Are Investors Irrational?---Study on China Warrant Market

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Abstract: This paper studies Chinese warrant price deviation. By observing "asymmetric price error" phenomena, we propose that the rational hedging and speculation motivation is one important cause for warrant price deviations. Investors do not speculate irrationally under the resale motivation all the time, neither do they ignore warrants' hedging function. Instead, investors would trade for hedging and speculation purpose and drive the warrant prices when the underlying assets are significantly undervalued or overvalued. The paper applies a model-free measure for warrant price deviation and verifies the proposal by studying five couples of warrants from 2006 to the beginning of 2008. It has been found that the rational hedging and speculation motivation dominates other trading motivation in the market.

Key Words: Warrant bubble; hedging motivation; rational speculation; put-call parity

JEL: G12，G32

I. Introduction

Chinese derivatives market is still in an early stage of development. Research about derivative market focuses on warrant price bubbles. From 2006 to 2008, there was a significant deviation between the theoretical price and the market price in Chinese warrants market. Existing studies documented serious overvaluation of warrant prices relative to Black-Scholes model prices. For example, according to Xiong and Yu (2009), strike prices of 16 Chinese warrants are much lower than their underlying stock prices, so that theoretical prices by Black-Scholes formula should be close to zero. While those warrants are still actively traded at market prices much higher than zero. Powers, Xiao and Yan (2009) also find that all put warrants are overvalued relative to their Black-Scholes counterparts. Liu, Zhang and Zhao (2012) and Liao, Zhang and Zhu (2012) both confirmed the findings.

There are mainly two explanations for Chinese warrants price deviation. The first one is the resale theory proposed by Xiong and Yu (2009). Namely, under the short-sell constraints in China market, due to the heterogeneous beliefs of investors, smart investors tend to purchase overpriced warrants hoping to resell them to a "greater fool". The other explanation is the convenience yield theory by Powers, Xiao and Yan (2009). The paper points out that the unique comfortable environment in Chinese warrants market, such as "T+0" settlement system, loose daily limit, low transaction costs and zeros transaction tax. Compared to the stock market, this comfortable trading environment has more liquidity and less market friction, so as to provide "convenience yield" to Chinese warrants investors. Thus, the price bubbles come from premium for the convenience.

Both papers' interpretations are mainly applicable to put warrants. An important stylized fact, defined as "the asymmetric price errors", however, is ignored to some extent. We find that in China warrant market, although both puts and calls tend to be overpriced relative to the modeled prices, while the extent of deviations are far from each other: the bubbles of call prices are much less than the bubbles of puts. We name the observation as "the asymmetric price error." This phenomenon raises new challenge to existing explanations: given the facts that short-sell restrictions imposed on both puts and calls simultaneously and these two types of warrants have the same investor groups, they are supposed to have similar price deviation in terms of direction and size. Thus the resale theory conflicts with the phenomenon of "asymmetric price errors." Also, as comfortable trading environment also applies to call warrants so as to increase their market prices, the theory proposed by Powers, Xiao and Yan (2009) cannot explain the phenomenon either. In addition, neither theory can fully explain warrants price deviation based on Black-Scholes formula (hereinafter referred to as BS). For example, the explanatory power R-square is below 40%.

The limitations of existing theories arouse our great interest. In this paper, we intend to address the following three issues.

First, the BS formula used to measure warrant price deviation is based on assumptions, which might not be accurate and would introduce model risk. A model-free method is therefore needed to reveal the real price deviation.

Second, since resale theory and convenience yield theory cannot explain the "asymmetric price errors" mentioned above, what drives the errors after all?

Third, what are the major factors causing the price deviation of Chinese warrants from their intrinsic value?

The paper is structured as follows: section 2 presents theoretical analysis; section 3 shows empirical research methods and results; Section 4 concludes.

II. Theoretical Analysis

2.1. Rational Hedging and Speculation Motivation

The resale theory and the convenience yield theory can only explain the bubbles in warrant prices, but fail to tackle the different degrees of deviation of puts and calls. This encourages us to propose a new motivation allowing pricing error in either direction. We propose that trading motivated by investors' rational hedging and speculation would drive warrant prices and generate the asymmetric price errors.

We define two types of speculation: one is to speculate the derivatives as equities directly ignoring the underlying assets. Speculations for resale option and trading for convenience yields belong to this type. This property is implied in the context of both Xiong and Yu (2011) and Powers, Xiao and Yan (2009). The other type is to speculate the derivatives according to the fluctuation of the underlying assets. We term the latter type as the “rational speculation”, as the investors are sensible enough to perceive the stock market condition and make correspondent trading decision in the derivative market. Literature with related findings include Pan and Poteshman (2005), Ni, Pan and Poteshman (2006), and Lakonishok, Lee, Pearson and Poteshman (2007).

The mechanism of the rational speculation is as follows. When stock market has bubbles, investors are rational so as to expect bubbles to burst and stock prices to fall in future. This expectation would generate demand for puts so as to raise puts more than calls. When the stock market is deemed to be undervalued, investors become aware of that and raises the demand for stocks and calls, so as to raise call prices more than puts.

Overall, there are two types of warrant price error asymmetries: a situation when puts are overpriced and calls are underpriced or less overprices; a situation when puts are underpriced and calls are overpriced or less underpriced. The rational hedging and speculation motivation allows either asymmetry to occur conditional on different economic environment. Most importantly, compared with the resale motivation and the convenience yield motivation, the rational hedging and speculation motivation is the only one that allows asymmetries.

2.2. Black-Scholes Model Risk

Most current studies use the BS model price as the benchmark to measure the price deviation. We decompose the BS pricing error into two parts: One part is the model error resulted from the difference between BS model assumptions and the real world, such as short-sale constraints, stochastic volatility and the fat-tail distribution of returns of the underlying assets; The other part is the price error due to market inefficiency, i.e. overvaluation or undervaluation of warrants caused by various market friction. In existing option pricing literature about western markets, scholars usually attribute the gap between the market option prices and the BS prices to the inaccuracy of BS model itself. While in recent studies about Chinese warrant market, BS model errors are completely ignored (Xiong and Yu (2011), Powers, Xiao and Yan (2009), Pan, Shi and Song (2008), Liu, Zhang and Zhao (2012), and Liao, Zhang and Zhu (2012)).

The ignorance can lead to at least two serious problems. First, according to previous literature, e.g. Chen and Cao (2004), there exist significant fat tails and negative skewness of stock returns in China market, which would lead to the famous "volatility smile" when implied volatilities are plotted against moneyness for options with the same underlying assets. Namely, BS model tends to under-estimate out-the-money puts and over-estimate in-the-money calls. Therefore, it is the model assumptions conflicting with reality that cause puts to be overpriced and calls to be underpriced or less overpriced. The unrealistic assumptions in BS model hence at least partially contribute to the phenomenon of asymmetric price errors.

Secondly, BS model is based on the assumption that the return of the underlying asset follows Geometric Brownian Motion without jumps in an efficient market. This assumption excludes the existence of bubbles in the underlying asset. While many previous literatures documented serious price bubbles in Chinese stock market, for example, Chen, Zhang, and Wang(2009), Meng, Zhou, and Wang (2008), and Zhao and Zeng (2008). Therefore, stiffly applying BS model in emerging markets is inappropriate and might lead to lopsided conclusions.

2.3. Put-call Parity

Arbitrage free is the fundamental of derivative pricing. As for European options, no arbitrage opportunity can be directly embodied as the put-call parity.

$$S = PV(K) + C - P + PV(D), \tag{1}$$

Where S is the stock price, $PV(K)$ is the present value of strike price, C is the call warrant price, P is the put warrant price, D is the anticipated dividends paid per share during the life of a warrant. The two types of warrants must have the same strike price and expiration date. There are two requirements for this relationship broken for a long time. First, there are factors driving the warrant price away from equation (1), such as investors resale motivation proposed in Xiong and Yu (2009), or the convenience yield factor proposed in Powers, Xiao and Yan (2009); Secondly, there exists short-sale constraints preventing the price from returning back to normal.

In China, both conditions are met in the warrant market. On one side, because of short-sell restrictions, investors are not allowed to short sell stocks; on the other side, even though institutional investors are permitted to arbitrage by creating puts and calls, because of the strict and costly approval process in China, warrants are seldom created.

Hereby, we propose that the extent of failure of Put-call Parity could serve as another measure of warrant price deviation. There are literatures about western markets studying the relationship between the short-sell costs and the failure of put-call parity, for example, Ofek, Richardson and Whitelaw (2004).

We define $\boldsymbol{S}^* = \boldsymbol{PV}(\boldsymbol{K}) + \boldsymbol{C} - \boldsymbol{P} + \boldsymbol{PV}(\boldsymbol{D})$ as the stock price implied by data and use $R = \ln\left(\frac{S}{S^*}\right)$ to measure the difference between the market price and the price in the absence of arbitrage opportunities. This ratio is a comprehensive measure of warrant price deviation: When puts are overpriced and calls are underpriced or less overpriced relative to puts, there is $R > 0$; when puts are underpriced and calls are overpriced or less underpriced relative to puts, there is $R < 0$; when there is no price deviation or both puts and calls have a comparable degree of price deviation in the same direction, there is $R = 0$. Please note that this price deviation or price error cannot be explained by more sophisticated option pricing models such as stochastic volatility models because the put-call parity relation holds under all distributions of stock returns.

This ratio has several advantages compared with BS pricing errors. First, it is model free and thus is not subject to any assumption about underlying assets. Secondly, if the rational hedging and speculation motivation is the dominant factor driving the warrant market, the level and the sign of R would be tightly connected to bubble level in the underlying stock: R tends to be positive in an overvalued market and tends to be negative in a undervalued market. Hence R would be significantly affected by the bubble level in the underlying stock prices. Instead, if the resale motivation or the convenience yield motivation dominates warrant trading in the market, put and call prices tend to move in the same direction and thus R is not sensitive to bubbles in stocks. This is so because when an investor trades warrants for resale options, he cares mostly about the characteristics of warrants themselves, such as price level and volatility, and pays little attention to the underlying assets. Therefore, warrants are traded more as equities instead of derivatives. We can thereby identify investors' trading motivation by examining whether there exists significant relationship between R and the bubble level in the underlying stock. We hereafter refer R as "the parity deviation" in order to distinguish it from price errors in a general sense.

III. Empirical Research Methods

3.1. Data Description

All warrants issued in China market are derivative warrants, which are issued by the third party and there is neither additional issuance when exercised nor dilution effects. We screen all puts and calls whose expiration dates or strike prices do not match. We finally collect daily trading data during 2006 to 2008 for five couples of warrants, which are Wuliangye, Baogang, Wugang, Yage and Wanhua[1]. Each couple of warrants has the same expiration date. All data come from Resset database.

Table 1a describes properties of underlying assets, including the sample size, the average daily return, daily volatility, skewness, kurtosis, and the leverage effect, which is defined as $\boldsymbol{Corr}(\boldsymbol{r}_t, \boldsymbol{\sigma}_t)$. It indicates that five stocks all have significant fat tails and three of them have significant skewness[2]. According to our analysis in Section 2.2, we could to some extent attribute the asymmetric price errors to the incorrect use of BS model.

Table 1b reveals related information about five couples of warrants during the sample period. We define price errors as $\boldsymbol{W}_0 - \boldsymbol{W}_{BS}$ in our context, where $\boldsymbol{W}_0$ is the observed warrant prices and $\boldsymbol{W}_{BS}$ is the modeled BS prices. We illustrate the average of the ratio $(\boldsymbol{W}_0 - \boldsymbol{W}_{BS})/\boldsymbol{W}_0$ in the first row. As we can see, for four stocks, Wuliangye, Baogang, Yage and Wanhua, puts are much more frequently traded than calls and therefore are much more overpriced relative to BS prices than calls. Only for Wugang stock, calls are traded more frequently than puts and are much more priced relative to BS prices than puts. We aggregate the ratio $(\boldsymbol{W}_0 - \boldsymbol{W}_{BS})/\boldsymbol{W}_0$ for all five couple of warrants and put the distribution in Figure1, which confirms the “asymmetric price errors.” First, almost all puts are overpriced relative to BS prices, while some calls are underpriced relative to BS prices or have negative bubbles; Secondly, a large amount of puts are extremely overpriced such that the ratio is very close to one. In comparison, calls are overpriced to a much milder degree.

Table 1b also illustrate the daily volatility, the average daily trading volume and the percentage of the number of trading days with creation or cancelation out of the total sample period. It can be seen that the percentage of the number of days with creation or cancelation is at a relative low level. This confirms that although institutional investors are allowed to arbitrage by creating new contracts, the significant costs dramatically reduce the maneuverability and sustain the price deviation.

3.2. Preliminary Results

We first would like to check to what extent the parity deviation *R* is correlated with the stock bubbles. As we analyzed in session 2.3, a significant positive correlation between *R* and stock bubbles suggests that the warrant price errors or price deviations are related to bubbles in stock prices. Therefore warrant trading is very likely to be driven by rational hedging and speculation motivation.

We first measure bubbles in stocks with the method proposed by Feltham and Ohlson (1995). Feltham and Ohlson proposed that a firm's intrinsic value is decided by current net assets and related profitability and persistence. To be more specific, the intrinsic value can be attributed to current net assets, expected future net assets, ROE, as well as the cost of capital. The bubbles then can be measured by

$$\boldsymbol{Bubble_t = S_t - V_t = S_t - \left(BV_t + \sum_{i=1}^{\infty} \frac{ROE_{t+i} - \rho_t}{(1+\rho_t)} \times BV_{t+i-1} \right)}$$

where V_t is the intrinsic value of a firm, BV_t is the book value, and ρ_t is the cost of capital. We then define $\boldsymbol{Bub_t = Bubble_t / V_t}$ as the percentage of the bubble value to the intrinsic value.

An alternative measure for bubbles is the AR(1) parameter λ in the auto-regression $\boldsymbol{S_{t+1} = \lambda S_t + e_{t+1}}$. Although λ is not a direct measure for bubbles, we propose that it can detect bubbles' tendency to accumulate or to burst during a window period. (See McQueen and Thorley (1994)) We apply rolling estimates to derive a time series of λ_t for our sample period.

Table 2 shows important information about the parity deviation *R* and bubbles. The first column measures the average of the parity deviation R_t. For Wuliang, Baogang, Yage and Wanhua, there are on average positive *Rs*, suggesting overvalued puts relative to calls. Wugang has a negative average *R*, suggesting overvalued calls relative to puts. These findings are consistent with the evidence in Table 1b. Also, the second and the third columns indicate that the correlations between the parity deviation R_t and two measures of bubbles are significantly positive across all five stocks. The last column lists the correlations between the observed stock prices, S, and those implied by the Put-Call parity, S^*. It suggests that the two price series are highly correlated (around 0.98), implying that the warrant market is not totally detached from the underlying.

3.3. The Model and Explanatory Variables Analysis

In this section, we go further to figure out the significance and effective direction of different factors in explaining the parity deviation R. We apply the parity deviation R as the dependent variable in the following regression model:

$$R_{it} = b_i + B_i^{'} F_t + \varepsilon_{it} \qquad t = 1,2,3....T_i \qquad (2)$$

where for each warrant i, R_{it} is the parity deviation at time t; F_t is the vector of explanatory variables; B_i is the vector of regression coefficients; b_i is a constant; ε_{it} is an identically distributed disturbance; T_i is the sample size of warrant i.

We select variables in F_t from three perspectives. First, we investigate factors that would impact on R under the rational hedging and speculation motivation; secondly, we employ explanatory variables which would function under the resale motivation and the convenience yield motivation; finally, we use other control variables that would be effective under all kinds of trading motivations.

a. Explanatory Variables under the Rational Hedging and Speculation Motivation

When investors trade for rational hedging or speculation purpose as risk hedgers, properties of underlying stocks, such as stock price bubble, price-earning ratio, return volatility and stock liquidity, would have influence on the warrant price deviation directly. Therefore, we take properties of underlying stocks as the first group of explanatory variables and we think that variables that are effective under the rational hedging and speculation motivation do not actively impact on R under the other two motivations.

First, we take the dynamic AR(1) parameter λ_t to indicate trends of bubbles. When bubbles are very high or when λ_t is high, investors tend to expect bubbles to burst and prices to fall. This helps to generate demand for puts and raise put prices. When bubbles are at a low negative level or when λ_t is low, investors will perceive that stocks are undervalued and thus generate demand for calls and stocks, so as to raise call prices. Therefore the warrants parity deviation R_t should increase with trends of stock bubbles.

Secondly, the leverage effect measures the effect of a new market shock to the market volatility of the next day. Specifically, it is a widely accepted fact that in western markets, good news smooth the market and bad news make the market more volatile. In China the emerging market, the opposite stories sometimes are observed and documented. Namely, the market becomes more volatile after good news while bad news helps to stabilize the market price (Chen and Cao (2004)). Table1a shows the leverage effect, defined as the correlation between stock returns of today and the market volatilities of the next day. For three out of five stocks, there is significant positive correlation. This suggests that when positive shocks to stock prices arrive continuously, as in an increasing market, investors will foresee stock price bubbles and buy puts in advance to hedge risk. When negative shocks to stock prices come continuously, as in a decreasing market, investors will sense the imminent undervaluation and switch to buy calls and stocks. Overall, the sign of impacts of stock volatilities on the warrant parity deviation R depends on the underlying stock's market condition.

Thirdly, stock liquidity can be measured by trading volumes, which tend to surge when the stock market rises or falls sharply. Given our previous analysis that the parity deviation R is increasing with the market, there would be a positive correlation between stock trading volume and the parity deviation R in an increasing market; and a negative correlation in a decreasing market. Thus, the relationship between stock trading volume and the parity deviation R depends on whether the stock is mainly increasing or decreasing during the sample period.

Fourthly, a unique feature in China stock market is the reform of non-tradable shares. The pressure from foreseeable future release of non-tradable shares in China market has a great influence in shaping investors' psychology and expectation and therefore the parity deviation. Usually, when a stock has a large percentage of non-tradable shares to be released on a prespecified date in future, the price of circulated shares tends to be suppressed by the very low holding costs of non-tradable share holders. During this period, there is more demand for calls than for puts. Once a large percentage of non-tradable shares are released, the stock price has a larger room to go up, so does the price of put warrants. Therefore, we expect to see that R is decreasing with the percentage of non-tradable shares. Please note that only two out of the five stocks released non-tradable shares once during their life spans.

b. Explanatory Variables under the Resale Option and Convenience Yield Motivation

When investors trade for resale options or for convenience yields, warrants are traded more like common securities such as stocks or bonds rather than derivatives. Investors concern more about profitability and performance of warrant prices themselves than the hedging function. Warrant properties such as liquidity and price volatility would thus catch more attention than properties of the underlying stocks. Hence, these control variables are effective under the other two trading motivations and are less effective under the rational hedging and speculation motivation.

Firstly, Scheinkman and Xiong (2003) confirm that a security price consists of two components, the basic value and the value of resale opportunities, based on investors' heterogeneous expectations and over confidence. When short selling is restricted, the security price is determined by the bidder with the highest evaluation, since investors are always able to sell securities to those with higher evaluation. According to Miller (1997), the volatility of prices measures the difference of opinions among investors. If the market is driven mostly by resale motivation, the more heterogeneous the investors are, the higher warrant price volatilities are, so as the bubbles in warrant prices. When we use the parity deviation R in our analysis, the structure in (1) decides that R correlates with call prices negatively and correlates with put prices positively. Hence, when heterogeneous investors trade for resale options, the parity deviation R correlates with put volatility positively and correlates with call volatility negatively. Also, since speculators are more willing to take part in a market with high liquidity, the higher the liquidity is, the more price bubbles there would be. The parity deviation R, therefore, correlates with put liquidity positively and correlates with call liquidity negatively.

Secondly, under the convenience yields motivation, security value is decided by the extra returns as well as normal returns. As described in the introduction, unique trading mechanisms in Chinese warrant market results in active market transactions. Especially "T+0" rule and exemption of transaction taxes make warrants an effective trading tool for "convenience" pursuers. Thus, pursuit of "convenience" helps to generate warrant price bubbles. If market price is driven by the convenience yields motivation, low price volatility and high liquidity would ensure investors get out of the game successfully. So the lower the warrant volatility is, or the higher the warrant liquidity is, the more bubbles warrant prices contain. For these reasons, the relationship between the parity deviation R and warrant liquidity is the same to the case of resale motivation above; while the parity deviation R correlates with put volatility negatively and correlates with call volatility positively, which is the opposite to the case of resale motivation. Therefore, we can identify which motivation is more effective by examining the relationship between the parity deviation R and the warrant volatility.

c. Explanatory Variables under All Kinds of Motivations

Creation and cancellation are committed by big institutions for arbitrage profit, and therefore are mostly driven by demands of investors. On one side, if the rational hedging and speculation motivation dominates, investors' demands for puts and calls would be different according to the market condition as we analyzed above. This can induce institutions to create one type of warrant and cancel the other type respectively to meet needs in the market. On the other side, if investors trade mostly for resale option or convenience yield, they are somehow indifferent to puts and calls. Institutions will simply issue both puts and calls to meet the demands in market. Overall, different trading motivations will generate relations between the parity deviation R and warrant supplies in different ways.

Finally, life cycle of warrants is another important concern that is effective under all types of trading motivations. A new issued warrant has a much wider prospect for traders than an old warrant about to expire, and thus has a larger room for rational hedging, speculation, resale option, convenience yields, and therefore bubbles. So the warrant price deviation should decrease around expiration date, which is known as the life cycle effect, for both calls and puts. However, since the parity deviation R is decided by the contrast between puts and calls, hence the relationship between the life cycle and the parity deviation R suggests which type of warrant has stronger life cycle effect.

3.4 Variables Construction and Estimation Results

Overall, we construct four variables related to properties of the underlying stock. These variables are supposed to work under the rational hedging and speculation motivation only. ***Bubble*** stands for trend in stock bubbles, which is measured by λ_t; we develop NGARCH model (Engle and Ng (1993)) to calculate daily volatility Vol_stock. $Volum\_stock$ is the log daily trading volume of stocks. We define

$$Percentage = \frac{Quantity\ of\ Non\text{-}tradable\ Shares}{Quantity\ of\ Total\ Shares}$$

to measure the pressure from future releasing of non-tradable shares[3].

We construct another two control variables about properties of warrants. These variables are supposed to impact on R actively only under the resale option and convenience yield motivations. We use

$$Liq\_C\ or\ Liq\_P = \frac{Daily\ Trading\ Volume\ of\ Warrant}{Daily\ Volatility\ of\ Warrant\ Price}$$

to measure liquidity of puts and calls according to Amihud (2002). We calculate daily warrant volatility $Vol\_C(Vol\_P)$ with warrant returns during the latest 30 trading days.

We use the quantity of warrants in circulation to reflect creation and cancellation. Specifically, we construct

$$\boldsymbol{Ratio\_outstand = \frac{Quantity\ of\ Calls\ in\ Circulation}{Quantity\ \mathrm{of}\ Puts\ in\ Circulation}}$$

, which have different relations with R under different trading motivations.

Under the rational hedging and speculation motivation, when stocks are undervalued, call prices tend to increase and put prices tend to decrease, and thus the parity deviation R tends to decrease. At the same time, institutions will create calls and cancel puts for arbitrage profit, so as to raise *Ratio-outstand*. When stocks are overvalued, call prices tend to decrease or put prices tend to increase, and thus the parity deviation R increases. Institutions will create puts and cancel calls for arbitrage profit, so as to reduce the ratio. Namely, there would be a negative correlation between this ratio and the parity deviation R[4].

Under the resale option or convenience yield motivation, institutions tend to create or cancel both puts and calls at the same time and therefore there would be no clear and significant relationship between the parity deviation R and *Ratio_outstand*.

We define the warrant life cycle as

$$Life = 1 - \frac{Days\ before\ Expiration}{Total\ Life\ Span}$$

The relationship between $Life$ and R is due to the contrast between the life cycle effect on puts and that on calls. To sum up, we put the relationships between the parity deviation R and all nine explanatory variables in Table 3.

Table 4 summarizes the regression results for the three groups of explanatory variables[5]. Overall, the R-squares of regression for each couple of warrant range from 57% to 89%, indicating a good explanatory power. The explanatory variables, which are supposed to be influential under the rational hedging motivation, affect the parity deviation significantly and almost all are consistently with our analysis: trend in stock bubbles ($\boldsymbol{Bubble}$) has significant positive impact on the parity deviation; stock return volatility (Vol_stock) and stock daily trading volume ($Volum\_stock$) almost all account for the parity deviation significantly; the percentage of non-tradable shares has significant negative impact on the parity deviation as we expect. These findings suggest that investors use warrants as hedging tools so that properties of underlying assets would influence investors' trading decisions and thus warrant prices. Therefore the warrant price deviation is caused to a great extent by the rational hedging and speculation motivation when there are bubbles or undervaluation of underlying assets.

Meanwhile, the warrant price deviation is also significantly influenced by factors which are effective under the resale motivation and the convenience yield motivation. First, call liquidity has negative impact on the parity deviation R and put liquidity has positive impact on the parity deviation; Secondly, it can be seen that for two of the stocks, the call volatility has significant negative impact on the parity deviation, which suggests that both resale option and convenience yield motivation are equally important in our sample.

It is not surprising to see that both two variables in the third group can significantly account for the parity deviation. First, the ratio between the quantity of calls to the quantity of puts has negative impact on the parity deviation. The significant negative relation suggests that the rational hedging and speculation motivation dominates. Investors' demands for puts and calls are different according to the market condition, which induces financial institutions to issue one type of warrants and cancel the other type to meet the demands and earn arbitrage profit.

Secondly, it is interesting to see that for all five underlying stocks, life cycles are significantly positively correlated to the parity deviation R, which implies that puts tend to have more bubbles than calls with the same maturity when all other factors maintain the same. Namely, life cycle effect is stronger for puts than calls.

It seems to be true that for Wugang warrants, the explanatory variables under the rational hedging and speculation motivations perform less significantly. We propose that it is probably because Wugang stock is the only stock that is undervalued (***E(R$_t$)<0***) during our sample period, and the rational hedging and speculation motivation is less dominant compared to other motivations when the underlying asset is underpriced.

3.5 Marginal Contribution of trading motivations to the parity deviation

In order to identify the marginal contribution of each group of explanatory variables to the explanatory power, we apply the concept of partial correlation. For each underlying asset *i*, we re-do the regression in model (2) excluding one variable *j*. We use $R_{i,j}^2$ to denote the new R-square. We use

$$PCORR_{i,j} = \frac{R_i^2 - R_{i,j}^2}{1 - R_{i,j}^2}$$

to reflect the marginal contribution of variable *j* for underlying asset *i*. R_i^2 is from Table 4. $PCORR_{i,j}$ is the average across stock *i*. We have

$$PCORR_j = \frac{1}{N-1}\sum_{i=1}^{N} PCORR_{i,j}$$

where N is five in our context; $PCORR_j$ reflects the average marginal contribution of variable *j* to the explanatory power across five models. Theoretically, a larger $PCORR_j$ indicates that the variable *j* has a greater explanatory power on the parity deviation R.

We illustrate the results in the last column of Table 4. First, life cycle effect dominates all other variables and has the highest marginal contribution of 25%. This indicates that overall, warrant lifecycle is the first concern of investors when picking warrants for investors with any trading motivation. Secondly, variables ***Bubble*** and

Volume _ stock rank the second and the third in terms of marginal contribution (10.15% and 9.84%). Overall, it can be seen that variables which function under the rational hedging and speculation motivation have greater marginal contribution than those variables function under resale motivation and convenience yield motivation. We therefore conclude that the rational hedging and speculation motivation plays even more important role in determining the warrant price deviation.

IV. Conclusions and Future Research

This paper studies factors causing warrant price deviation in China market. Existing literatures apply the BS model price as the benchmark and find dramatic bubbles for puts and much less bubbles for calls in China market. They tend to attribute the price deviation to investors' irrational resale motivation or convenience yields by holding warrants. While each theory ignore the "asymmetric price errors" and could not completely account for the pricing error by yielding a low R-square.

Concerning limitations of previous literatures, this paper has three contributions. Firstly, we propose the rational hedging and speculation motivation. Namely, investors do not speculate irrationally under the resale motivation all the time, neither do they ignore warrants' hedging and speculation function. Instead, investors would trade for rational hedging and speculation purpose when the underlying assets are significantly undervalued or overvalued. For example, when stock market has bubbles, investors expect bubbles to burst and stock prices to fall in future. This expectation would generate demand for puts so as to raise puts more than calls. When the stock market is deemed to be undervalued, demand for stocks and calls increase, so as to raise calls more than puts. So far the rational hedging and speculation motivation is the only one that allows "asymmetric price errors".

Secondly, we construct a model-free measure for warrant price deviation based on put-call parity, so as to avoid model risk caused by unrealistic assumptions and to ensure validity and accuracy of research results.

Thirdly, the rational hedging and speculation motivation means that existence of bubbles or undervaluation of the underlying stocks significantly shapes investors' demand for warrants and therefore drives warrant prices. Studying five couples of warrants and their underlying assets from 2006 to the beginning of 2008, we empirically confirm that the rational hedging and speculation motivation is one of the main causes of warrant price deviation.

One limitation of our study is that only those warrants that have both puts and calls can be investigated in our empirical study. Most of warrants in China market therefore cannot be taken into consideration because the parity deviation is unavailable. These warrants, however, are supposed to have more price errors due to the lack of arbitrage conditions. Therefore, a more sophisticated pricing method allowing short-sale constraints as well as bubbles or jumps in underlying assets needs to be developed in order to fully explore the story.

Another study perspective is to investigate investors' trading motivation directly by observing details of warrant holders' accounts. An example is Lakonishok, Lee, Pearson and Poteshman (2007).

Our research methodology can also be applied to price errors of other financial derivatives in emerging markets, for example, corporate convertible bonds and forthcoming foreign exchange options in China.

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Table 1 Summary Information of the Underlying Stocks and Warrants

	Average Level	**Wuliangye**		**Baogang**		**Wugang**		**Yage**		**Wanhua**	
Table1a Prices of the Underlying Stocks	**Sample Size**	441		202		204		206		206	
	Return	1.19E-03		1.87E-03		3.53E-04		2.40E-03		5.41E-03	
	Volatility	1.67E-02		1.40E-02		9.26E-03		1.52E-02		3.00E-02	
	Skewness	-1.64*		0.46*		-0.73*		0.12		-0.14	
	Kurtosis	17.74*		4.35*		12.56*		4.14*		3.79*	
	Leverage Effect	-0.03		0.34*		0.17*		0.23*		-0.06	
Table1b Properties of the Warrants		**Wuliangye**		**Baogang**		**Wugang**		**Yage**		**Wanhua**	
		C	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**
	Mean of Percentage of Price Errors	-6.20%	98%	45%	77%	72%	30%	20%	99%	-5.97%	99%
	Price Daily Volatility	2.18	0.4	0.22	0.07	0.11	0.07	0.75	0.08	9.99	0.66
	Daily Trading Volume (10^7)	6.03	42.9	76.11	86.35	103.7	55.61	6.588	55.29	10.57	22.13
	Percentage of Creation or Cancellation over the Sample Size	0	0	12.87%	6.44%	15.20%	4.41%	13.11%	11.17%	3.40%	28.16%

Notes: Table1a describes properties of five underlying stocks, including the average daily return, the average daily volatility, the average skewness, the average kurtosis and the leverage effect, which is defined as $Corr(r_t, \sigma_t)$. Normality tests and person correlation tests are applied. Table1b shows information of warrants. The first row is the mean of percentage of price errors defined as $(W_0 - W_{BS})/W_0$, the difference between the observed prices and the modeled BS prices over the observed prices. The rest are the daily volatility, the average daily trading volume and the percentage of trading days with creation or cancellation out of the total sample size. "*" indicates significance at the 5% confidence level.

Table 2. Means and Correlations of Stock Bubbles and *R*

Warrant	$E(R_t)$	$Corr(\lambda_t, R_t)$	$Corr(Bub_t, R_t)$	$Corr(S_t, S_t^*)$
Wuliang	0.127	0.13*	0.81*	0.98*
Baogang	2.20E-02	0.73*	0.78*	0.99*
Wugang	-8.70E-02	0.50*	0.40*	0.76*
Yage	1.26E-03	0.73*	0.68*	0.99*
Wanhua	9.43E-02	0.62*	0.47*	0.99*

Note: In Table 2, we apply two measures of stock bubbles: Bub_t, the F-O measure of bubbles proposed by Feltham and Ohlson (1995) and λ_t, the AR(1) parameter in the auto-regression $S_{t+1} = \lambda S_t + e_{t+1}$. The first column measure the average of the parity deviation R_t. The second and the third columns report correlations between the parity deviation R_t and two measures of bubbles. The last column lists the correlations between the observed stock prices, *S*, and those implied by put-call parity, S^*. λ_t are derived with rolling estimates. "*" denotes that the correlation is significant at the 5% confidence level. Source of data: www.resset.cn.

Table 3. Relationships between Explanatory Variables and the Parity Deviation *R*

Motivations	Variables	Impact on *R*
Rational Hedging Motivation	*Bubble*	+
	Vol_stock	depends on the underlying stock's market condition
	Volum_Stock	
	Percentage	-
Resale Option/ Convenience Yield	*Liq_C*	-
	Liq_P	+
	Vol_C	- for resale option
		+ for convenience yield
All Motivations	*Life*	depends on which type has the stronger lifecycle effect
	Ratio_Outstand	-for rational hedging and speculation

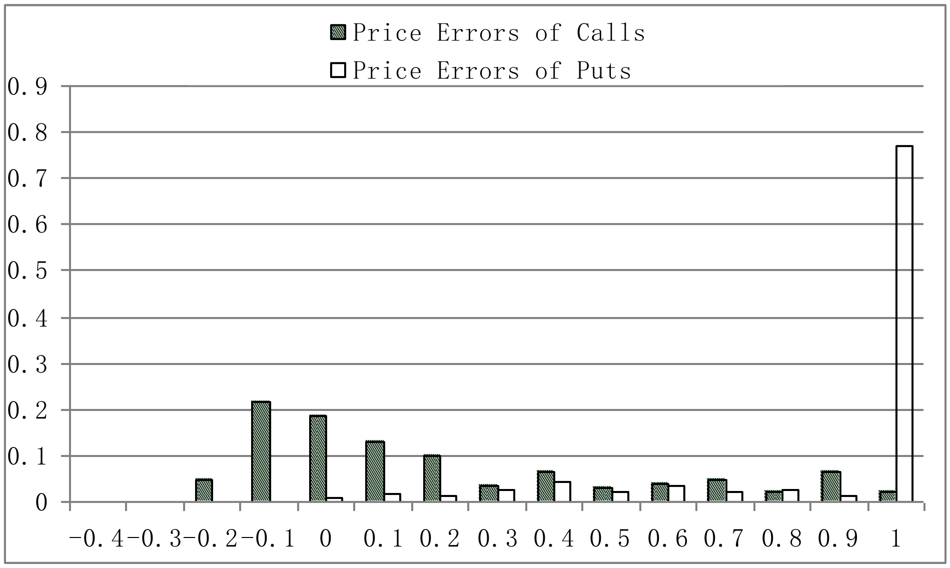
Notes: Table 3 summarizes relationships between the parity deviation *R* and different variables. *Bubble* stands for trend in stock bubbles, which is measured by λ_t; *Vol_stock* is the daily return volatility calculated by returns in last 30 trading days; *Volum_Stock* stands for daily trading volume; *Percentage* stands for releasing pressure from non-tradable stocks; *Ratio_Outstand* reflects creation or cancellation, using quantity of calls in circulation over quantity of puts in circulation; *Liq_C* and *Liq_P* stand for call liquidity and put liquidity, using daily trading volume over daily price volatility; *Vol_C* stands for daily volatility of returns of calls, using call prices in last 30 trading days; *Life* measures the life cycle, using 1- days before expiration/ total life span. Source of data: www.resset.cn.

Table 4 Model Estimation

	Wuliangye	Baogang	Wugang	Yage	Wanhua	$PCORR_j$
Bubble	6.991E-02**	1.258E-01*	-3.255E-02	8.427E-02***	3.184E+00***	10.15%
	(2.005E+00)	(1.822E+00)	(-1.075E+00)	(2.841E+00)	(9.544E+00)	
Vol_Stock	1.329E+00*	8.325E-01*	-3.627E-01	1.449E+00*	1.144E+00***	2.10%
	(1.845E-01)	(1.804E+00)	(-3.709E-01)	(1.870E+00)	(3.046E+00)	
Volum_Stock	4.012E-02***	1.641E-02	9.656E-03**	2.303E-02***	-9.108E-03***	9.84%
	(6.407E+00)	(3.999E+00)	(2.315E+00)	(5.924E+00)	(-2.742E+00)	
Percentage	-1.587E+00***				-5.584E-01***	4.89%
	(-4.877E+00)				(-4.691E+00)	
Liq_C	-8.680E-08***	-4.490E-10***	6.030E-11	-4.490E-09**	-5.220E-08	4.36%
	(-6.110E+00)	(-3.063E+00)	(4.280E-01)	(-.298E+00)	(-8.969E-01)	
Liq_P	-3.770E-09	3.790E-11	8.590E-10***	8.930E-11	-5.170E-09	1.65%
	(-8.827E-01)	(3.017E-01)	(3.036E+00)	(2.497E-01)	(-8.898E-01)	
Vol_C	-5.413E-01*	-3.362E-01***	3.068E-01***	-1.095E-01	1.979E+00***	4.78%
	(-1.777E+00)	(-2.896E+00)	(2.590E+00)	(-5.398E-01)	(6.504E+00)	
Life	1.276E-01***	2.235E-01***	1.671E-01	5.013E-02***	1.304E-02**	25.00%
	(3.960E+00)	(1.245E+01)	(1.252E+01)	(3.457E+00)	(6.026E-01)	
Ratio_Outstand		-6.849E-03	-2.831E-02***	5.210E-02	-3.181E-01***	3.36%
		(-2.361E-01)	(-2.885E+00)	(8.250E-01)	(-2.632E+00)	
Adj. R^2	61.20%	89.00%	64.87%	78.37%	57.35%	

Notes: Table 4 shows the regression results of model (2). We use data of five couples of warrants from 2006 to the beginning of 2008. "*", "**", and "***" indicate that regression coefficient significantly different from 0 at confidence level of 10%, 5% and 1%. *Bubble* stands for trend in stock bubbles, which is measured by λ_t ; *Vol_stock* is the daily return volatility calculated by returns in last 30 trading days; *Volum_Stock* stands for daily trading volume; *Percentage* stands for releasing pressure from non-tradable stocks; *Ratio_Outstand* reflects creation or cancellation, using quantity of calls in circulation over quantity of puts in circulation; *Liq_C* and *Liq_P* stand for call liquidity and put liquidity, using daily trading volume over daily price volatility; *Vol_C* stands for daily volatility of returns of calls, using call prices in last 30 trading days; *Life* measures the life cycle, using 1- days before expiration/ total life span.

Figure 1 Distribution of the Percentage of Price Errors



Note: Figure 1 aggregates the ratio $(W_0 - W_{BS})/W_0$ for all five couple of warrants and illustrates the distribution, which confirms the "asymmetric price errors."

[1] Except that Wuliangye is Bermuda warrant, the other three couples are all European warrants. Considering that the one-week exercise duration of Wuliangye can be ignored compared with its 731-day life span, we regard it as a European warrant.

[2] Normality tests are applied here: the sample skewness and the sample kurtosis are normally distributed with mean 0 and 3 and variances 6/T and 24/T.

[3] Please note that the variable *Percentage* does not change for other stocks during the sample period except to Wuliangye and Wanhua.

[4] Since there is no creation or cancellation in the sample duration of Wuliangye, this variable does not apply to Wuliangye.

[5] We apply unit root test and cointegration tests to all variables before regression. For those variables of I(1) and are not cointegrated, we difference them to ensure stationarity.