

Put-Call Parity Violations and Market Frictions in China's SSE 50 ETF Options Market: Evidence from the AI Boom of 2023

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Abstract

This paper empirically investigates the deviation of the put - call parity (PCP) in China's SSE 50ETF options market (510050 XSHG) for the whole year of 2023-when the release of ChatGPT triggered an unprecedented investor sentiment hype of artificial intelligence. Based on 15,604 pairs of matched call-put options covering all 242 trading days, we detected that there was always a systematic and persistent overpricing of calls over put options. We interpret this phenomenon as follows: The explosive market demand by retail investors on call options-a leveraged sentiment on AI-related market bullishness-out-weighted the arbitrage capacity of constrained arbitrageurs by market frictions to make corrections to the mispricing through a reverse arbitrage strategy (selling call options, buying put options, and buying spot options). Using quarterly dummy variables as proxies for AI market sentiment cycle, we found that by controlling time stage variables, the R^2 rose from 8.9% to 71.67% to confirm that demand dynamics driven by market sentiment rather than the specific features of contracts-are the primary drivers for the variability in the PCP violation phenomena. Compared with the baseline of AI craze hype in the first quarter, the quarterly effect shows monotonically decreasing, while the implied residuals bias the fourth quarter, which is still a positive one. Confirmed is that the permanent structural friction lower limit will persist even after the sentiment premium of AI fades. Our research result provides fresh evidence in terms of behavioral demand shocks' interaction with the institutional friction on in emerging markets, thereby creating option price biases.

Keywords

put-call parity, option mispricing, SSE 50 ETF options, investor sentiment, market frictions

1. Introduction

Put-call parity (PCP) represents an important fundamental no-arbitrage condition in finance economics [1]. In a frictionless market, the equality $c - p = S_0 - Ke^{-rT}$ must always be fulfilled strictly: if DEV is positive ($DEV > 0$) call options are overpriced with respect to puts, while for negative ($DEV < 0$) put options are overpriced and the vice versa. In either case, arbitrageurs should be capable to arbitrage away the mispricing.

In fact, market frictions (transaction cost, capital constraint, and institutional limitations) can lead to sustainable deviation within a band around the theoretical parity.

China's securities options market provides an interesting and illustrative case in point. The SSE 50 ETF options market (510050 XSHG) that launched in 2015, has been operating under a regulatory regime that limits securities lending, requires high margin reserves on writing options, and features a large domestic retail investor population characterized by strong directional biases. All these features set into the conditions for persistent and economically meaningful violations of PCP.

The year of 2023 added a new strong factor for behavioral dimensions: the AI-driven euphoric frenzy sparked by the launch of ChatGPT in late 2022 has spawned an unprecedented demand by retail investors to use call options as a leveraged tool to express bullish views about AI-related technologies. Our main hypothesis is that this explosion in demand for calls pushed the prices of calls consistently over their PCP prices, leading to positive ($DEV > 0$) or DEV (i.e., call overpricing) in this case. This effect is most marked in Q1 2023 - when AI sentiment has been at its peak - but gradually fades throughout Q4s.

2. Literature Review

2.1 Put-Call Parity: Theory and Empirical Evidence

Standard PCP is the result of the application of the law of one price to a portfolio consisting of a portfolio of options and the underlying stock asset [1]. With the presence of transaction costs in the market, the identity becomes a no arbitrage band condition [2, 3]. For mature markets, Kamara and Miller [4] and Nisbet [5] find that most of observed PCP violations disappear once bid-ask spreads and commissions have been accounted for. For China's options of the SSE 50 ETF market (510050 XSHG), Xia [6] offers a general four-element analysis of PCP deviations, and identifies that bid-ask spreads, brokerage fees, the rate of financing spread and option writing costs are the key friction elements in the system.

2.2 Call Overpricing, Retail Demand, and Option Writing Constraint

For the case of $DEV > 0$, call options are overpriced relative to puts. The theoretical arbitrage strategy that should eliminate this discrepancy is: sell overpriced calls, buy underpriced puts, buy the underlying spot, and borrow the present value of the strike price. This strategy does not involve a short sale of the underlying, but it does involve writing (selling) call options, an action that is heavily constrained in China's options market. Writing an option requires a deposit of substantial margin guarantee, often on the order of 10–20% of the underlying value in addition to the option premium, which makes it a capital-intensive scale of massive arbitrages feasible. Han [7] and Bollen and Whaley [8] prove that directional demand (with for specific options e.g., calls), particularly retail investor demand for calls, can result in persistent options mispricing when arbitrage capacity of professional intermediaries is limited by their capital constraints.

The link between retail sentiment and call overpricing is well established. Garleanu, Pedersen, and Poteshman [9] show that end-user demand for options is an important pricedetermining factor in option other than the Black Scholes model, and that retail investors net call-buying pressure results in an upward bias of implied volatility in calls. In the China where retail investor investors account for more than 70% of the total volume of option options trading, this channel is particularly intense.

2.3 Short-Selling Limitation: Indirect Impact to Call over Pricing

While the restriction on short selling primarily operates as a mechanism that restricts arbitrageurs by eliminating call over pricing ($DEV > 0$), it has a secondary effect of amplifying call over pricing, via the delta hedging channel. Market makers who write (sell) call have to delta hedge by buying the underlying ETF, but they cannot effectively manage their inventory risk if they are restricted from being able to short the ETF. The resulting limited hedging capacity forces market makers to charge a higher premium to their writing, resulting further driving c up, thereby increasing $DEV > 0$. This transmission channel is formal in [Diamond and Verrecchia [10], and Li, Du, and Hu [11] document the empirical relevance of the channel in Chinese equity options markets.

2.4 Investor Sentiment and the AI Boom

Baker and Wurgler [12] establish that market investors' sentiment has an impact on asset price independent of their fundamentals. Da, Engelberg, and Gao [13] develop internet search intensity as a proxy for retail attention, documenting that this variable can predict short-term short-pressure on stock prices. The context of Chinese options market, Fang, Wen, and Zhang [14] document the prediction effect of Baidu search intensity on the asymmetries of the implied volatility. But daily search index is subject to high frequency noises, key selection bias and concerns for manipulation. We follow the literature of macro sentiment [11, 15] that using quarterly dummies as regimes proxies, which will eliminate noise of idiosyncratic daily variations, while maintaining the macro phase structure of AI sentiment cycles with economical meaningfulness.

There has been previous literature for frictional structures [6], retail demand [7, 9], and short selling constraint [10]; The 3 dimensions [11] respectively explained the reasons for option pricing bias, but these 3 have not been added into the unified system, lack of identification and measurement of how event-driven emotional shocks synergistically amplify bias on the existing institutional frictions. There are 3 contributions of this article. Firstly we demonstrated PCP bias of SSE 50 ETF Options market in 2023 is consistent positive, all 15604 observations generated $DEV > 0$. Which indicates that the systematic pricing of call options is too high compared to put option, which is consistent with AI-driven call option speculative demand. Secondly we introduced quarterly dummy variables as a tool of artificial intelligence sentiment cycle, avoiding noise of daily search index and key words biased, and clearly identified the macro stage shift from optimism in the 1st quarter and normalization in the 4th quarter. This design elevated R^2 value from 8.9% to 71.67% indicated that the time variation drivers by emotion is the primary driving factor. Thirdly, we demonstrated the option writing constraint - the major friction preventing calls' pricing correction - has formed a structure of bottom at around 0.1241 yuan, which will exist after AI sentiment premium fades. These contributions filled the aforementioned research gap. Chapter 3 builds a theoretical framework that involves the lower limit structural friction and the component of emotional premium based on that, providing a hypothetical base of empirical analysis.

3. Theoretical Framework

3.1 Put-Call Parity and the Sign of Deviations

For European options on a non-dividend-paying underlying, PCP requires:

$$c - p = S_0 - Ke^{-rT} \quad (1)$$

Note: SSE 50 ETF generates minor annual cash dividends. This paper ignores dividend yields for simplicity, and the resulting bias toward PCP deviations is empirically negligible.

We define the raw PCP deviation as:

$$DEV = c - p - (S_0 - Ke^{-rT}) \quad (2)$$

The sign of DEV determines which option is relatively overpriced:

Table 1: Sign of DEV and indications

Sign of DEV	Meaning	Corrective Arbitrage	Friction Involved
$DEV > 0$	Call overpriced relative to put ($c - p$ too large)	SELL call + BUY put + BUY spot + BORROW	Option writing margin; transaction costs
$DEV < 0$	Put overpriced relative to call ($c - p$ too small)	BUY call + SELL put + SHORT SELL spot + INVEST	Short-selling restrictions on underlying ETF

Our empirical confirmation of constant positive DEV (100% positive; mean = +0.1524 yuan) identifies a consistent call overpricing regime for the entire 2023 period. The corrective arbitrage—sell call, buy put, buy spot, borrow—does not mandate shorting of the underlying ETF. The major friction lies in capital requirements for writing calls and round trip transaction costs

3.2 No-Arbitrage Band under Option Writing Constraints

Following the asymmetric friction framework of Jouini and Kallal [3], the no-arbitrage condition becomes a band:

$$[-C_{\text{lower}}, +C_{\text{upper}}] \quad (3)$$

where C_{lower} incorporates the cost of the forward arbitrage (correcting $\text{DEV} < 0$, being limited by short-selling costs), and C_{upper} incorporates the cost of the reverse arbitrage (correcting $\text{DEV} > 0$, being limited by option writing margin and transaction costs). C_{upper} widens the larger the writing margin requirements for calls are—as is usually the case with China exchanges requiring 10–20% of the underlying value of calls as naked call writing collateral—allowing larger positive deviations to persist without activating a profit-reversing reverse arbitrage.

Restricted short selling also indirectly widens C_{upper} through the market maker channel: the restricted delta-hedging capacity limits the premium market makers charge to write calls, increasing c and widening the observed DEV . These option writing margin, transaction, and market-maker delta-hedging premium together create a structural no-arbitrage floor $\text{DEV} > 0$, which cannot be arbitrated away.

3.3 The AI Sentiment Amplification Mechanism

We interpret the observed deviation as two components:

$$\text{DEV}_t = \text{Floor} + \text{Sentiment}_t + \varepsilon_t \quad (4)$$

where Floor indicates the cost of the underlying friction (option writing constraints + delta-hedging premium), which creates a permanent overpricing, and Sentiment_t captures the further deviation from call demand in retail AI sentiment. In Q1 2023, the height of the ChatGPT-induced euphoria, rampant retail call demand significantly inflated Sentiment_t . As AI sentiment normalized during Q2–4, Sentiment_t continuously dropped, letting DEV drop to approach Floor. Therefore, this framework offers three testable predictions: (i) $\text{DEV} > 0$ for the whole sample; (ii) DEV has its maximum Q1 and continuously decreases; (iii) Q4 still shows substantial structural floor presence.

4. Data and Methodology

4.1 Data Sources and Sample Construction

Our sample includes the daily closing prices of all SSE 50 ETF options (510050 XSHG) traded on Shanghai Stock Exchange for entire 2023. Options prices are extracted from JoinQuant's OPT_DAILY_PRICE database. SSE ETF 50 closing prices and fixed annualized risk-free rate of 2% (comparable with prevailing three-month Treasury bill) are used to derive PCP benchmarks.

We construct matched call-put pairs by restricting to identical strike K and expiry date on the same day. We remove contracts that are within five days before the expiry (to eliminate the expiry bias) and contracts that have zero closing price (to eliminate liquidity problems). The original sample contains 612 option contracts over total 242 trading days for 2023. After applying the aforementioned inclusion and exclusion filters, we have 15,604 matched call- put pairs from final sample. Table 2 presents the descriptive statistics of key variables, including ETF closing price, call closing price, put closing price, and time to expiry retrieved and DEV , $|\text{DEV}|$ and Moneyness through calculation.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
DEV (yuan)	0.1524	0.0235	0.0953	0.2408
DEV (yuan)	0.1524	0.0235	0.0953	0.2408
S_0 — ETF closing price (yuan)	2.4479	0.1283	2.1700	2.6770
c — call closing price (yuan)	0.1363	0.1383	0.0001	0.7600
p — put closing price (yuan)	0.1180	0.1210	0.0001	0.6250
T — time to expiry (years)	0.2471	0.1854	0.0164	0.6685
Moneyness: $\ln(S_0/K)$	-0.0558	0.0896	-0.2910	0.2333

Notes: $\text{DEV} = c - p - (S_0 - Ke^{(-rT)})$. $\text{DEV} > 0$ indicates call overpricing relative to put. $r = 2\%$ p.a. Sample: 15,604 matched call-put pairs from 612 contracts on the SSE 50 ETF (510050.XSHG), covering all 242 trading days of 2023. All 15,604 observations yield $\text{DEV} > 0$ (100% call-overpricing rate).

4.2 Phase Classification

Table 3: Quarterly Breakdown of PCP Deviations

Quarter	Market Phase	DEV Mean	DEV Std. Dev.	N
2023 Q1	AI Euphoria — peak call demand	0.1721	0.0083	4,820
2023 Q2	Transition — sentiment moderating	0.1616	0.0127	3,571
2023 Q3	Correction — AI re-rating	0.1516	0.0148	3,219
2023 Q4	Stabilization — sentiment normalized	0.1210	0.0150	3,994
Full Year	2023	0.1524	0.0235	15,604

Notes: DEV declines monotonically across all four quarters, consistent with diminishing AI sentiment premium. The Q4 mean of 0.1210 yuan is 29.7% below the Q1 mean of 0.1721 yuan. F-test for equality of quarterly means rejects H_0 at $p < 0.001$.

4.3 Empirical Model

Daily internet search indices to find AI-related terms are noisy with high-frequency and keyword selection bias [13], so we use quarterly dummy variables as instruments to the AI sentiment sentiment cycle following the literature [12, 15]. Q1 (January–March 2023) is the omitted group to reflect the peak of AI euphoria and maximum call demand. Our main specification is:

$$|DEV_{it}| = \alpha + \beta_1 \times SPREAD_{it} + \beta_2 \times MONEYNESS_{it} + \beta_3 \times T_{it} + \gamma_2 \times Q2_t + \gamma_3 \times Q3_t + \gamma_4 \times Q4_t + \varepsilon_{it} \quad (5)$$

where SPREAD it represents transaction cost of calls (round-trip 2% of combined call and put price), MONEYNESS it = $\ln S_0/K$, T it is time-to expiry (in years), and Q2 t, Q3 t and Q4 t are time indicators with Q1 being the omitted group. The hypothesis about sentiment states that $\gamma_2 < \gamma_3 < \gamma_4 < 0$: With the fading in AI-driven call demand over quarters, sentiment-amplified call overpricing also falls, causing a reduction of DEV. Standard errors heteroskedasticity-robust (HC1). The constant term α represents structural friction floor that is independent sentiment shock.

5. Empirical Results

5.1 Descriptive Evidence: Systematic Call Overpricing

Table 2 shows the sample mean deviation of PCP across entire 15,604 observations is +0.1524 yuan (std. dev. = 0.0235 yuan). Significantly, the lowest deviation across the sample mean is +0.0953 yuan not single observation has $DEV \leq 0$, we have 100% positive deviation rate that directly proves call options systematically and persistently overpriced relative to puts, for entire 2023 period. The corrective arbitrage—sell call, buy put, buy spot, borrow—fails to arbitrage due to the capital constraints to write calls and related transaction costs which places the deviation in the upper limit of the no-arbitrage band, Cupper. Thus result has economic meaning within 2023 AI sentiment context. The massive retail retail call needs for call options— instruments leveraged against AI speculation—constantly raises c level above its PCP implied value. Professional arbitragers who should correct the wedge by writing calls are constrained by margin requirements and delta hedging premiums charged by short-seller market makers market makers struggling with their residual inventory.

Table 3 shows the monotone quarterly decreases predicted by sentiment amplification model. The mean DEV continuously reduces from 0.1721 (Q1)→ 0.1616 (Q2)→ 0.1516 (Q3)→ 0.1210 (Q4), a 29.7% cumulative drop. Furthermore, the within quarter standard deviation of DEV drops monotonically from the 0.830 in Q1 to 0.0150 in Q4, proving that the market continuously stabilizes by the gradual normalization of AI sentiment. Remarkable, even at Q4 when the ChatGPT novelty premium had disappeared, the mean of 0.1210 yuan deviation are economically meaningful to verify the existence of a structural friction floor that remains under independent sentiment shocks.

5.2 Regression Results

Table 4: Regression Results: Determinants of $|DEV|$ with Quarter Fixed Effects

Variable	Coefficient	Robust Std. Err.	t-statistic	p-value
SPREAD (transaction cost proxy)	0.1211	0.0508	2.38	0.017**
MONEYNESS $\ln(S_0/K)$	0.0086	0.0012	7.38	0.000***
T (time to expiry, years)	-0.0110	0.0007	-16.63	0.000***
Quarter 2 (Q2)	-0.0102	0.0002	-43.24	0.000***
Quarter 3 (Q3)	-0.0198	0.0003	-74.27	0.000***
Quarter 4 (Q4)	-0.0502	0.0003	-180.75	0.000***
Constant (α , Q1 Baseline)	0.1743	0.0003	630.13	0.000***
Observations	15,604			
R-squared	0.7167 (vs. 0.089 without quarter dummies)			
F-statistic	7,856.76 (df = 6, 15597)			0.000***

Notes: Dependent variable is $|DEV_{it}|$. OLS with heteroskedasticity-robust standard errors (HCl). *** $p < 0.01$, ** $p < 0.05$. SPREAD = $2\% \times (c + p)$. MONEYNESS = $\ln(S_0/K)$. T = time to expiry in years. Q1 (AI Euphoria, January–March 2023) is the omitted baseline. Without quarter dummies, $R^2 = 0.089$.

Since we have all positive DEVs from across all observations, we apply $|DEV_{it}|$ as dependent variable, which numerically identical to DEV_{it} . Table 4 shows the main regression results. The model has $R^2=71.67\%$, which is considerable increase than the basic model that has $R^2=8.9\%$. The jump of model explanatory power verifies the sentiment cycle hypothesis that most variation of PCP deviations is explained the macro sentiment changes of AI sentiment investors from quarter to quarter, but not on contract level features.

The constant term ($\alpha = 0.1743$, $t = 630.13$) is the Q1 base line (Q1 2023—the peak period of AI euphoria) which combines the structural friction floor and the maximum sentiment premium of AI sentiment. It is quite similar to the actual mean DEV value in Q1 of 0.1721 which confirms the model fit.

The quarterly dummy coefficients are all negative, monotonically increasing absolute value, and significantly large (all $p < 0.001$), as we expected. In comparison with the Q1 base line (Q1 2023, peak of AI mania), call over-pricing, reduced by 0.0102 yuan ($t = -43.24$), 0.0198 ($t = -74.27$), and 0.0502 yuan ($t = -180.75$) respectively. The monotone compression of PCP wedge from quarter to quarter provides substantial evidence that the call overpricing found is driven by the AI sentiment dynamics: while speculative enthusiasm about generative Ai cooled down from quarter to quarter, excess demand for calls reduced, resulting in approaching the no-arbitrage interval.

Remarkably, at Q4, the implied deviation is still $0.1743 - 0.0502 = 0.1241$ yuan. Thus structural floor—which still at Q4 where the whole sentiment premium completely disappeared—is a result of the continued existence of the option writing constraint and market maker delta hedging premium, which are the permanent friction component of call over pricing in the options market in the options market.

Of the contract level control terms, the coefficient of SPREAD is positive ($\beta = 0.1211$ ($t = 2.38$), which confirms the fact that a higher transaction cost lead to wider no arbitrage range. The coefficient of MONEYNESS are positive and significantly large ($\beta = 0.0086$ ($t = 7.38$), showing the fact that in the money is higher than out of money, this is also consistent with with replication demand which leads to higher money. Time to expiry is a negative coefficient ($\beta = -0.0110$, $p < 0.0001$), reflecting the fact that closer to the day of expiration, the the larger is the deviation from PCP as the liquidity deteriorates.

5.3 Decomposing Sentiment and Structural Components

Based on the result from the baseline regressions, we decompose the total mispricing into structural friction component and sentiment premium components. The regression setup allows for a neat disentangling of the total discrepancy of PCP into two economy components:

Table 5: Components of PCP deviation

Component	Value (yuan)	Share of Q1 DEV	Interpretation
Structural floor (Q4 implied)	0.1241	72.1%	Option writing constraints + market-maker delta-hedging premium; persists permanently
AI sentiment premium (Q1 – Q4)	0.0502	27.9% (= Q4 coefficient)	Excess call demand from AI euphoria; dissipates as sentiment normalizes
Total (Q1 baseline)	0.1743	100%	Peak call overpricing at height of ChatGPT mania

This decomposition does have important policy implications. The structural component (72.1%) reflects structural frictions—option writing capital requirements and market maker delta hedging—which can be alleviated by regulatory reforms. The sentiment component (27.9%) reflects the sentiment dynamics of investors—which is likely to be repeated in other future speculative episodes around other technologies or macro economic sentiments—and is not possible to eliminate through regulatory interventions.

6. Robustness Checks

We perform three robustness tests. First, restricting the sample to near the money contracts $|\ln(S_0/K)| < 0.05$ results in same monotone quarterly pattern with the R2 still remaining high with greater than 68%, ruling out the concern that the observation from the high illiquidity of deep OTM or ITM contracts. Second, restricting to contracts with between 30 and 90 day left to expiry provides 9,214 observations, all of which of which dummy coefficients remains the sign and magnitude and statistical significance. Third, by using the changing in risk free rate from The change on mean DEV by each quarter only in less than one one 0.002 yuan among all four quarter, and regression parameters are all within one standard error from the baseline values, which means the short maturity (mean of 0.247 years) of the considered options, and the discount value (by a rate of one decimal point) is insensitive the rate variation.

7. Conclusion

This paper empirically examines the put-call parity deviations in the Chinese SSE 50 ETF options market in 2023, using the AI sentiment wave generated by ChatGPT as a natural identification strategy. Three major results are achieved. First, 2023 is a year where call options are systematically and persistently overpriced relative to puts, with not a single observation giving $DEV \leq 0$. Second, the inclusion of quarterly dummy variables as proxies for the AI sentiment cycle raises R2 from 8.9% to 71.67%, indicating that the main source of PCP deviation dynamics is sentiment-driven time variation. Third, the structural decomposition uncovers that 72.1% of the peak Q1 deviation is a permanent friction floor due to option writing constraints and market-maker hedging costs, while 27.9% is the transient AI sentiment premium that dissipates by Q4.

So, we are inspired by the above findings. Even in a highly regulated environment (including Option Writing Constraints and Market-maker Delta-hedging Premiums) call options are still overvalued and obvious PCP deviations are still present even if AI sentiment completely fades (Q4). If the regulators want to reduce the deviations in the options market, they should not focus on the sentiment of retail investors. Instead, they should appropriately reduce the margin ratio for option sellers or relax restrictions on ETF short selling, so that arbitrageurs can implement the “sell call, buy put” strategy at a lower cost and smooth out deviations, especially during special periods affected by shocks (AI) and sentiment. If a call option is purchased in Q1 2023, a sentiment premium of 0.0502 yuan must be borne. For the average retail investor, when a highly innovative technological concept is already quite well known (Q1), it is best to stay calm as the purchase of call options at this point would entail an extra sentiment premium. It would be more cost effective to sell call options at this point or wait for sentiment to subside (Q4) to buy back. For quantitative researchers, the quarterly decomposition method mentioned in the text can be used to predict the size of the price deviation through the sentiment cycle, and adjust the strategy in advance. In the meantime, in the Chinese SSE 50ETF options market, the existence of the price floor of 0.12 yuan, the theoretical no-arbitrage range should be not set at 0 when researchers carry out arbitrage strategies but 0.12. Arbitrage is only profitable when the price deviation is much higher than 0.12 yuan. Several limitations need to be acknowledged. The transaction cost measure is approximate; a more accurate friction decomposition would be possible with direct bid-ask spread data. We assume the risk-free rate is fixed, but robustness checks show little sensitivity to this assumption. The

single-year sample only represents one sentiment episode. A multi-year panel is more appropriate to study the co-evolution of structural and behavioral components with regulatory reform and market development in China.

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Conflicts of Interest

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