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Derivative pricing for convertible bonds

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Abstract. This paper examines volatility-driven mispricing in China's Convertible Bond (CB) market by comparing GARCH-based historical volatility with implied volatility. Using market data and contractual features, we examine how redemption policies and conversion-price adjustments affect convertible-bond valuation. Our results show that the embedded option component is systematically undervalued, implying persistent mispricing in China's CB market. We develop and backtest volatility-based trading strategies and demonstrate that incorporating CBs into traditional portfolios enhances both diversification and risk-adjusted returns.

Keywords: convertible bonds, volatility mispricing, GARCH model, implied volatility, arbitrage strategy, portfolio diversification

1. Introduction

Convertible Bonds (CBs) are an important part of today's capital markets because they combine features of both fixed-income securities and equity options. They offer bondholders regular coupon payments and give them the choice to turn them into common stock if certain conditions are met. Because of this unique structure, CBs are affected by changes in both interest rates and stock prices, which makes pricing them difficult. Pricing complexity comes from more than just how sensitive stocks and bonds are. It also comes from contract features like redemption and reset clauses that add extra options. This makes convertible bonds a great place to find mispriced and trading opportunities [1].

The convertible bond market in China has grown quickly because of changes in policy and more people getting involved in the market. However, this growth has shown that prices are not always fair, especially when it comes to the option trigger value of the option. This has led to worries about mispricing and how it could affect investors. Additionally, empirical research on China's convertible bond market has revealed significant undervaluation. Zhang, Tang, and Liu [2] found that the average degree of undervaluation was about 10.2%. They attributed this mispricing to differences in investor types and the risks created by unpredictable trading behavior. This demonstrates that there are evident inefficiencies in the price-setting mechanisms of this market. Recent studies have found that convertible bonds not only experience pricing inefficiencies but also influence the prices of their underlying stocks. This cross-market interaction suggests possible channels of risk contagion within China's capital market [3]. The theoretical valuation of convertible bonds heavily relies on volatility estimation. Models like GARCH reflect historical volatility, while implied volatility from options pricing shows market expectations for future volatility. When a persistent gap exists between the two, especially when GARCH volatility exceeds implied volatility, it suggests a consistent undervaluation of the embedded option.

Building on these observations, our study aims to deepen the understanding of mispricing mechanisms by focusing on the volatility structure underlying convertible bond valuation. While previous research has pointed out valuation biases, the persistent discrepancy between implied and historical volatility suggests a potentially structural underpricing of embedded options. This phenomenon, however, has not been studied in depth. Compared with previous studies, our paper utilizes a larger dataset, enabling a more systematic analysis of the volatility. Furthermore, we stress-test the proposed volatility-based trading strategies and assess the implications of convertible-bond inclusion for portfolio construction and risk management.

This paper contributes to the literature by:

(1) Providing the first large-sample comparison (942 bonds) between GARCH-based and implied volatilities in China's convertible bond market. This extends beyond prior studies such as Zhang and Zhao [1]. Their research developed a closed-form pricing model based on the Black-Scholes framework. However, it did not include large-sample empirical validation.

(2) Developing volatility-spread trading strategies and testing their robustness under stress conditions. The results show that these strategies remain profitable and stable during stressed market periods. This finding contrasts with Long [4], whose simulation-based approach examined only 154 bonds using an LSM pricing model and did not include stress testing.

(3) Evaluating the role of convertible bonds in portfolio allocation and diversification. We further examine the improvements in diversification and Sharpe ratios when CBs are added to traditional stock-bond portfolios. The findings provide new evidence that CBs act as both arbitrage instruments and risk stabilizers in China's evolving capital markets.

Overall, these contributions distinguish this study from earlier research on Chinese convertible bonds. The differences lie in the dataset size, the breadth of empirical analysis, and the inclusion of stress testing. The study provides a comprehensive understanding of volatility-driven mispricing and its practical implications.

2. Background of convertible bonds in China

2.1. Growth and mispricing in China's convertible bond market

The convertible bonds market has developed vigorously in China since 2000, when the convertible bond market was opened. Initially, the issuance of convertible bonds was subject to strict regulation by the China Securities Regulatory Commission (CSRC), due to a rigorous approval process. Consequently, these instruments were primarily used by state-owned enterprises. With the gradual opening up of China's capital markets, the CSRC had established a more market-based regime for convertibles, paving the way for widespread participation from institutional and retail investors.

The CSRC eased issuance rules and simplified the approval process, resulting in more convertible bond issuances. Unlike IPOs, the pricing of convertible bonds is typically influenced by both market demand and the embedded option's valuation. Issuers can still design key contract terms like the conversion price, reset clauses, and redemption rules. While these terms improve the issuer's financing flexibility, they also introduce additional option features, making pricing more complex.

By 2020, convertible bonds had become one of the fastest-growing asset class in China's fixed-income market. This rapid growth was mainly driven by strong demand from institutional investors for such hybrid instruments, which offer downside protection while retaining the potential for equity upside. At the same time, because of relatively low entry barriers and their perception as "low-risk, high-return" securities compared to stocks, retail participation also increased significantly.

However, the explosive growth of China's convertible-bond market has introduced new challenges. Empirical research shows that Chinese CBs are, on average, undervalued. This undervaluation occurs because the option value is embedded in the coupon rate. As a result, they are systematically mispriced. This can be attributed to the market inefficiency, low-level investor awareness and difficulty in modeling contractual features. Thus, the volatility estimation plays an intensive role in convertible bond pricing. Traditional volatility pricing approaches, such as the GARCH model, capture volatility behavior based on past information. On the other hand, the implied volatility extracted from the convertible bond option equivalent model reflects the market's foresighted attitude. The mismatch between these two models is significant. Specifically, the implied volatility is lower than the GARCH volatility. This difference is proof of the general mispricing of convertible bonds. It also presents an arbitrage opportunity for advanced investors.

Additionally, the institutional nature of China's convertible bonds market is special. Permission from the CSRC is needed for issuance, and there are often many new bonds on issue on the same issuing day resulting in a heavy supply. In addition, early redemption and mandatory conversion options commonly result in price fluctuation making the price process more complicated. These characteristics make this market system unique compared to other countries. As a result, it provides a good environment for analyzing mispricing, trading strategies, and portfolio diversification effects.

2.2. Literature review

2.2.1. CB mispricing

The pricing of convertible bonds is complex, leading to questions about potential mispricing in the market. Early empirical studies in the U.S. [5, 6] revealed a systematic bias in contingent-claims valuation models. These models tend to overvalue out-of-the-money convertible bonds, where the conversion value is lower than the straight debt value. They also slightly undervalue in-the-money bonds. These findings support the widespread view among practitioners. They suggest that the hybrid structure, embedded options, and often suboptimal call behavior contribute to the difference between market prices and theoretical values. This difference indicates that arbitrage opportunities may arise under certain conditions.

Ammann, Kind, and Wilde [7] conducted one of the most influential large-sample studies by using French market data over an 18-month period with daily observations. They employed a stock-based binomial-tree model with exogenous credit risk. The results showed that, on average, theoretical values were more than 3% higher than observed market prices. This confirmed that the mispricing was both significant and systematic. The mispricing was more pronounced in out-of-the-money convertibles than in at-the-money or in-the-money bonds. Additionally, the undervaluation tended to increase with maturity. Importantly, their results demonstrated that even in a relatively liquid and well-developed market such as France, arbitrage frictions and model complexity prevented mispricing from being fully arbitraged away.

These findings highlight that CB mispricing is not confined to emerging or less efficient markets but is also observable in mature European markets. For the Chinese market, similar inefficiencies have been documented, often attributed to volatility estimation issues and contract-specific complexities [1]. Long [4] uses a Least Squares Monte Carlo (LSM) method designed for the Chinese market, including features like reset clauses, and analyzes 154 bonds. The study shows that the values predicted by the model often differ from market prices by more than 10%. This indicates large and regular inefficiencies. These inefficiencies create exploitable arbitrage opportunities for informed investors. The difference between GARCH volatility and implied volatility indicates that the embedded option component is systematically undervalued, thereby creating arbitrage opportunities.

2.2.2. Volatility modeling in CBs

Volatility plays a crucial role in convertible bond valuation, given that CBs combine fixed-income and equity option characteristics. Early single-factor models, such as Ingersoll [8], Brennan and Schwartz [9], largely emphasized equity volatility while underestimating the contribution of interest rate dynamics.

Ho and Pfeffer [10] significantly advanced this literature by proposing a two-factor arbitrage-free model that integrates both stock and interest rate volatilities within a binomial lattice. Their framework demonstrates that the correlation between equity risk and interest rate risk can have a significant impact on the value of convertible bonds. This effect is particularly pronounced for callable issues. The framework also decomposes CBs into three components: investment value, latent warrant, and call or forced conversion value. Moreover, the associated sensitivity measures offer important insights into the behavior of CB prices. These measures show how prices respond not only to changes in equity volatility, but also to movements in the term structure of interest rates. As a result, they support more accurate hedging techniques and improve relative valuation strategies. However, despite these theoretical advances, several limitations remain in the empirical and practical application of volatility modeling in CB markets. First, most models do not systematically compare implied and GARCH volatilities across the full market, leaving uncertainty about the persistence of volatility-driven mispricing. Second, they often neglect the interaction between contractual features (e.g., conversion price adjustments) and volatility dynamics, which can materially affect the option value. Third, few studies link volatility-driven mispricing to practical trading strategies or portfolio allocation decisions, limiting their relevance for investors.

Given these limitations, we compare GARCH and implied volatilities for all actively traded convertible bonds in China. Our results show a consistent positive volatility spread, confirming the structural undervaluation of the embedded options. By explicitly incorporating contractual terms—such as redemption rules and conversion-price adjustments—we quantify their marginal effects on convertible-bond valuation. Based on this, we design and backtest trading strategies targeting undervalued convertible bonds. Finally, we evaluate the portfolio role of CBs, showing that their inclusion enhances diversification and improves Sharpe ratios compared to traditional stock-bond portfolios. In sum, our study contributes to volatility modeling, mispricing analysis, and strategy design in China's evolving CB market.

2.2.3. Portfolio role of CBs

Convertible bonds have long been studied as a distinct asset class that enhances portfolio diversification due to their hybrid characteristics. Early work by Lummer and Riepe [11] positioned CBs as a separate asset class, emphasizing their defensive qualities relative to equities while retaining upside potential.

Ranaldo and Eckmann [12] provide one of the most systematic analyses of the international CB market, examining their risk-return profile and portfolio implications. Their study shows that CBs display a positively skewed return distribution, which is attractive for investors concerned about downside risks. Empirically, CBs lose only about half as much as equities in bear markets. They capture approximately 70% of equity asymmetry. With moderate volatility situated between bonds and equities, CBs are positioned as an efficient hedge asset. From a portfolio optimization perspective, Ranaldo and Eckmann [12] find that including CBs in a global bond–equity portfolio significantly improves the Sharpe ratio. In particular, minimal-risk portfolios allocate as much as 20% to CBs while reducing equity exposure to only 2.5%, This fully demonstrates the asset allocation value of convertible bonds.

Building on this foundation, our study highlights the portfolio role of convertible bonds in the Chinese market. While prior research has emphasized the general diversification benefits of CBs, we provide systematic evidence that substituting a portion of equities with convertible bonds significantly enhances risk-adjusted performance. Specifically, portfolio analysis shows that CBs reduce downside exposure while retaining meaningful upside participation, thereby improving the Sharpe ratio relative to traditional stock–bond allocations. Table 2 provides portfolio performance metrics under varying CB allocations, showing that higher CB weights reduce volatility and raise sharpe ratios. As shown in Table 4 and Figure 3, the inclusion of convertible bonds shifts the efficient frontier upward, indicating improved risk-adjusted returns and diversification benefits. This finding positions

CBs as instruments to exploit volatility-driven mispricing. It also highlights CBs as effective substitutes for equities. This makes them useful for achieving superior portfolio efficiency in China's evolving capital markets.

3. Data and methodology

3.1. Data description

Our sample contains detailed daily data on 942 actively traded convertible bonds in China from January 2016 to February 2024. For each bond, we collected daily opening and closing prices, conversion prices, conversion values, and delta values, providing a foundation for analyzing convertible bond pricing dynamics.

To assess volatility and potential mispricing, we include two volatility measures for each bond on a daily basis: GARCH volatility and implied volatility. The GARCH volatility is estimated using the baseline GARCH (1,1) model, which models how volatility changes over time based on past return data. Specifically, we estimate the conditional variance using the following equation:

$$\sigma_t^2 = \omega + \alpha \times r_{t-1}^2 + \beta \times \sigma_{t-1}^2 \tag{1}$$

where σ_t^2 is the conditional variance at time t, r_{t-1} is the lagged return, and ω, α, and β are parameters to be estimated.

Implied volatility is estimated from the price of the embedded call option in each convertible bond using the Black-Scholes model. The Black-Scholes call option pricing formula is defined as:

$$C = S_0 \times N(d_1) - K \times e^{-rT} \times N(d_2) \tag{2}$$

where C is the call option price, S_0 is the current underlying stock price, K is the strike price, r is the risk-free rate, T is the time to maturity, and $N(d_2)$ is the cumulative distribution function of the standard normal distribution. In our case, the maturity of the option is set to the maturity of the CB, ensuring consistency in the estimation across the full sample.

We define the volatility spread as the difference between GARCH volatility and implied volatility. This spread serves as a key indicator of potential mispricing in CBs. To support this analysis, we also include historical volatility that matches the timing and method used for the GARCH and implied volatility. This helps us better understand how volatility behaves over time.

To analyze how the volatility spread varies across different bonds and changes over time, we calculate the percentiles, average, and standard deviation for each trading day. In addition, we create a time series of the equal-weighted average. This average is based on the volatility spread across all bonds. It helps us observe whether the overall market tends to overvalue or undervalue the embedded options. Figure 1 illustrates this time series and shows that the volatility spread remains persistently positive over 2016–2024, indicating systematic undervaluation.

Our dataset also includes key structural features of each convertible bond's embedded option—such as when it can be converted and the conditions for early redemption. These details are crucial for understanding how CBs are priced in practice. With this information, we are able to conduct detailed studies on mispricing caused by volatility differences, and design trading strategies like delta-hedging based on signals from the volatility spread.

3.2. Volatility-based trading strategy

Our findings are consistent with Song and Heavey [13], as they pointed out that convertible bond arbitrage profits mainly originate from volatility mispricing. They also confirmed that the pricing discrepancy between implied volatility and realized volatility continuously provides profit opportunities for arbitrageurs. This is especially true in volatile markets. In this paper, we propose a trading strategy based on volatility to detect undervalued and overvalued convertible bonds in the Chinese market. The approach focuses on the difference between two main measures of volatility: GARCH volatility (historical price swings) and implied volatility (market expectations for future price). We speculate that if there exists a large gap between GARCH volatility and implied volatility, the embedded options in CBs may be undervalued or overvalued. More specifically, when GARCH volatility is greater than implied volatility, the option embedded in the CB is undervalued, and the CB is selling at a discount to its theoretical level. On the contrary, if the implied volatility is larger than the GARCH volatility, the CB may be overvalued. By monitoring the evolution of the volatility gap, we can recognize CB opportunities which are either buying or selling points. For a CB that is undervalued (i.e., the GARCH volatility is much higher than its implied volatility), we make a purchase in the CB with a short in the stock to cover our position. Vice versa, if CB is overvalued, we would instead sell CB and buy the stock to hedge the position.

We adopt a rolling window approach to calculate the percentile distribution of the volatility gap. The window size is set to 200 periods, meaning that the volatility gap is calculated based on the most recent 200 data points. The sampling frequency is daily, ensuring that the volatility gap is updated each day using the latest market data.

To compute the percentiles, we first calculate the volatility gap for each trading day. Then, we determine the percentile rank of the current gap. This is done relative to the historical distribution of the past 200 periods. This enables us to continuously track the evolution of the volatility gap and detect significant changes. The buy and sell thresholds are derived from the historical distribution. The 99th percentile defines a strong-buy threshold indicating pronounced undervaluation, whereas the 55th percentile marks a reversion to equilibrium and serves as the exit trigger.

The selection of these thresholds is supported by backtesting results. These results show that extreme volatility discrepancies, represented by the top 1% of the distribution, typically correspond to rare but profitable arbitrage opportunities. This finding aligns with Song and Heavey [13], who emphasize that convertible bond arbitrage profits primarily arise from volatility mispricing. They note that this is especially true during periods of heightened market turbulence. In line with their observation that implied volatility often lags realized volatility during volatile regimes, our use of the 99th percentile captures precisely these moments of temporary dislocation. The 55th percentile, on the other hand, acts as a neutral exit point. This is consistent with the literature's view that profit opportunities diminish once market volatility normalizes.

After testing the trading strategy, we found that the maximum drawdown was 9.2%, with an average holding period of 39.82 days. The strategy achieved a win rate of 71.65%. This performance demonstrates the effectiveness of the volatility gap-based approach in identifying profitable opportunities in the convertible bond market. The relatively low drawdown indicates that the strategy is robust, with minimal risk during market fluctuations. The win rate further highlights the high probability of successful trades. This occurs when the volatility gap reaches extreme levels. It confirms the hypothesis that large volatility discrepancies between GARCH and implied volatility can be reliable indicators. These discrepancies help identify undervalued or overvalued convertible bonds. Table 3 reports these performance metrics for both the full sample and stressed periods, confirming robustness of the volatility-spread strategy.

4. Pricing mechanism and market dynamics

4.1. Convertible bond pricing framework

Convertible bonds are hybrid securities combining debt-like and equity-option characteristics. The price of a CB is primarily determined by two factors. On one hand, it is influenced by the value of the embedded option. This option allows the bond to be converted into the stock of the issuer. On the other hand, the price is also affected by the bond's fixed-income characteristics. Overall, the pricing of convertible bonds can be divided into two main components: the bond value and the option value.

The bond component is valued by discounting expected coupon payments and principal at maturity using the risk-free rate or an appropriate yield curve. However, this basic model of bond pricing does not take into account the conversion to equity, something that makes the pricing of CBs complex.

The value of the option in a CB comes from the embedded call option, which allows the bondholder to exercise and convert the bond into a predetermined number of shares at the conversion price. This tends to make CBs responsive to changes in both the price and volatility of the stock. The value of the option is usually determined by option pricing models, subject to the stock price, conversion price, time to maturity, volatility and so on.

According to Dutordoir et al. [14], there are four main theories that explain why companies issue convertible bonds: the sequential-financing theory [15], the risk-shifting theory [16], the risk-uncertainty theory [17, 18], and the backdoor-equity theory [19]. All of these theories point out that the option feature of convertible bonds is important. This feature can help firms lower conflicts with investors. It also reduces problems caused by information gaps. Additionally, it provides more flexible ways to raise money. These ideas also show why volatility is a key factor in pricing convertible bonds and why features such as callability and conversion price adjustments matter in practice.

Volatility is important in the pricing of the embedded option. Volatility can be estimated in two main forms, using past conditional volatility (historical volatility, which GARCH models aim to model), or the market prices of the CB and other options (implied volatility). In this study, a main indicator is the volatility spread (that is, the spread between GARCH volatility and implied volatility). This positive spread indicates that the embedded option in the CB is undervalued. The value of the CB is not consistent with its theoretical value according to the market expectation of the future volatility. On the contrary, a negative spread may imply that the option is overvalued, which consequently brings the CB price higher than its nominal value.

The relationship between the bond value and the embedded option can be made even more complex by other features of the CBs, such as changes in the conversion price, callability, and redemption clause. These concerns motivate issuer and investor decision making. For instance, a conversion-price adjustment directly impacts the embedded option value by shaping bondholders' conversion privileges. In general, the conversion price is related to the likelihood that a conversion might take place. As a result, the conversion price can affect the pricing and trading of the CBs. It often does influence these factors.

In this paper, we rely on GARCH-volatility and the implied volatility both to value the convertible bond and to detect mispricing. We can monitor the gap between these two types of volatility. This helps us identify when the CB's embedded option is undervalued or overvalued. In turn, this lays a foundation for potentially profitable trading strategies when volatility is mispriced.

4.2. Market mispricing in China

In our examination on 942 convertible bonds in China, we obtained the spread of GARCH volatility and implied volatility in terms of each bond, forming a spread time series. The spread is, on average, positive. Descriptive statistics of the spread across years, summarized in Table 1, further confirm that the mean spread remains positive in nearly all sample years. This suggests that the embedded options in Chinese CBs are undervalued. This finding is consistent with the work of Zheng and Lin [20]. It also aligns with early theoretical work by Zhang [21], who applied the Black-Scholes model to the Chinese market and highlighted the practical challenges in pricing CBs. This implies that the market seems to be mispricing these bonds, where the embedded options are generally less expensive than they should be based on implied volatility.

The positive spread of our sample lent further evidence to the hypothesis that CBs in China are undervalued. The spread values tend to remain above zero throughout the time period, which indicates that convertible bond options are undervalued in the market over time. This persistent undervaluation likely reflects market inefficiencies, limited investor sophistication, and challenges in modeling complex contractual features.

Moreover, these price anomalies represent an attractive investment opportunity for traders, especially when the volatility spread is at its extreme values, denoting significant undervaluation or overvaluation of the CBs. Additional analysis shows that high spreads generally correspond to undervalued CBs, and we can go long accordingly. Such opportunities can be exploited by investors who have put together trading strategies to benefit from the mispricing in the market.

4.3. Impact of conversion price on convertible bond valuation

The conversion price is one of the most important factors affecting the valuation of CB, because it significantly influences the value of the embedded option that is linked to the stock price underlying. Our analysis identifies a strong linkage between conversion-price adjustments and implied volatility, demonstrating that CB valuation is highly sensitive to conversion-price dynamics.

One interesting finding was that as the conversion value of a CB declined by about 50%, the implied volatility for the bond decreased significantly. This rapid decrease of the implied volatility is a very important factor that affects the pricing of the embedded option. A decrease in the conversion value indicates that the bond is less attractive to convert into equity, therefore the option value decreases. Consequently, the spread between GARCH and implied volatility widened significantly. For example, in our case study, the differences between GARCH and implied volatility on one day moved from -0.46 to 0.1 on the next day. This sudden reversal of the spread demonstrates the sensitivity of CB pricing to the movement of the conversion price and, in this case, that such movement can reflect mispricing in the market. The gap between the volatilities widened, indicating that the less appealing convertible bond is now priced below its true embedded option value.

To expand our analysis, we extended the study to cover all convertible bonds in the market and examined the impact of declining conversion price. Specifically, we analyzed different cases where the conversion price decreased by 50%, 45%, 40%, 35%, and 30%, respectively to observe how CB prices and implied volatilities responded under varying degrees of stress. The relationship between the decline in conversion price and the widening of the volatility spread is summarized in Figure 2, which shows that a decrease in the conversion price leads to an expansion of the volatility spread.

In this study, we found that when the conversion price decreased by 30%, the spread increased by 0.281. Subsequently, for every 5% decrease in the conversion price, the spread increased by an average of 0.037, up until the conversion price decreased to 45%. When the conversion price declined to 50%, the increase in the spread was slightly lower compared to when the conversion price decreased to 45%.

The analysis shows that smaller changes in the conversion price result in corresponding changes in the spread. However, larger changes may cause smaller adjustments. This could be because investors start to see the bond's conversion feature as less attractive as the price keeps dropping.

This case shows the need to monitor the conversion price behavior and its impact on volatility measures because even a slight change is enough to produce variation of the price. These results highlight the need for investors to closely monitor factors related to conversions. Such factors can cause material changes in implied volatility. They can also significantly affect the overall valuation of convertible bonds.

5. Investment strategies and risk management

5.1. Convertible bond arbitrage and risks

To translate volatility mispricing into actionable investment outcomes, we implement a delta-hedged convertible-bond arbitrage framework. In implementing a convertible bond arbitrage strategy, we perform calculations that are crucial for trade execution and risk management. The first is the capital deployed, which is the cost of buying the convertible bonds minus the proceeds from short-selling the underlying stock. This measure shows the net capital required to set up the arbitrage position. The second is the number of shares to hedge, which is calculated by multiplying the delta of the convertible bond, the number of bonds held, and the conversion ratio. This tells us how many shares of the underlying stock need to be shorted to offset the stock exposure in the convertible bond, ensuring the hedge works effectively. Together, these metrics help measure capital investment and manage risk, providing key insights for executing convertible bond arbitrage. As Zhang and Zhang [22] demonstrated, the convertible bond market in China exhibits a similar reaction speed to common information shocks as the stock market. This similarity provides a theoretical foundation for cross-market arbitrage strategies based on volatility effects. However, it should be noted that during periods of market stress, such a close link may potentially amplify liquidity risks.

While this trading strategy looks promising in terms of profitability, it's important to be aware of the risks that could affect its effectiveness, especially in the Chinese convertible bond market. Funding and liquidity issues have been major risks for similar strategies during periods of market stress, such as the 2008 financial crisis. Many convertible bond arbitrageurs suffered heavy losses when liquidity dried up and financing became harder to get, forcing them to close leveraged positions even when there were profitable opportunities [23]. In addition, extreme liquidity events like the LTCM crisis showed that not being able to execute hedged positions can lead to significant losses [24].

In the case of the Chinese market, several specific frictions should be considered. First, redemption clustering is a notable phenomenon where multiple convertible bonds approach their maturity dates around the same period, creating a concentration of redemption activity. This could potentially lead to liquidity shortages or sudden price fluctuations in the market, affecting the ability to execute trades efficiently. Furthermore, the Chinese market is characterized by retail speculation, with a high proportion of individual investors influencing price movements. Retail investors often exhibit herding behavior, which can lead to significant mispricings and increased volatility. While this might present opportunities for the strategy, it also introduces additional risk factors, such as unexpected price movements due to shifts in retail sentiment or speculative bubbles.

These market frictions highlight the importance of incorporating dynamic liquidity management and market impact assessments in the risk management framework. Additionally, the strategy's reliance on delta-hedging may need to be adjusted in the face of sudden liquidity crises or extreme market volatility. In such cases, it may become difficult to maintain optimal hedges. Overall, the strategy exhibits strong potential under normal market conditions, yet its effectiveness depends critically on managing liquidity constraints, investor-behavioral factors, and structural frictions specific to China's CB market.

5.2. Strategy in stressed market

To assess the performance of the convertible bond arbitrage strategy in a stressed market, we applied the same percentile approach as in the previous analysis. We used a rolling window size of 100 to calculate the percentiles. This method was applied to market data from the 2020 pandemic period.

The analysis showed that the strategy still worked well even in a stressed market. As reported in Table 3, it had a win rate of 70.08%, with 782 trades in total. Out of these, 548 trades were profitable, showing that the strategy remained strong during times of high market stress. These results suggest that, despite the challenges of the 2020 pandemic, the convertible bond arbitrage strategy was able to stay profitable, proving its strength in tough market conditions.

This strategy is not just about making profits. It's also important to consider how practical and scalable it is. The size of the strategy is limited by factors like the depth of the market, how easily bonds and stocks can be traded, and the costs of transactions. In the Chinese convertible bond market, some issues are of small size. Additionally, there is high participation from retail investors. These factors can make it harder to take large positions. As a result, this limits how much the strategy can be scaled.

However, one advantage of this strategy is that it uses signals from a variety of convertible bonds, not just one or two specific bonds. These signals come from mispricing in volatility, which is seen in many bonds, not just a few. This allows the strategy to spread out its risk by taking smaller positions in a larger number of bonds, which helps avoid problems with liquidity in any one bond. This kind of diversification helps increase the overall size of the strategy without losing profitability. Additionally, if institutional investors can get financing and hedging tools at a low cost, they can scale the strategy even more easily.

While the strategy showed profits and performed well during market stress, like during 2020, deploying it on a large scale still requires considering real-world factors like market depth, liquidity, and capital efficiency. These insights suggest that convertible bond arbitrage can be profitable and scalable, especially when managed well through a diversified portfolio, making it a useful strategy for institutional investors in tough market conditions.

5.3. Practical implication

The empirical and theoretical findings of this study yield several practical implications for investors, issuers, and regulators in China's convertible-bond market. For investors, the continuing mispricing in volatility provides systematic opportunities for arbitrage and portfolio improvement. The positive volatility spread shows that the embedded options in convertible bonds are often undervalued. Investors can take advantage of this by using volatility-spread trading strategies or by adding convertible bonds to diversified portfolios to improve Sharpe ratios and reduce overall risk. For issuers, the findings highlight the importance of carefully designing conversion and call features. Adjustments in conversion prices and early redemption rules can significantly affect both volatility and bond prices. Issuers should balance flexibility in financing with fair valuation to reduce underpricing and improve the efficiency of issuance. For regulators, the evidence of systematic undervaluation indicates the need to improve transparency and disclosure in pricing practices. Clearer rules for volatility estimation, more transparency about pricing models, and better secondary market liquidity mechanisms could help correct pricing inefficiencies and support a healthier and more efficient convertible bond market.

6. Limitation and extension

Despite the contributions of this study, several limitations should be acknowledged. First, the current framework does not incorporate credit risk, which is a central component of convertible bond valuation since issuers face different chances of default. Ignoring credit spreads may overstate the role of volatility mispricing while underestimating downside risks. Second, while we highlight the role of volatility spreads, the framework does not account for liquidity shocks. During periods of market stress, convertible bond arbitrage can become unprofitable due to funding shortages and sudden drops in market depth. Finally, the study does not systematically address regulatory frictions in China's convertible bond market, including issuance clustering and mandatory conversion rules, all of which may distort pricing and limit arbitrage opportunities.

Addressing these limitations through integrated multi-factor models would enhance pricing accuracy and inform future policy reforms in China's convertible bond market. Building on these limitations, several extensions can be explored. An important direction is the development of multi-factor models that jointly capture equity, interest rate, credit, and liquidity risks, providing a more holistic view of convertible bond pricing. Another possible extension is to use machine learning methods. These can improve volatility forecasts and detect complex links between bond features and pricing errors. It is also useful to conduct international comparisons. Comparing emerging and developed markets can show if China's undervaluation is a global pattern or only a local feature. Such cross-market analyses would illuminate how regulatory frameworks and investor compositions jointly shape pricing efficiency across diverse convertible-bond markets.

7. Conclusion

In this study, we investigate the pricing mechanisms, patterns of mispricing, and portfolio applications associated with convertible bonds in the Chinese financial market. We present systematic empirical evidence indicating that the embedded options within convertible bonds are consistently undervalued. This conclusion is derived by comparing GARCH-based volatility estimates with implied volatilities. The persistent and positive volatility spread suggests the existence of structural inefficiencies in China's convertible bond market. These inefficiencies are likely attributable to factors such as the immaturity of the market, underdeveloped investor demand, and the complexity of contractual features—particularly redemption provisions and conversion price adjustments.

Motivated by these empirical insights, we construct trading strategies that exploit the volatility spread and evaluate their effectiveness through delta-hedged portfolio analysis. The strategies demonstrate a high success rate, exceeding 70%, thereby indicating that volatility arbitrage opportunities can be systematically and consistently realized. Moreover, our portfolio analysis reveals that convertible bonds outperform traditional stock-bond allocation strategies in terms of both risk diversification and risk-adjusted returns.

Overall, our findings suggest that convertible bonds in China serve as an effective means of corporate financing and represent a compelling investment option for market participants seeking diversification and arbitrage opportunities. Nevertheless, convertible-bond arbitrage is not risk-free: episodes of market stress can sharply curtail arbitrageurs' ability to exploit mispricing due to liquidity and funding constraints. Future research may extend this analysis by incorporating liquidity and credit risk into valuation models, and by examining the implications of evolving regulatory frameworks on pricing efficiency in China's capital markets.

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Appendix

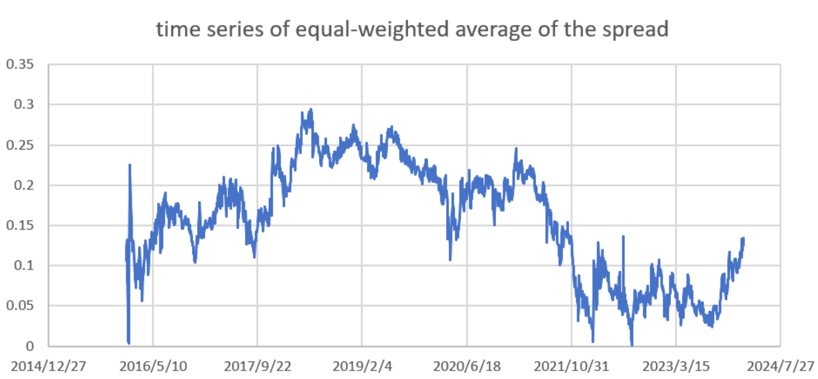

Figure 1. Time series of volatility spread (2016–2024)

This graph (Figure 1) illustrates the daily equal-weighted average of the volatility spread (GARCH volatility minus implied volatility) across all convertible bonds from 2016 to 2024. The persistently positive spread indicates a systematic undervaluation of Chinese convertible bonds.

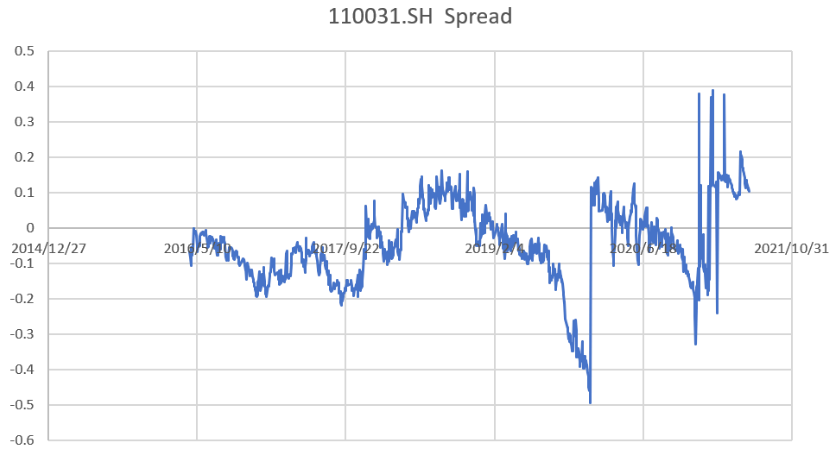

Figure 2. Impact of conversion price decline on volatility spread

This graph (Figure 2) illustrates the relationship between the percentage decline in conversion price and the corresponding change in the volatility spread. As the conversion price decreases, the embedded option becomes less attractive, leading to a decline in implied volatility and an expansion of the volatility spread.

Table 1. Descriptive statistics of volatility spread

Year	Mean	SD	Min	P25	P50	P75	Max	Ske	Kur
2016	0.137	0.034	0.003	0.117	0.142	0.161	0.225	-0.802	1.413
2017	0.170	0.028	0.110	0.151	0.166	0.188	0.249	0.517	0.029
2018	0.244	0.024	0.174	0.229	0.246	0.258	0.295	-0.373	-0.002
2019	0.236	0.018	0.201	0.221	0.233	0.249	0.273	0.264	-0.974
2020	0.187	0.021	0.107	0.177	0.192	0.202	0.224	-1.101	0.895
2021	0.160	0.053	0.032	0.128	0.177	0.205	0.245	-0.592	-0.689
2022	0.065	0.024	0.002	0.048	0.064	0.083	0.136	0.163	-0.002
2023	0.061	0.021	0.024	0.044	0.055	0.075	0.117	0.495	-0.621
2024	0.113	0.012	0.091	0.103	0.111	0.120	0.134	0.198	-0.831
Overall	0.157	0.070	0.002	0.093	0.167	0.215	0.295	-0.238	-1.103

Table 1 presents the descriptive statistics of the volatility spread for each year from 2016 to 2024, as well as the overall period. The values are calculated as the equal-weighted daily average of the spread across all convertible bonds. For each year, “Mean” represents the equal-weighted mean value, “SD” represents standard deviation, “Min” and “Max” represents minimum and maximum value, and “Pxx” represents the xxth percentile of its distribution. Moreover, “Ske” means skewness, and Kur means kurtosis. These statistics summarize the central tendency, dispersion, and shape of the distribution of the volatility spread. The persistently positive values further support the view that embedded options in Chinese CBs are systematically undervalued, consistent with inefficient option pricing predicted by hybrid security theory.

Table 2. Portfolio performance with varying convertible bond weights

weight of the CB (%)	weight of the CSI 300 Index (%)	return (%)	SD (%)	SR
0	60	7.08	15.13	0.47
2	58	7.06	14.85	0.48
4	56	7.05	14.58	0.48
6	54	7.03	14.31	0.49
8	52	7.01	14.04	0.50
10	50	7.00	13.78	0.51
12	48	6.98	13.53	0.52
14	46	6.96	13.28	0.52
16	44	6.95	13.03	0.53
18	42	6.93	12.80	0.54
20	40	6.91	12.57	0.55

Table 2 presents descriptive statistics of portfolio performance across different allocations of convertible bonds. The CSI Aggregate Bond Index weight is fixed at 40%, while the CSI 300 index weight decreases from 60% to 40%. For each allocation, "SD" represents standard deviation, and "SR" represents Sharpe ratio. Consistent with the theoretical framework, results show that increasing CB weights reduces portfolio volatility and raises Sharpe ratios, reflecting the hybrid nature and systematic undervaluation of CBs, which enhance diversification benefits beyond traditional stock-bond allocations.

Table 3. Performance of volatility-spread trading strategy

	full period	stressed period
total trade	2,395	782
profitable trades	1,716	548
win rate	0.72	0.70
Average Holding Period	39.82	24.11
Maximum Drawdown	0.09	0.17

Table 3vreports the performance of the volatility-spread trading strategy during the full period and the stressed market in 2022. Consistent with the theoretical framework, persistent positive spreads between GARCH and implied volatility signal systematic undervaluation of embedded options and provide arbitrage opportunities. The full-period results confirm the strategy's profitability with a high win rate and moderate drawdown, while the 2022 sub-sample highlights its robustness under market stress.

Table 4. Efficient frontier of portfolio combinations

two-asset portfolio (stocks + bonds)							
return (%)	4.37	5	6	7	8	9	10
std (%)	1.69	3.88	9.19	14.69	20.21	25.74	31.27
three-asset portfolio (stocks + bonds + convertible bonds)							
return (%)	4.37	5	6	7	8	9	10
std (%)	1.69	3.25	7.14	11.79	16.19	20.62	25.06

Table 4 summarizes the efficient frontier analysis based on the results of portfolio optimization, where the portfolio includes stocks, bonds, and convertible bonds. Consistent with modern portfolio theory, the efficient frontier illustrates the trade-off between risk and return, indicating that higher returns are typically associated with greater volatility. After incorporating convertible bonds, the efficient frontier shifts upward, implying enhanced portfolio efficiency and further confirming the significant role of convertible bonds in improving diversification and risk-adjusted performance.

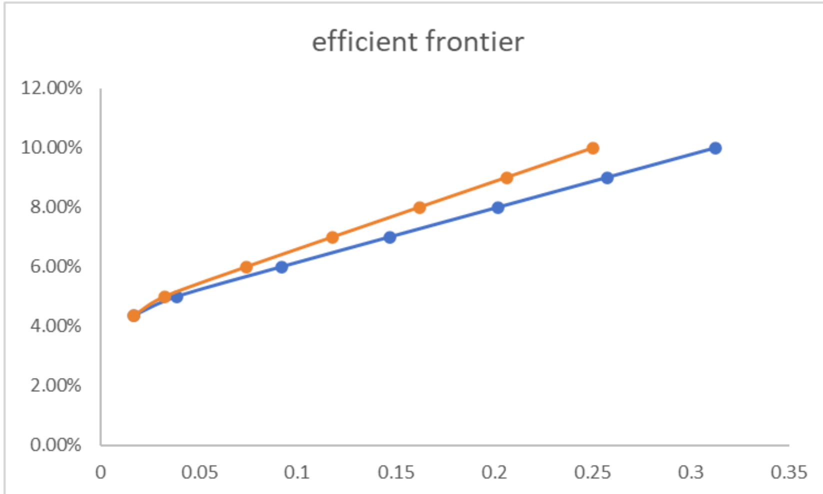

Figure 3. A comparison of efficient frontiers between two-asset and three-asset portfolios

This chart (Figure 3) compares the efficient frontiers of two asset portfolios (stocks and bonds) with a three-asset portfolio that includes convertible bonds. The upward shift of the three-asset portfolio's efficient frontier indicates that adding convertible bonds can enhance risk-adjusted returns.