on the pricing of Chinese convertible bonds. *Journal of Tsinghua University: Science and Technology*, 58(1), 5.

[18] Xiong, B., Zhu, J. (2024). Research on pricing methods of convertible bonds in China. *China Prices*, **3**, 5–10.

[19] Li, J., Li, Y. (2023). Research on convertible bond pricing in China based on the Black-Scholes model. *Business and Management*, **12**, 6–13.

[20] Wind Information Co., Ltd. *Wind Database*. Available at: https://www.wind.com.cn/portal/zh/WDS/index.html. Accessed: March 2025.

[21] Fama, E. F. (1970). Efficient capital markets. Journal of finance, 25(2), 383-417.

[22] Grossman, S. J., and Stiglitz, J. E. (1980). On the impossibility of informationally efficient markets. The American economic review, 70(3), 393-408.

[23] Malkiel, B. G. (2003). The efficient market hypothesis and its critics. Journal of economic perspectives, 17(1), 59-82.