The Chinese Warrants Bubble*

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Abstract

In 2005-08, over a dozen put warrants traded in China went so deep out of the money that they were certain to expire worthless. Nonetheless, these warrants attracted a speculative frenzy: for each warrant, billions of Yuan traded with an average daily turnover rate close to 300%, and at substantially inflated prices. The publicly observable underlying stock prices make the zero warrant fundamentals common knowledge to all market participants. This warrants bubble thus presents a unique opportunity to study bubble mechanisms, so far only available in laboratory environments. We find evidence supporting the resale option theory of bubbles: investors overpay for a warrant hoping to resell it at an even higher price to a greater fool.

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1 Introduction

Asset price bubbles, i.e., asset prices that exceed assets' fundamental values, have always been a subject of interest to economists. However, a clear identification of a price bubble is challenging due to the difficulty of measuring an asset's fundamental value. Without exception, there is an open debate about whether each historical episode constitutes a bubble. For example, Garber (2000) proposes market fundamental explanations for three famous bubbles, the Dutch tulip mania (1634-37), the Mississippi bubble (1719-20) and the closely connected South Sea bubble (1720). Pastor and Veronesi (2006) challenge the existence of an Internet bubble in the late 1990s. The difficulty in measuring asset fundamentals makes it even more challenging to analyze economic mechanisms that drive up price bubbles.

In this paper, we use a unique data sample from China's warrants market to study asset price bubbles. In 2005-08, several Chinese companies issued put warrants on the Shanghai Stock Exchange and the Shenzhen Stock Exchange. These put warrants, with a long maturity ranging from 9 months to 2 years, give their holders the right to sell the issuing companies' stocks at predetermined strike prices during a pre-specified exercise period. The dramatic stock market run up in China between 2005 and 2007 pushed most of these put warrants so deep out of the money that they were certain to expire worthless. However, they had become targets of frenzied speculation, which generated a spectacular bubble as dramatic as, if not more than, any historical bubble episode. For each warrant, billions of Yuan traded with an average daily turnover rate close to 300%, and at substantially inflated prices. Several reasons make these warrants particularly appealing for analyzing bubbles: First, we can reliably measure the warrants' fundamental values to be zero using the underlying stock prices; second, the publicly observable stock prices also make the zero warrant fundamentals common knowledge to all market participants; third, these warrants have a predetermined finite maturity. These features so far are only available in laboratory environments.

We analyze the market dynamics of all of the 16 put warrants with expiration dates before May 2008. We use a number of measures to quantify the warrants' fundamental values. One of such measures is based on the celebrated Black-Scholes model. For each warrant, we use its daily underlying stock price and the previous one-year rolling daily return volatility to compute its Black-Scholes value. Interestingly, each warrant had a period in which its Black-Scholes value dropped to economically negligible levels below half of the minimum trading tick of 0.1 penny. While one might argue that the Black-Scholes model may not be accurate in measuring fundamental values of the Chinese warrants, a Black-Scholes value of less than 0.05 penny is a reliable indication that the warrant only has a tiny probability, if any, of being in the money at expiration and that it has virtually no value. The length of the zero-fundamental period ranges from a minimum of 6 trading days to a maximum of 165 trading days, with an average of 54 trading days. Despite its zero fundamental value in the period, each warrant had been traded at substantially higher prices with an average of 1.00 Yuan. In addition, the prices varied considerably across warrants. The ZhongJi put warrant rose to as high as 7.12 Yuan, while the WanKe put warrant's maximum price only reached 9 pennies.

We also construct a less model-specific upper bound for the put warrants' fundamental values. Stock price in China is only allowed to drop by no more than 10% each day. Thus, the current stock price implies a lower bound on the future stock price before the warrant expiration, or equivalently, an upper bound on the payoff from the put warrant. Among the 16 put warrants in our data, 13 had violated this fundamental upper bound for a period averaging 6 days.

Furthermore, two of the put warrants, HuaLing and WuLiang, had prices even higher than their strike prices, an even more relaxed fundamental upper bound which can be realized only if the underlying stock prices drop to zero before the warrant expiration.

Taken together, the fact that the warrant prices not only substantially exceeded fundamental values implied by the Black-Scholes model, but also the model-free fundamental upper bound, leaves no doubt that there was a bubble in the warrant prices. Like many historical bubble episodes, the warrants bubble was accompanied by a trading frenzy and extraordinary price volatility. Each warrant in its zero-fundamental period had an average daily turnover rate of 291% and an average daily volume of 1.26 billion Yuan. On an extreme day, the ZhaoHang put warrant had a volume of 45.68 billion Yuan (roughly 7 billion dollars) even though the warrant was fundamentally worthless. On their last trading day, these warrants had an average turnover rate of 1,235% in four hours of trading time, which means about 100% turnover every 20 minutes! The return volatility of these put warrants averaged 248% per annum in their zero-fundamental period. In an extreme case, the return volatility of the WuGang put warrant shot up to 2,297% per annum on its last trading day.

Despite the extreme prices, frenzied trading and wild volatility in the warrants market, there is also a systematic pattern in the prices of these worthless warrants—as the last trading day approaches, the prices gradually drop down to zero. This clear downward trend suggests that many investors are conscious about the approaching maturity and the fact that these deep out-of-the-money warrants would pay nothing at maturity.

Because of the restrictive legal ban on short-selling financial securities (including warrants) in China, it is easy to understand the force that prevents smart investors from arbitraging the bubble and causing the price to plummet. However, it is more difficult to understand the origin of the bubble—the mechanism that drives investors to trade and to pay insanely high prices.[1] Economists have proposed several bubble formation mechanisms. We use the unique warrants bubble sample to examine these mechanisms.

One strand of the literature builds solely on rational agents. Blanchard and Watson (1983) show that in a model with an infinite number of periods, a rational bubble component can exist in asset prices as long as it is always expected to grow at a rate equal to the discount rate. The finite maturity of warrants disqualifies this type of rational bubble in the warrants market. Allen, Morris and Postlewaite (1993) demonstrate that when asymmetric information makes the presence of a bubble not commonly known among rational agents, a rational finite bubble may appear. However, the publicly observable underlying stock prices make the zero warrant fundamentals common knowledge to all market participants.

Several experimental studies, e.g., Smith, Suchanek and Williams (1988) and others, find that bubbles arise in various laboratory settings even when asset fundamentals are common knowledge. The Chinese warrants market displays several key features—a finite warrant maturity and common knowledge about warrant fundamentals—which are probably the closest resemblance one can find in any field study to those in the experimental studies. The dramatic price bubble and frenzied trading in the warrants market thus confirm the key findings of those experimental studies.

A resale option theory of bubbles has been formally developed by Harrison and Kreps (1978), Scheinkman and Xiong (2003), and Hong, Scheinkman and Xiong (2006), based on short-sales constraints and interactions between heterogeneous agents. In this theory, investors agree to disagree about their beliefs regarding asset fundamentals. Bubbles arise from investors'

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[1] Because these put warrants have only a small and statistically insignificant return correlation with the underlying stocks in their zero-fundamental period, it is difficult to argue that investors trade these warrants to hedge the underlying stocks. There is also little evidence of positive skewness in the warrant returns to support a hypothesis that investors treat these warrants as lottery tickets.

expectation to resell their asset to a "greater fool" in the future when other investors become more optimistic. This theory can explain bubbles with common knowledge about fundamentals and is particularly appealing for the Chinese warrants market because of the likely presence of heterogeneous investors. Warrant contracts are new to many Chinese investors. Some investors have been trading the warrants without a complete understanding of the warrant contracts, while some others well understand the contracts and the market. Those investors who understand the presence of such investor heterogeneity, constrained by the ban on short-selling, may naturally speculate on selling an overvalued warrant at an even higher price later to a greater fool.

The resale option theory provides several testable predictions on the size of price bubble both across maturity and across warrants. The theory implies that when there is less trading time remaining, there are less resale opportunities and therefore a smaller price bubble. This implication exactly explains the gradually declining trend in warrant prices. The resale option theory also predicts that the size of price bubble is positively related to trading volume and return volatility, and negatively related to asset float (i.e., number of tradable shares). The more investors disagree about future price movement, the more intensively they trade with each other, and, at the same time, the more they are willing to pay for the resale option. When the asset return is more volatile, investors also tend to disagree more, which in turn makes the bubble larger. When investors have a limited risk-bearing capacity and when there is a larger asset float, investors expect that it takes a more optimistic belief of the future greater fool to make a profit, thus leading to a smaller bubble. Our panel regression analysis provides evidence supporting these predictions.

In analyzing the time-series dynamics of the warrants bubble, we also find evidence of positive feedback to past warrant returns in both warrant returns and turnover changes. The joint feedback in returns and turnover changes further highlights the importance of incorporating investor heterogeneity in analyzing the warrants bubble. Despite the positive feedback in warrant returns, it is not profitable on the margin to ride the bubble by buying recent winners, because the pronounced downward price trend caused by the approaching warrant maturity offsets the upward short-term price momentum created by positive past returns. Consistent with Brunnermeier and Nagel (2004), this result suggests that smart investors likely have been actively riding the bubble and, by doing so, have eliminated additional opportunities for such momentum trades.

By analyzing a field data sample, our study shows that even when asset fundamentals are easy to measure, a spectacular bubble could arise as long as short-sales are constrained and there exist heterogeneous investors. This bubble mechanism sheds light on other more complicated bubble episodes, including the recent housing bubble across many regions in the U.S. Our study also compliments the existing empirical literature on speculative bubbles, e.g., Shiller (2000), Cochrane (2003), Lamont and Thaler (2003), Ofek and Richardson (2003), and Hong and Stein (2007). Our study also adds to the quickly growing literature on analyzing speculative trading and the subsequent market dynamics in emerging markets, e.g., Mei, Scheinkman and Xiong (2005) and Barber, Lee, Liu and Odean (2008).

The paper is organized as follows. Section 2 provides a brief introduction of China's warrants market. Section 3 describes the speculative bubble in the market. Section 4 examines the driving mechanism of the warrants bubble. Finally, we conclude in Section 5.

2 China's Warrants Market

China has experienced rapid economic growth in the past 30 years, with GDP increasing by an average of 9.9% per year. Along with the economic growth, Chinese residents have accumulated a large amount of savings with a high savings rate of 50%. Where do Chinese residents keep their savings? They have only limited choices. Their default choice is to deposit in monopolistic state banks. Because of the inefficiency in the Chinese banking system, the central government has kept the deposit rate at a low level, sometimes even below the inflation rate. Chinese residents could also invest in illiquid real assets such as housing. Another alternative is to invest in China's quickly developing financial markets, which until recently had offered only stocks and stock-based mutual funds. The two main stock exchanges, Shanghai Stock Exchange and Shenzhen Stock Exchange, listed over 1,500 stocks with a total market capitalization in September 2007 of over 25 trillion Yuan, equivalent to roughly 3.5 trillion US dollars. While the stock market appears large, it is rather small relative to the national saving. The government bond market is illiquid, and the corporate bond market and financial derivatives market barely exist yet.

To provide more investment choices for Chinese residents, the China Securities Regulatory Commission (CSRC) introduced a small number of warrants starting in August 2005 as an initial step to open up the financial derivatives markets.[2] Warrants are essentially financial options

[2] The central government had been deeply worried about the speculative nature of derivatives markets since 1995, when a notorious manipulation scandal by a security firm in the Treasury bond futures market caused the government to close out all financial derivatives markets. The government's share reform in 2005

issued by publicly listed firms. There are two basic types. A call warrant gives its holder the right to buy stock from the issuing firm at a predetermined strike price during a pre-specified exercise period, while a put warrant gives its holder the right to sell stock back to the issuing firm. Both call and put warrants derive their values from the underlying stock price: the value of a call warrant increases with the stock price, while that of a put warrant decreases.

By May 2008, 18 put warrants and 29 call warrants had been issued to the public. Among them, 32 were traded in the Shanghai Stock Exchange and 15 in the Shenzhen Stock Exchange.

To maintain the usual advantages of financial derivatives for hedging and speculation purposes, the CSRC has provided a more trading-friendly environment for the warrants market than for the stock market, which is reflected in several dimensions. First, stock trading is subject to the so called "T+1" rule, which requires investors to hold their stocks for at least one day before selling. Warrants trading is subject to the "T+0" rule, which allows investors to sell warrants they purchase earlier on the same day. As a result, investors can pursue day-trading strategies in warrants but not in stocks.

Second, investors incur a lower transaction cost when trading warrants. When trading stocks (either buying or selling), investors pay a stamp tax to the government, a registration fee to the stock exchange, and a brokerage fee. The stamp tax is determined by a flat percentage of the total proceeds. The tax rate has changed several times in the past, ranging from 0.1% to 0.3%. The registration fee is 0.1% of the total proceeds. The trading commission is negotiable with brokers and is capped at 0.3% of the total proceeds. Investors are exempted from paying any stamp tax and registration fee when trading warrants. They still pay a brokerage fee, which is also

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provided a good opportunity for CSRC to reintroduce financial derivatives to the market, without being rejected by the central government. Before the reform, most shares (about two thirds) of public firms were owned either directly by the government or indirectly by its local agencies. These shares were restricted from trading in the public market. Realizing that bureaucrats and government agents are not suitable for the responsibility of enforcing governance of public firms, in 2005 the central government announced a plan to convert its large non-tradable share holdings into tradable shares and eventually to float them in the market. However, this plan had encountered resistance from investors who worried that the dramatic increase in the number of freely tradable shares would depress share prices and cause large losses in their portfolios. To persuade the public to accept the share reform plan, the government decided to compensate investors of the floating shares for their potential losses. Seizing this opportunity, CSRC allowed some firms involved in the share reform to issue warrants as part of their compensation packages to the public investors.

negotiable and is capped at 0.3% of the total proceeds. Because of the large volume in the warrants market, brokers usually charge a lower trading commission on warrants than on stocks.

Third, warrants have a wider daily price change limit. CSRC imposes a 10% limit on daily price increase or decrease of any stock traded on the two stock exchanges. Once the price of a stock rises or falls by 10% relative to the previous day's closing price, the trading of this stock is halted for the day. With the large volatility in China's stock market, individual stocks often hit their daily price-change limit. The daily permissible price increase (decrease) of a warrant in Yuan is equal to the daily permissible price increase (decrease) of the underlying stock in Yuan, multiplied by 125% and the warrant's exercise ratio.[3] Since a warrant usually has a high leverage ratio, its price-change limit is much wider in percentage terms than the limit on the underlying stocks. In practice, warrants seldom hit their daily price-change limit despite their dramatic price volatility, which we will discuss in the next section.

Despite the goodwill of the CSRC in providing a friendly environment for investors to use warrants as a tool to hedge or speculate on the underlying stocks, the warrants market has attracted a speculative frenzy, as we will describe in the next section.

Finally, it is important to note that investors are prohibited by law from short-selling stocks or warrants in China. The severe short-sales constraint makes it impossible for investors to arbitrage any stock's overvaluation relative to its fundamentals. It also prevents investors from arbitraging a warrant's overvaluation relative to its fundamental value determined by the underlying stock price. Meanwhile, companies cannot easily arbitrage overvaluation of their warrants by issuing more shares because new issuance is subject to restrictive quota constraints set by the central government.

The Shanghai Stock Exchange (SHSE), one of the two main stock exchanges, had experimented a limited shorting mechanism for the SHSE-traded warrants by allowing a small group of designated brokerage firms to create additional shares of the SHSE-traded warrants.

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[3] For example, consider NanHang put warrant on November 2, 2007. On the previous trading day, the warrant's closing price was 1.122 Yuan and the underlying NanHang stock's closing price was 21.61 Yuan. The warrant had an exercise ratio of 0.5, i.e., one share of the warrant gave its holder the right to sell 0.5 share of NanHang stock to the issuing firm. With the 10% daily price change limit, the price of NanHang stock was allowed to increase or decrease by 2.16 Yuan on this day. Then, the warrant price was allowed to increase or decrease by 2.16×125%×0.5=1.35 Yuan, which corresponded to 120% of the warrant's closing price from the previous day.

Every time a designated firm wants to create more shares of a warrant, it has to obtain approval from the SHSE, which weighs a set of unwritten political and economic factors in making the decision. After obtaining approval from the SHSE, the firm is required to deposit to a clearing house sufficient shares of the underlying stocks for covering the potential exercise of the created call warrants or full amount of capital for covering the potential exercise of the created put warrants. The created warrants are traded in the market undistinguished from the original warrants, and the firm can buy back warrants from the market to offset its earlier creation.[4] The creation mechanism caused the floating shares of the SHSE warrants to change over time, but it had not fully eliminated the overvaluation of these warrants because of the program's limited scope and restrictive capital requirement.

3 The Price Bubble in Put Warrants

We obtain data on all of the 16 put warrants with expiration date before May 2008 from the GTA data company.[5] Our data include the initial contract terms and later contract modifications (such as adjustments for stock splits), daily price information (open, close, high, and low), daily trading volume, intraday transactions (time, price and quantity), and warrant exercises. We also substitute the information about the underlying stocks from the Wharton Research Data Services (WRDS) database.

3.1 The WuLiang Put Warrant

The WuLiang put warrant provides a vivid example of the bubble in the Chinese warrants market. On April 3, 2006, WuLiangYe Corporation, a liquor producer in China, issued 313 million shares of put warrants on the Shenzhen Stock Exchange. The warrant has a maturity of two years with expiration date of April 2, 2008. Investors are allowed to freely trade the warrant before the last trading date of March 26, 2008. After the last trading day, warrant holders have five business days between March 27, 2008 and April 2, 2008 to exercise the warrant. The put warrant was issued in the money with an initial stock price of 7.11 Yuan per share and a strike price of 7.96 Yuan per share. At issuance, each share of the warrant gives its holder the right to sell one share of WuLiang stock to WuLiangYe Corporation during the exercise period. We call

[4] Creations and cancellations are publicly disclosed by the SHSE within the same day.

[5] The same company supplies the Chinese stock market data to the WRDS database, which is commonly used in the finance academic community.

this number the warrant's exercise ratio. The warrant is adjusted for any stock split and dividend payout during its life. After such adjustments, the warrant's strike price became 5.627 Yuan per share, and its exercise ratio became 1.402 before expiration.

Figure 1 plots the daily closing prices of WuLiang stock and the put warrant during its lifetime.[6] The WuLiang stock price increased from 7.11 Yuan on April 3, 2006 to a peak of 71.56 Yuan on October 15, 2007, and then retreated to around 26 Yuan when the warrant expired. While the put warrant was initially issued in the money, the big run up of WuLiang stock price soon pushed the put warrant out of money after two weeks, and it never came back in the money. Surprisingly, the figure also suggests a positive price comovement between the put warrant and its underlying stock: the warrant price moved up with the stock price from an initial price of 0.99 Yuan to as high as 8.15 Yuan in June 2007 and only gradually fell back to one penny at the last minute of the last trading day.

Was there a bubble in the WuLiang put warrant price? The warrant's fundamental value is determined by the price and return volatility of the underlying WuLiang stock. The celebrated Black-Scholes model provides a convenient tool to estimate the warrant's fundamental value. We use WuLiang stock's daily closing price and previous one-year rolling daily return volatility to compute the warrant's Black-Scholes value.[7] Figure 1 also plots the daily Black-Scholes value together with the market price. The warrant was traded at prices above the Black-Scholes value throughout its life, except for a brief two-week period in the beginning. For convenience of discussion, we say that the warrant price is zero if it falls below an economically negligible level, marked at 0.05 penny (half of the minimum trading tick of 0.1 penny). The warrant's Black-Scholes value dropped to zero after July 23, 2007 and stayed at zero for the warrant's remaining 9-month lifetime. Notably, during this zero-fundamental period, the warrant mostly traded for several Yuan! The price dropped to below one Yuan only in the last few trading days.

There are two caveats for using the Black-Scholes model to measure the warrant's fundamental value. First, the Black-Scholes model builds on an arbitrage mechanism linking the price of a warrant to that of its underlying stock. Investors cannot arbitrage any price discrepancy between the two in China because they cannot short sell either the stock or the warrant. Second,

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[6] WuLiang stock had a stock split during this period. Figure 1 is based on the pre-split share unit.

[7] We have implemented a binomial model to adjust for the extended five-day exercise period in computing the Black-Scholes value.

the Black-Scholes model relies on a set of assumptions about the underlying stock price dynamics, such as a geometric Brownian motion process with constant volatility, which may not fit the stock price dynamics in China. These considerations caution us not to over-interpret the exact Black-Scholes value. Nevertheless, when the Black-Scholes value of a warrant drops to below 0.05 penny, it indicates that there is only a tiny probability, if any, that the warrant could be in the money at expiration and that the warrant has virtually no value. Moreover, the valuation error of the Black-Scholes model is likely small in absolute terms (Hauser and Lauterbach (1997)).

We also construct a model-free upper bound to demonstrate overvaluation of the warrant, based on the following consideration. The WuLiang stock price, like other common stocks traded in China, is only allowed to drop by no more than 10% each day. This implies that the stock price on an earlier day puts a floor on the stock price before the warrant's expiration day. Consequently, the warrant payoff is capped by the implied floor on the stock price. To illustrate this cap, consider March 7, 2008, 13 trading days before the warrant's last trading day and 18 days before its expiration day. WuLiang stock closed at 50.61 Yuan on this day. This price implies that the lowest level WuLiang stock price could reach before the warrant expiration is $50.61\times(1-10\%)^{18}=7.596$ Yuan, assuming that the stock would hit its daily price drop limit in 18 consecutive days. Then, the maximum payoff from the put warrant could only be 0.294, which is the difference between the warrant's strike price 7.89 Yuan and the lowest possible stock price before expiration of 7.596 Yuan. The closing price of the warrant on this day stood at 0.543 Yuan, which was higher than the warrant's highest possible payoff.[8]

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[8] All the 16 put warrants in our sample are stock settled. As a result, it is theoretically possible that warrant holders may expect to gain from hedging a big jump in the stock price towards zero. However, the magnitude of the implied gain does not appear plausible. For example, the close prices of the WuLiang warrant and WuLiang stock two weeks before the warrant's last trading day (which is fifteen days before the warrant expiration date) are 0.440 and 34.85 Yuan, respectively. Each warrant can be exercised for 1.402 underlying shares. Suppose that the WuLiang stock price might jump down to zero before the warrant expiration, and we denote the (risk-neutral) probability as p. Upon the occurrence of such an extreme event, the warrant generates the maximum payoff of 5.627 (its strike price from Table 1) per share. For simplicity, we ignore the fifteen-day time value of money below which does not affect the result. From $0.440/1.402=p\times5.627$, $p=0.0558$. This implies the (risk neutral) expected return of the WuLiang stock conditioning on no jump (denoted as r) satisfies $p(-1)+(1-p)r=0$, hence $r=5.91\%$ in the fifteen-day period, which is equivalent to $5.91\%\times252/15=99\%$ per year! However, China's risk-free rate (measured by the bank deposit rate) has stayed below 5% per year in the same sample period (data source: IMF International Financial Statistics). Calculations using other days-to-maturity show similarly implausible (risk-neutral) expected return for this hedging argument to support the warrant price.

Figure 1 also plots the fundamental upper bound based on WuLiang stock's closing price on each day. This upper bound dropped to zero and stayed there right after March 7, 2008. Thus, the price of the WuLiang put warrant was above its maximum payoff implied by the underlying stock price and the daily price drop limit for 14 consecutive trading days before the warrant expiration!

Also note that the put warrant's strike price provides a more relaxed upper bound on the warrant payoff. A put warrant can generate a payoff equal to its strike price only when the underlying stock price drops to zero before the warrant's expiration day. Figure 1 shows that the price of the WuLiang put warrant was even above its strike price on June 13 and 14, 2007. On June 13, the warrant had reached an intraday high of 8.51 Yuan and closed at 8.00 Yuan. On June 14, 2007, it had reached an intraday high of 9.33 Yuan and closed at 8.15 Yuan. These prices were all substantially higher than the warrant's strike price of 7.89 Yuan.

To sum up, there is clear evidence that there was a price bubble in the WuLiang put warrant. Its price had exceeded any reasonable estimates of its fundamental value—it had exceeded the Black-Scholes value by large margins; it had also gone above the fundamental upper bound implied by the current stock price and the daily stock price drop limit; and it had even exceeded the warrant's strike price.

Like the Internet bubble analyzed by Lamont and Thaler (2003) and Ofek and Richardson (2003) and many other historical bubble episodes, the price bubble in the WuLiang put warrant came with a trading frenzy and extraordinary volatility. Figure 2 plots its daily turnover rate and daily volume (measured in billions of Yuan). The daily turnover rate was impressive. It averaged 140% and shot up to as high as 1,841% on the last trading day, i.e., the WuLiang put warrant changed hands for more than 18 times on that day. The warrant had an average daily volume of 1.06 billion Yuan (roughly 150 million US dollars because the exchange rate was about 7 Yuan/dollar during this period). The volume was especially high during the second half of the warrant's life after July 23, 2007 when the warrant's Black-Scholes value dropped to zero. The volume rose to as high as 12 billion Yuan on a single day in July 2007. In other words, investors traded a pile of essentially worthless papers for almost 2 billion US dollars on a single day! If we assume a 0.2% trading commission for both buyers and sellers to pay to their brokerage firms, this warrant generated a trading commission in the order of 8 million US dollars each day.

To put the trading frenzy in the WuLiang put warrant in perspectives, it is useful to compare its turnover rate with that in a few other markets. Stocks listed on New York Stock Exchange, a liquid market by many measures, have a turnover rate of about 100% per year. The WuLiang put warrant's turnover rate on average is 340 times higher than that of NYSE stocks and on the last trading day is 4,600 times higher. Another useful benchmark is Palm stock, one of the iconic stocks in the Internet bubble. As documented by Lamont and Thaler (2003), Palm stock in its glorious days of early 2000 was traded at a rate of 100% per week. The WuLiang put warrant's turnover rate on average is 7 times of the Palm's turnover rate and on the last trading day is 90 times higher than the Palm's. The WuLiang put warrant is extremely active even in the Chinese standard. A-share stocks (shares issued to domestic residents) on the Shanghai and Shenzhen stock exchanges have an average turnover rate of 500% per year, e.g., Mei, Scheinkman and Xiong (2005), while across the Taiwan strait on the Taiwan Stock Exchange stocks have an average turnover rate of 300% per year, e.g. Barber, Lee, Liu and Odean (2008).

Figure 2 also plots the daily return volatility of the WuLiang put warrant constructed from its intraday 5-minute returns. The annualized warrant volatility varied dramatically over time between a minimum level of 18% and a maximum level of 1,475%. The average was 111%. The volatility of a typical U.S. stock is about 40%. Thus, the warrant's average volatility was about three times that of a typical U.S. stock and its maximum volatility was more than 30 times higher. It is also interesting to note that while there was a large return volatility, the price of the WuLiang warrant had not crashed down to zero before its last day of trading.

3.2 Other Warrants

Table 1 provides a complete list of the 16 publicly traded put warrants, in the order of their expiration date. These warrants have a long maturity, ranging from 9 months to 2 years, and an exercise period right before the expiration date. The exercise period lasts from 1 to 5 business days, with the exception of the JiChang put warrant which has an exercise period of 9 months. Each warrant also has a trading period starting from the issuance day until right before its exercise period, again with the exception of the JiChang put warrant whose trading period overlaps with its exercise period. Some of the warrants were issued in the money with their underlying stock prices lower than their strike prices, while others were issued out of the money. These warrants are adjusted for any stock split and dividend payout during their lifetime.

The Shanghai Stock Exchange Composite Index, a representative price index for China's stock market, shot up from 1,080 points in June 2005 to an all-time peak of 6,124 points in October 2007. This dramatic market run up had caused all of the 16 put warrants to be out of money on their respective expiration days. Among them, 14 were 20% out of money (i.e., the underlying stock prices were 20% higher than the corresponding strike prices) and 13 were 50% out of money. These put warrants are the focus of our analysis.

Each of the 16 put warrants had experienced a price bubble similar to that exhibited by the WuLiang put warrant. Each warrant had a period in which it had zero fundamental value (defined as the Black-Scholes value dropping below 0.0005 Yuan). Table 2 summarizes the market dynamics of each warrant during this zero-fundamental period. This period tended to be right before the warrant expiration. Its length varied across warrants from a minimum of 6 days to a maximum of 165 days, with an average of 54 days. Despite zero fundamental value in the period, each warrant had been traded at substantially higher prices with an average of 1.00 Yuan, which was only slightly lower than the average warrant price in the full sample. The price range varied substantively across warrants. The ZhongJi put warrant had a price as high as 7.12 Yuan, while the WanKe put warrant's highest price only reached 9 pennies.

Much like the WuLiang experience, each warrant had been actively traded at an average daily turnover rate of 291% and an average daily volume of 1.26 billion Yuan during the zero-fundamental period. The ZhaoHang put warrant even had a one-day volume of 45.68 billion Yuan. The return volatility of these put warrants averaged at 248% per annum and went to as high as 2297% per annum on a single day for the WuGang put warrant.

Table 3 shows each warrant's violation of the fundamental upper bound implied by the underlying stock price and the daily stock price drop limit. Among the 16 put warrants, 13 had violated this fundamental upper bound with a minimum of 1 day and a maximum of 16 days. The violation period on average lasted 6 days. During the violation period, the warrant prices surpassed the fundamental upper bound by an average of 0.42 Yuan. In an extreme case, JiaFei put warrant had a price 4.90 Yuan above its fundamental upper bound. The broad violation of the fundamental upper bound confirms that the kind of price bubble displayed by the WuLiang put warrant was widespread among all put warrants.

Could the abnormally high prices and extremely active trading of these put warrants be caused by investors' demand for hedging the underlying stocks? Interestingly, Table 2 shows that on average, these put warrants had a small and insignificant return correlation of -0.031 (p-value 60.3%) with their underlying stocks during their respective zero-fundamental periods. At the individual level, only one of the 16 put warrants, GangFan, had a significantly negative return correlation with the underlying stock. The lack of return correlation between these warrants and their underlying stocks refutes the argument that investors trade these warrants to hedge the underlying stocks.

Investors may treat warrants like lottery tickets. Gamblers prefer a lottery ticket despite its unfavorable odds because it provides a positively skewed payoff, i.e., the payoff can either take a large positive value with a small probability or a small negative value with a large probability. Several recent economic theories suggest that investors might have a similar risk preference toward financial investment and cause assets with positive skewness to be overvalued.[9] Are warrants lottery tickets? Table 2 shows that for the daily returns, 13 of the 16 warrants have negative return skewness with an average of -1.362 and a significant t-statistic of 2.29.[10] In unreported results, skewness of the 5-minute intraday warrant returns also tends to be negative. The lack of evidence of positive skewness in both intraday and daily warrant returns refutes gambling behavior as a reasonable explanation of the warrants bubble.

3.3 Maturity Effects

Each warrant has a predetermined last trading date. How does the approaching of the last trading date affect the warrants market dynamics? We analyze this question by focusing on the data sample of the 16 put warrants in their zero-fundamental periods. As we discussed before, in each warrant's zero-fundamental period, it has an economically negligible fundamental value, and thus its price approximates the price bubble. We call this data sample the bubble sample, which will be the primary focus of our analysis from now on.

Figure 3 plots the warrants' price bubble and daily return volatility, averaged across the 16 warrants in the bubble sample, with respect to the number of trading days remaining. An interesting pattern is that while there is a clear downward trend in the price bubble as the last trading day approaches, the price drop is gradual in the sense that there is not any dramatic crash down to zero before the last day of trading. The price moves from an average of around 1.4 Yuan

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[9] Barberis and Huang (2008) develop such a theory based on a behavioral bias that when evaluating risk, people tend to overweigh the tails of the distribution. Brunnermeier, Gollier and Parker (2007) also propose a theory based on the idea that agents derive utility not only from consumption at that time, but also from anticipation of future consumption. Both theories predict overvaluation of assets with positive return skewness relative to the prediction of standard expected utility models.

[10] We also examined the return skewness after excluding the last trading, during which warrant prices usually experience dramatic drops to near-zero levels. While the skewness increases after excluding the last trading day, there is still no evidence for positive skewness.

when there are 50 trading days remaining down to 0.7 Yuan when there are 6 trading days remaining. The price drop speeds up during the last few trading days, with the price eventually ending in pennies at the end of the last trading day. The price volatility gradually increases from 100% per annum when there are still 50 trading days remaining to over 200% when there are 6 trading days remaining, and shot further up in the last few days to 1,400% at the end.

Figure 3 also plots the warrants' daily turnover rate and Yuan volume, averaged across the 16 warrants in the bubble sample, with respect to the number of trading days remaining. The daily turnover rate gradually increases from about 100% when there are still 50 trading days remaining to about 400% when there are only 6 trading days remaining and eventually shoots up to over 1,000% on the last trading day. The average daily Yuan volume displays a different pattern. It fluctuates around 3 billion Yuan when there are 40 to 60 trading days remaining, drops to around 1 billion Yuan when there are 10 to 40 trading days remaining, and then shoots up to over 3 billion Yuan when there are only 7 trading days remaining. Despite the dramatic increase in the daily turnover rate during the last few trading days, the Yuan volume drops to 800 million Yuan on the last trading day, because of the large price drop at the end.

The price dynamics on the last trading day provide probably an even sharper way of examining maturity effects. Figure 4 plots the price movement of WanHua put warrant during its last trading day on April 19, 2007. This warrant was traded on the Shanghai Stock Exchange with regular trading hours from 9:30AM to 11:30AM in the morning and 1PM to 3PM in the afternoon. Figure 4 displays several interesting features. First, the price of WanHua put warrant did not have any sudden burst during the last trading day. It started at 34.2 pennies at the opening and gradually moved down to 8.7 pennies at the closing. Second, while there was a clear downward trend in the price, there were also several large price runups during the day. One evident run occurred shortly after the opening from 35 pennies to 44 pennies. The last half hour of trading was even more dramatic. The price quickly rose from 7 pennies to near 15 pennies, and then fell back to 7 pennies, but only to run up again to 14 pennies with only 12 minutes away from the closing. Finally, the closing price was substantially above zero even though the put warrant was deep out of the money and had absolutely no chance of getting back in the money during its exercise period.

As shown in Table 3, 13 of the 16 put warrants in our sample on their last trading days had absolutely no chance of getting back in the money during their exercise periods. Nevertheless, each of them had an extremely active final trading day, just like the WanHua put warrant, with a substantially positive price at the opening and a gradual downward price trend during the day. Table 4 summarizes the opening, closing and average prices of these 13 warrants on their last trading days. The opening price varied from 4 pennies for the MaoTai put warrant to as high as 42 pennies for the JiaFei put warrant, with an average of 18.4 pennies. Each of the warrants had a closing price substantially below its open price. The closing price varied from 0.1 penny for the HaiEr put warrant to as high as 10.7 pennies for the JiaFei put warrant, with an average of 2 pennies. Despite the downward trend, each warrant also had a higher price during the day than the opening price. The JiaFei put warrant had an intraday high of 93 pennies, 51 pennies higher than its opening price.

In summary, there are evident maturity effects in the warrants bubble. As the maturity approaches, the price bubble gradually declines to zero, accompanied by an increasing trend in return volatility and warrant turnover. While people usually think that a bubble will end with a crash, this warrants bubble only deflates gradually.

4 The Bubble Mechanism

Given the restrictive legal ban on short selling, it is easy to understand the failure of arbitrage. However, why would anyone be willing to pay the insanely high prices for these worthless warrants in the first place? In this section, we examine the underlying mechanism that leads to the warrants bubble.

4.1 Rational Bubbles

Economists have made many attempts to explain price bubbles in settings with only rational agents. There are two classes of rational bubble theories, one with symmetric information and the other with asymmetric information. Blanchard and Watson (1983) provide an example of rational bubbles under symmetric information in a discrete-time model with infinite periods. In each period, a bubble component in asset prices on average grows at the same rate as the discount rate. This type of rational bubble cannot arise for warrants with finite maturities because rational investors' backward induction rules it out in the earlier periods.

Rational finite bubbles might also appear when agents possess asymmetric information about asset fundamentals. Asymmetric information could make the presence of a bubble not commonly known, i.e., it is possible that everyone knows a bubble exists, but everyone may not know everyone else knows a bubble exists. Allen, Morris and Postlewaite (1993) show that the lack of common knowledge makes it possible for a finite rational bubble to appear under certain necessary conditions. The warrants' final payoffs are determined by the underlying stock prices. Since the underlying stocks are traded simultaneously with the warrants on the same exchanges with the prices publicly observable, it is difficult to justify an assumption that investors possess asymmetric information about warrant fundamentals. Thus, it is unlikely that the warrants bubble is caused by the lack of common knowledge among rational investors about the presence of a bubble.

4.2 Bubbles with Common Knowledge

Bubbles could arise even when asset payoffs are common knowledge. Several experimental studies have documented the occurrence of this type of bubbles in various laboratory settings. In the classic study of Smith, Suchanek and Williams (1988), markets are created for assets with a lifetime of a finite number of periods (typically 15 or 30 periods) and a dividend in each period. The only source of intrinsic value is the dividend, which is identical to each trader and whose distribution is commonly known by all traders. They find that the assets are often traded in high volumes at prices substantially above the fundamental value. Similar findings are also reported in several other studies. See Sunder (1995) for a review.

Can this experimental result survive in the field data? The Chinese warrants market displays several key features of those experimental asset markets. There is a stringent short-sales constraint; the warrants have a finite maturity with a final payoff determined by the underlying stock price; and the publicly observable stock price makes the warrant fundamentals common knowledge to all market participants. This unique setting is probably the closest resemblance one can find in any field study to those in the experimental studies. The dramatic price deviation from fundamentals and the frenzied trading in the warrants market confirm the key finding of those experimental studies that bubbles could arise even with common knowledge about asset fundamentals.

Smith, Suchanek and Williams (1988) interpret the bubble discovered in their experimental study as arising through agent uncertainty about the behavior of others. More precisely, the bubble occurs because traders doubt about the rationality of other traders and therefore speculate that future prices may not track the fundamental value and instead would provide opportunities for trading gains. Interestingly, this speculative hypothesis also fits well with the Chinese warrants market because of the presence of investor heterogeneity. Despite the fact that the warrant fundamentals can be readily derived from the publicly observable underlying stock prices, the derivation requires a sufficient degree of understanding about the warrant contracts.

Trying to anticipate the behavior of other investors and their effect on the warrant prices requires further sophistication. As warrants are a new type of security to Chinese investors, some of them do not fully understand the nature of warrants. We have two pieces of evidence confirming the existence of less than fully rational investors. First, Table 4 shows that at the last trading minute of each of the 13 definitely worthless put warrants, there were still a large number of unfilled orders trying to buy the warrant at positive prices. The bids of these orders ranged from 0.1 penny to as high as 10.7 pennies. These unfilled buy orders had an average value of 1.1 million Yuan.[11] Second, some warrant holders had chosen to exercise their out-of-money warrants at losses. Table 4 shows that among the 13 put warrants, 9 had warrant exercises by investors at losses, with a total loss of 326 thousand Yuan per warrant on average, although the irrationally exercised warrants were only 0.38% of the outstanding shares of these warrants.

On the other hand, there also exist sophisticated investors to whom the existence of less than fully rational investors provides a profit opportunity. Indeed, a report issued by the Shanghai Stock Exchange shows that half of the exchange's warrant trading volume involved the top 1% most active accounts (measured by trading volume) and that these accounts (likely sophisticated professionals) had managed to make a profit trading these overvalued warrants.[12]

Experimental studies also find that as traders gain more trading experience, the divergence in their price expectations is attenuated, and markets become thinner. How does the warrants market evolve over time as investors observe the previous warrants expiring out of money? Our data sample spans three years. If investors learned their lesson from trading warrants in the earlier period, we would expect the market to become less speculative in the later period. To examine this investor-learning hypothesis, we split the 16 put warrants in our sample into two halves (each with 8 warrants) based on their expiration dates, and report separate statistics for the two subsamples in Tables 2, 3, and 4. Table 2 shows that the last 8 warrants on average had a longer zero fundamental period than the first 8. During the zero fundamental periods, the last 8 warrants had an average price level of 1.47 Yuan, while the first 8 only had an average of 0.53 Yuan. The difference is significant with a p-value of 0.01. Table 3 also shows that the last 8 warrants had a greater number of trading days in violation of the fundamental upper bound than the first 8. The

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[11] These investors could simply be using forward induction to extrapolate past prices, as consistent with the finding of Hirota and Sunder (2007) in an experimental study.

[12] We have no access to the account level trading data to analyze the heterogeneity across accounts.

differences between these two subsamples in other dimensions, such as daily turnover, Yuan volume, daily volatility, the magnitude of violating the fundamental upper bound, the last trading day price, and irrational warrant exercises, are insignificant. Taken together, we do not see any evidence of investor learning. If anything, the last 8 warrants had larger price bubbles over longer periods relative to the first 8.[13]

4.3 The Resale Option Theory

Economic theorists have formally developed the resale option theory of bubbles based on the interaction between investors with heterogeneous beliefs. When short-sales of assets are constrained and investors hold heterogeneous beliefs about an asset's fundamentals, Miller (1977) suggests that in a static setting, the asset's price is biased toward the optimists' belief because pessimists cannot short sell and will only sit on the sideline. Harrison and Kreps (1978) show that in a dynamic setting, an optimist is willing to pay more than his already optimistic belief of asset fundamentals, anticipating the possibility to resell the asset in the future to even more optimistic investors. This resale option can drive price higher than the most optimistic belief about asset fundamentals by any investor and thus forms a bubble. The resale option theory is consistent with the aforementioned speculative hypothesis and can explain bubbles with common knowledge.

The institutional setting of China's warrants market satisfies the two necessary ingredients of the resale option theory—short-sales constraints and heterogeneous investors. First, it is illegal for investors to short warrants. While the Shanghai Stock Exchange (SHSE) had set up a creation program to allow a group of designated brokerage firms to issue warrants on the SHSE, as we discussed in Section 2, the scope of this creation program was limited. Indeed, the creation force was too feeble to cool off the warrants bubble. Second, there exists a mix of heterogeneous investors as discussed earlier.

Unable to short sell, it is natural for a smart investor to speculate on selling an overvalued warrant at an even higher price to another buyer in the future. Without knowing his own limitation in warrant trading (or in other words, by being overconfident), a less sophisticated investor could also have a similar speculative motive, i.e., he buys a warrant aiming to resell it at

[13] The lack of investor learning over a period of 3 years is not so surprising because there was a steady flow of new investors attracted into the Chinese financial markets by the stock market boom. By analyzing all the accounts involved in trading one call warrant, issued by the BaoGang Cooperation, Pan, Shi and Song (2008) provide direct evidence that the flow of new investors had a positive impact on the warrant price.

a higher price later. In such an environment, warrant prices are determined by investors' speculative motives instead of the underlying stock prices. Even when a warrant is deep out of the money, investors still trade it as long as its price fluctuates, which may be viewed as profit opportunities by these investors. In fact, the trading-friendly environment of the warrants market, which we discussed in Section 2, further fuels the investors' speculative frenzy and the spectacular price bubble.

Scheinkman and Xiong (2003) further develop the resale option theory by presenting a continuous-time model, in which overconfident investors trade an asset with each other under short-sales constraints. Their model provides a sharp prediction that the magnitude of the price bubble is positively correlated with trading frequency. Overconfidence causes investors to interpret information differently and form heterogeneous beliefs about future price movement. The more the beliefs of these overconfident investors diverge from each other, the more intensively they trade with each other, and, at the same time, the more they are willing to pay for the option to resell the asset to other investors.

Does this positive correlation appear in the Chinese warrants bubble? We pool together the daily closing prices of the 16 put warrants according to their maturities (number of trading days remaining). We focus our attention on the bubble sample, i.e., each warrant in its zero-fundamental period (its Black-Scholes value is less than 0.05 penny, half of the minimum trading tick) so that the warrant price is approximately the bubble size. Table 5 provides various panel regressions of the warrant prices. Since there is a strong maturity effect in prices, we include a maturity fixed effect in these regressions. In regression (1), we regress warrant price on daily turnover,

$$PRICE_{it} = b_0 + b_1 * TURNOVER_{it} + \text{MATURITY FIXED EFFECT} + e_{it}. \tag{1}$$

$PRICE_{it}$ is the closing price of warrant i on day t, which is indexed by the number of trading days remaining, and e is a generic term capturing sampling noise. The coefficient of interest is b_1 in front of the daily turnover measure $TURNOVER_{it}$. This coefficient is positive and highly significant with a t-statistic of 8.97, confirming a positive correlation between the price bubble and turnover.

Another implication of this theory is that a bubble is positively correlated with its price volatility. When the prices are more volatile, investors' beliefs about the warrants' future prices fluctuate more, and the resale option is more valuable. Note that this prediction is opposite to the standard asset pricing theories, which predict a negative correlation between asset price and volatility because of the tradeoff between risk and expected returns. In regression (2) of Table 5, we regress daily warrant price on warrant return volatility,

$$PRICE_{it} = c_0 + c_1*VOL_{it} + \text{MATURITY FIXED EFFECT} + e_{it}. \quad (2)$$

VOL_{it} is the return volatility of warrant i on day t constructed from 5-minute intraday returns. The coefficient of interest is c_1 in front of the volatility. The coefficient is again positive and highly significant with a t-statistic of 5.33.

Hong, Scheinkman and Xiong (2006) develop a model to show that asset float (number of tradable shares) has a large effect on the size of bubble. When investors have a limited risk-bearing capacity, a larger float implies that it takes a greater difference between the optimists' and pessimists' beliefs for optimists to drive out pessimists. This implies that it takes a greater belief divergence in the future for an existing asset holder to resell profitably, which in turn means that the resale option is less valuable today. In regression (3) of Table 5, we examine the relationship between asset float and the warrants bubble,

$$PRICE_{it} = d_0 + d_1*FLOAT_{it} + \text{MATURITY FIXED EFFECT} + e_{it}. \quad (3)$$

$FLOAT_{it}$ is the total number of warrants outstanding for warrant i on day t. The coefficient of interest is d_1 in front of the float. The coefficient is negative and highly significant with a t-statistic of 12.43, confirming the prediction that price bubble is negatively related to asset float.

We also combine turnover, volatility and float in a single regression—regression (4),

$$PRICE_{it} = f_0 + f_1* TURNOVER_{it} + f_2* VOL_{it} + f_3*FLOAT_{it}$$

$$+ \text{MATURITY FIXED EFFECT} + e_{it}. \quad (4)$$

Each variable has a similar effect on the warrants bubble as in the previous individual regressions.

Note that the number of tradable shares of the warrants traded on the SHSE changes over time because of the exchange's share creation program. Panel A of Table 6 provides a summary of the number of shares issued by the designated brokerage firms for the 10 SHSE-traded warrants. Because of the tight control by the SHSE, the shares issued by the brokerage firms in the secondary market for most warrants are small relative to the initial shares, although two warrants (WanHua and ZhaoHang) had more shares issued by the brokerage firms at some points of time. To control for the effect of the time-varying float in our analysis of the warrant price, we decompose the total float into the initial float and the net new issuance and repeat regressions (3) and (4) using the decomposed float variables. As reported in Panel B of Table 6, the warrant price is negatively correlated with the initial float but positively correlated with the net new issuance, and both coefficients are statistically significant. The positive correlation between the warrant price and the net new issuance shows that the designated brokerage firms tend to issue more shares when warrant prices are high.[14] The negative effect of the initial float on the warrant price remains the same as that in Table 5.

Overall, Tables 5 and 6 provide a set of regression results supporting various implications of the resale option theory of bubbles. The positive correlation between the warrant price and trading volume corroborates a similar observation about many historical bubbles, such as the tulip mania in seventeenth century Holland, the stock market bubble before the great crash of the late 1920s in the U.S., and more recently the Internet bubble in the late 1990s, e.g., Cochrane (2003) and Hong and Stein (2007). The negative correlation between the warrant price and asset float is also consistent with the finding of Ofek and Richardson (2003) that the large increase of float in the early 2000 after the lockup expiration of many Internet firms is an important driving factor for the burst of the Internet bubble. This result is thus favorable evidence for the Shanghai Stock Exchange's creation program even though it did not manage to fully control the bubble.

[14] By examining the time series of each individual brokerage firm's issuance, we find no evidence of short squeeze. Instead, the issuance generally increases with the price bubble, consistent with the regression result in Panel B of Table 6.

4.4 Understanding the Maturity Effects

The resale option theory has a direct implication for the effect of asset maturity on price bubble. As the maturity approaches, anticipating that there is less time for reselling his shares in the future, a buyer values the resale option less, thus leading to a smaller price bubble. The gradual decline in warrant prices before and during the last trading day supports this theory prediction. The observation of such a clear maturity effect also indicates the presence of sophisticated investors and that the basic backward induction mechanism is still operating even in the dramatic price bubble.

Figure 3 further shows that the warrant price drop accelerates during the last several trading days. For a deep out-of-the-money warrant approaching maturity, its return (negative on average) largely represents the loss of speculative value. Figure 5 plots the daily percentage drop in warrant price averaged across all warrants with a given number of trading days remaining. It shows that, while the price drop is relatively stable in the earlier period, there is a dramatic rise during the last 8 trading days, indicating a higher resale option value associated with each of the days near expiration. This is consistent with Figure 3 which shows that the return volatility and share turnover shoot up during the last several trading days, especially on the last day. Interestingly, once the maturity effect in warrant return is scaled by the corresponding daily turnover rate or warrant return volatility, it becomes rather stable across maturity. It confirms the resale option theory that the higher resale option value associated with the last several days is related to the intensified trading at the end.

As pointed out by Benartzi, Michaely, Thaler and Weld (2007), while the nominal price level does not contain any specific economic meaning, it could nevertheless affect investors' demand for financial assets because of social norms. As the maturity approaches, the warrant price gradually drops from the range of several Yuan to pennies, especially in the last few days. This low price level can be perceived by some investors as being cheap and therefore attracts more speculative trading. While we do not have account level trading data to verify this hypothesis, the dramatic increase of share turnover in the last few days suggests intensified speculation. This in turn makes the resale option associated with each of the last several trading days more valuable.

4.5 Positive Feedback

A large volume of behavioral finance studies suggests that various behavioral biases can lead inexperienced individual investors to feedback positively to past returns.[15] Does this feedback effect exist in the warrants market? Examining the feedback effect can help us understand the time-series dynamics of the warrants bubble.

We study the joint dynamics of the warrants' return, turnover change and return volatility change in the bubble sample by running the following regressions:

$$RET_{it} \text{ (or } \Delta TURNOVER_{it}\text{, or } \Delta VOL_{it}) = h_0 + h_1{*}\, RET_{it-1} + h_2{*}\, RET^{+}_{it-1} + h_3{*}\Delta TURNOVER_{it-1} + h_4{*}\, \Delta VOL_{it-1} + \text{WARRANT FIXED EFFECT} + \text{MATURITY FIXED EFFECT} + e_{it} \quad (5)$$

where $RET^{+} = \max(0,RET)$. RET_{it}, $\Delta TURNOVER_{it}$, and ΔVOL_{it} refer to the one-period return, one-period proportional change in turnover, and one-period proportional change in the volatility of warrant i in period t. We also include RET^{+}, the truncated positive part of the lagged warrant return in our analysis to examine asymmetry in the feedback effects.[16] We examine the dynamics in different time intervals, including each period being 1-minute, 5-minute, 10-minute, 30-minute, 1-hour, 2-hour and 1-day intervals. We use 1-minute warrant returns to estimate warrant return volatility in longer time intervals. To insure reasonable accuracy, we employ only volatility in

[15] Barberis, Shleifer and Vishny (1998) show that representativeness bias, a tendency to view events as typical or representative of some specific class, can lead a representative investor to extrapolate past price changes into expectations of future price changes. Daniel, Hirshleifer and Subrahmanyam (1998) and Gervais and Odean (2001) show that self-attribution bias, a tendency to attribute success to one's own ability but failure to external reasons, can also cause investors to feedback to past price increases. Hong and Stein (1999) provide a model to show that gradual diffusion of information among heterogeneous investors can lead to price momentum. Grinblatt and Han (2005) show that the interaction between smart investors and individual investors with disposition effect, a propensity to sell shares of a stock that has risen in value rather than one that has fallen (e.g., Odean (1998)), can result in a feedback effect.

[16] We have also examined specifications without RET^{+}. Dropping RET^{+} does not affect the regression coefficients of other variables.

intervals longer than 10 minutes in our analysis. We omit volatility in analysis where a period is shorter than 10 minutes.[17]

Table 7 reports the empirical results. Panel A shows the pooled regression results of warrant return on lagged warrant return, turnover change and volatility change. Several interesting patterns emerge from the panel. First, the coefficient of lagged warrant return is significantly positive in regressions with 1-minute, 5-minute and 10-minute intervals, but not with longer intervals such as 30-minute, 1-hour, 2-hour and 1-day intervals. This result indicates a positive feedback effect in warrant returns, albeit only in frequencies much faster than what are typically observed in other markets. For example, numerous empirical studies following Jegadeesh and Titman (1993) find price momentum in individual stocks across the world in time intervals of around 6 months. The difference in the feedback frequency of these markets is consistent with the dramatic difference in their turnover rates—the average *daily* turnover of the Chinese warrants is 291% (e.g., Table 2), while the average *yearly* turnover of the U.S. stocks is less than 100%. The fast feedback frequency of 10 minutes in the warrants market confirms that the market operates at a much higher speed.

Furthermore, there is little evidence of feedback effects in warrant returns to past turnover changes and volatility changes.[18] Finally, there is little evidence of asymmetric feedback of warrant returns to past warrant returns, because the coefficient of the truncated positive part of lagged warrant return is insignificant across all regression intervals.

Panel B shows the pooled regression results of turnover change. Besides a significant mean-reverting effect in turnover, we also observe several other effects from this panel. First, consistent with the feedback effect in warrant returns, there is a statistically significant positive feedback effect in turnover changes to past warrant returns in time intervals up to 1 hour. Second, the response of turnover changes to past warrant returns is asymmetric. The coefficient of the truncated positive part of lagged warrant return is significantly negative in regressions with time

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[17] To mitigate the effect of microstructure noise on volatility estimation (see for example Aït-Sahalia, Mykland and Zhang (2005)), we feature 1-minute return volatility as opposed to transaction-to-transaction return volatility, though the result is similar using alternative measures of volatility. The bubbling Chinese warrant market is very liquid using a number of traditional measures of liquidity. Therefore, using 1-minute return to measure volatility likely strikes a balance between sample size and microstructure noise.

[18] The regression coefficient of warrant return on past volatility change in a 10-minute interval is significantly positive. However, this coefficient is not robust to alternative volatility measures we use.

intervals up to 1 hour, suggesting that the drop in turnover in response to a negative warrant return is more pronounced than the increase in turnover in response to a positive warrant return. Finally, there is no response in turnover changes to past volatility changes.

Panel C shows the regression results of volatility change. In addition to the well known mean reversion (ARCH-GARCH) in volatility, we also observe the following. First, there is a significantly positive response in volatility changes to past warrant returns in the regressions with 30-minute and 1-hour time intervals. Second, there is some evidence of asymmetry in the response of volatility changes to past warrant returns with a 1-hour interval. Third, there is no evidence of response in volatility changes to past turnover changes.

The presence of positive responses of both warrant returns and turnover changes to past warrant returns again highlights the importance of incorporating investor heterogeneity in understanding the warrants bubble, consistent with the key insight of our earlier analysis.

4.6 Riding the Bubble

Are there profit opportunities in the warrants market for smart investors to exploit? Given the presence of the positive feedback effect in the warrant returns, it is naturally to evaluate momentum trading strategies. A typical momentum strategy involves buying past winners and simultaneously shorting past losers. We pool together the 16 put warrants in their zero-fundamental periods based on the number of trading days remaining. We construct hypothetical winner and loser portfolios based on the warrant returns in a formation period and then compute the portfolio returns in a holding period. Table 8 reports the portfolio returns under different portfolio specifications. We let the length of the portfolio formation and holding periods to be equal and vary it from 1 minute to 1 day. In panel A, the winner portfolio consists of the top half of warrants based on their returns in the formation period, while the loser portfolio consists of the bottom half; in panel B, the winner portfolio consists of the top quartile, while the loser portfolio consists of the bottom quartile; in panel C, the winner portfolio includes warrants with positive returns in the formation period, while the loser portfolio includes those with negative returns.

Since investors are not allowed to short warrants, we look at the returns of the winner and loser portfolios separately. Interestingly, across all specifications, the returns of the winner portfolios are mostly negative and statistically insignificant, except that at the very short horizon of 1 minute the winner portfolios provide a significantly positive profit. Even this profit is too small to offset the brokerage fee and bid-ask spread. In other words, based on the market prices it is not profitable for additional momentum traders to ride the warrants bubble. Given the presence of the positive return feedback effect in 5-minute and 10-minute intervals, why is riding the past winners not profitable at these frequencies? The answer lies in the maturity effect in warrant prices. As we discussed in Section 3.3, there is a pronounced downward trend in prices, which largely offsets the short-run positive momentum. Table 8 also shows that the returns of the loser portfolios are negative across all specifications and most of them are statistically significant. If investors were able to short the loser portfolios, the momentum strategies would be profitable.

The absence of positive momentum profit suggests that smart investors likely have been actively riding the warrants bubble and, by doing so, have eliminated additional opportunities for such momentum trades. This result is consistent with the evidence presented by Brunnermeier and Nagel (2004) that during the recent Internet bubble, many hedge funds (the likely smart investors) had been active in riding the bubble, instead of attacking it.[19]

5 Conclusion

In this paper we examine a speculative bubble that occurred in 2005-08 in China's warrants market. Despite being so deep out of the money that there is no chance of getting back in the money before maturity, 16 put warrants had been turned over on average almost 300% a day at substantially inflated prices. Since the publicly observable underlying stock prices make the zero warrant fundamentals common knowledge to all market participants, this warrants bubble presents a unique opportunity to study bubble mechanisms. We find evidences supporting the resale option theory of bubbles: in an environment where short-sales are constrained and investors are heterogeneous, they overpay for a warrant and hoping to resell it at an even higher price to a greater fool. This bubble mechanism sheds light on other more complicated bubble episodes, including the recent housing bubble across many regions in the U.S.

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[19] Some commentators had even suggested the existence of large manipulators using pump-and-dump strategies (e.g., Delong, Shleifer, Summers and Waldmann (1990)) to take advantage of the large number of naïve investors in the warrants market. Because of the lack of account level data, we cannot directly examine this hypothesis.

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Figure 1. WuLiang put warrant prices

This figure shows the daily closing prices of WuLiang stock and its put warrant, along with WuLiang warrant's strike price, upper bound of its fundamental value assuming WuLiang stock price drops 10% every day before expiration (maximum allowed per day in China's stock market), and its Black-Scholes price using WuLiang stock's previous one-year rolling daily return volatility.

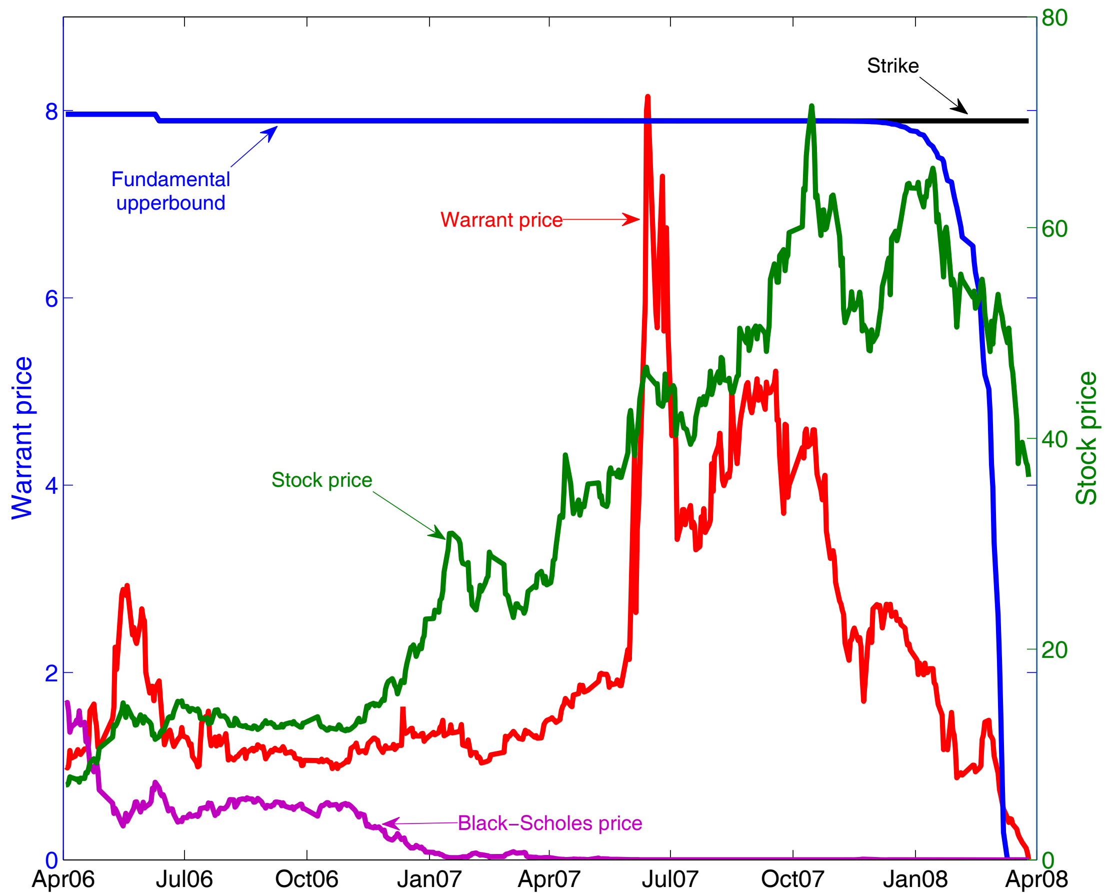

Figure 2. Volume and volatility of WuLiang put warrant

This figure shows WuLiang put warrant's daily turnover, daily trading volume (in billion Yuan), and 5-minute return volatility (annualized) in each trading day.

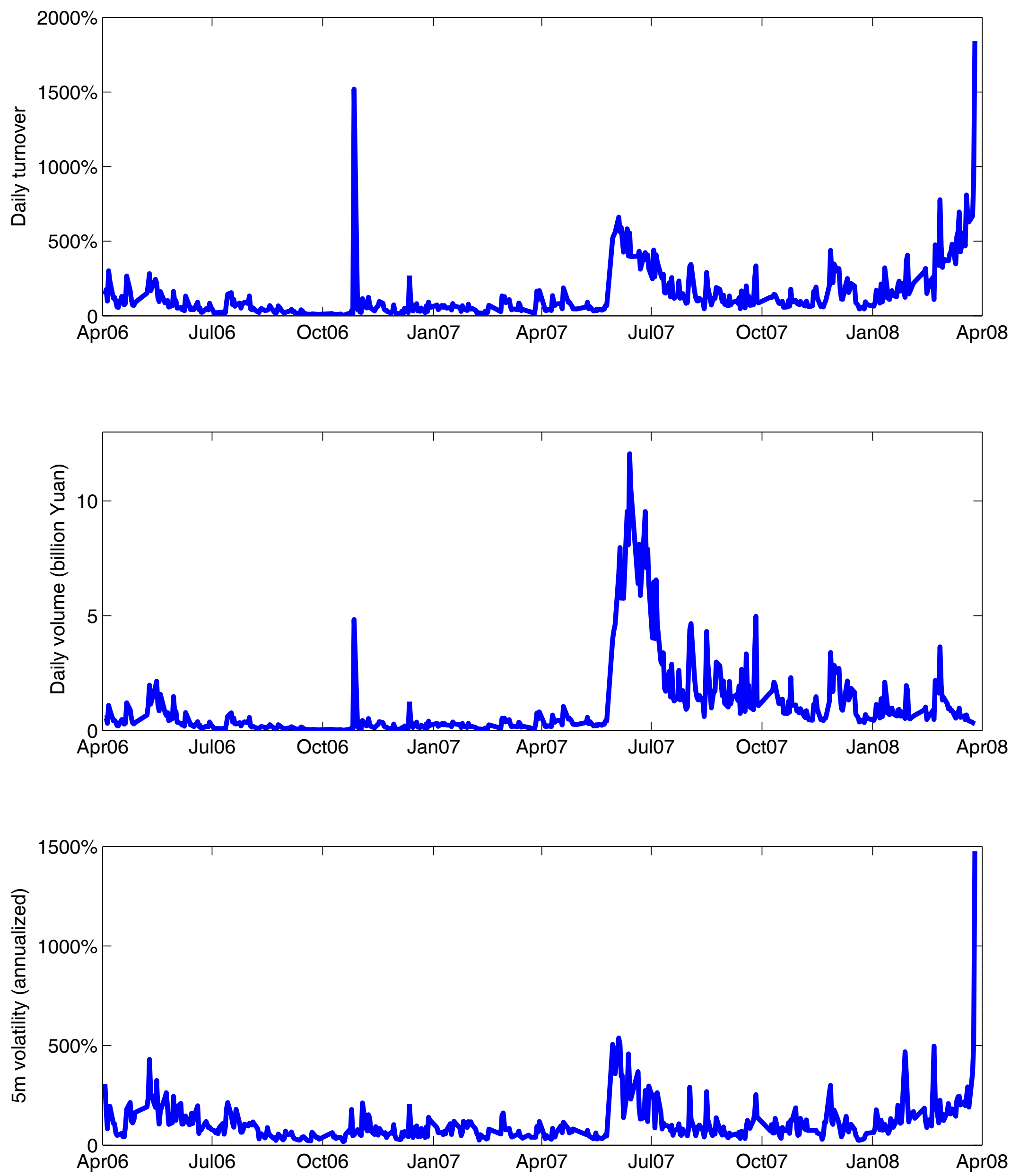

Figure 3. Dynamics for zero-fundamental warrants

This figure shows the average warrant price, the average daily warrant turnover, the average 5-minute warrant return volatility (annualized), and the average daily warrant trading volume (in million Yuan) against the number of trading days remaining for the 16 put warrants in their respective zero-fundamental periods. The averaging is across all warrants with a given number of trading days remaining.

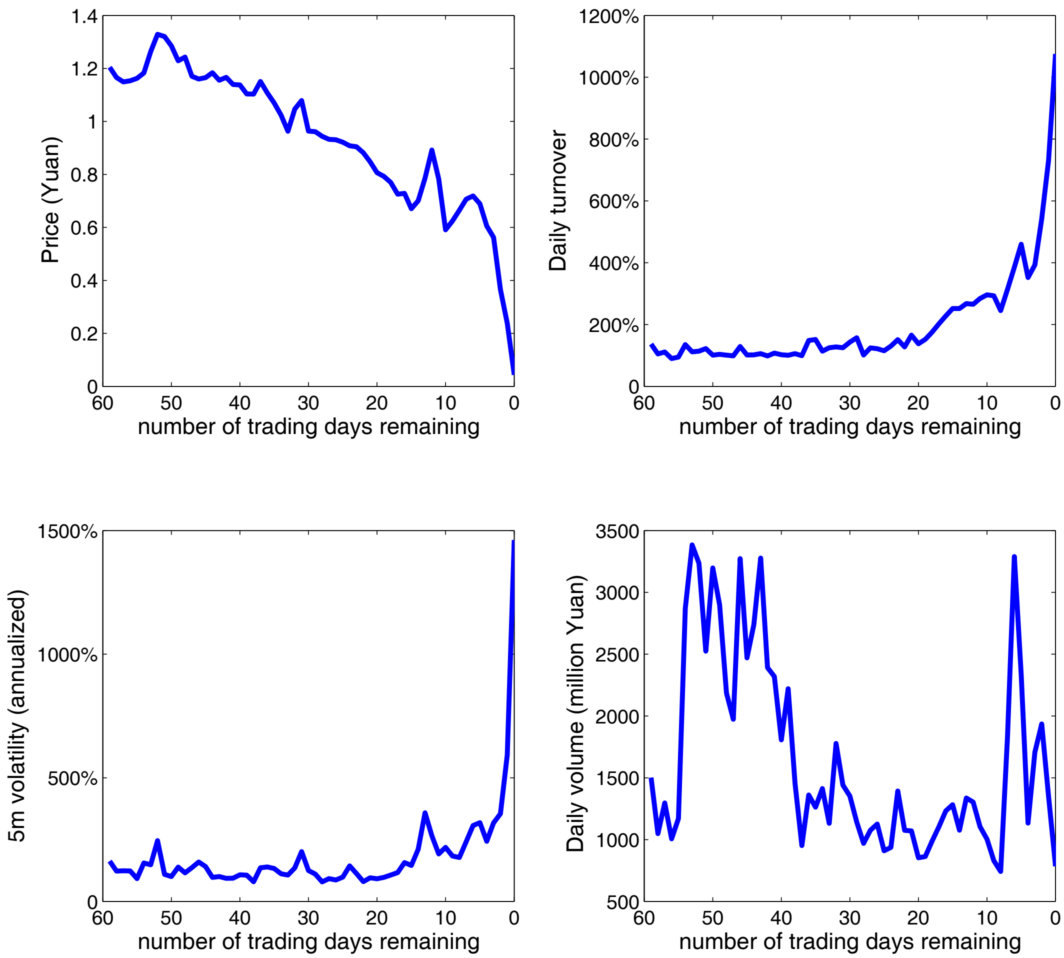

Figure 4. Last-day price dynamics of WanHua put warrant

This figure shows the intra-day transaction price history of the WanHua put warrant on its last trading day (April 19, 2007).

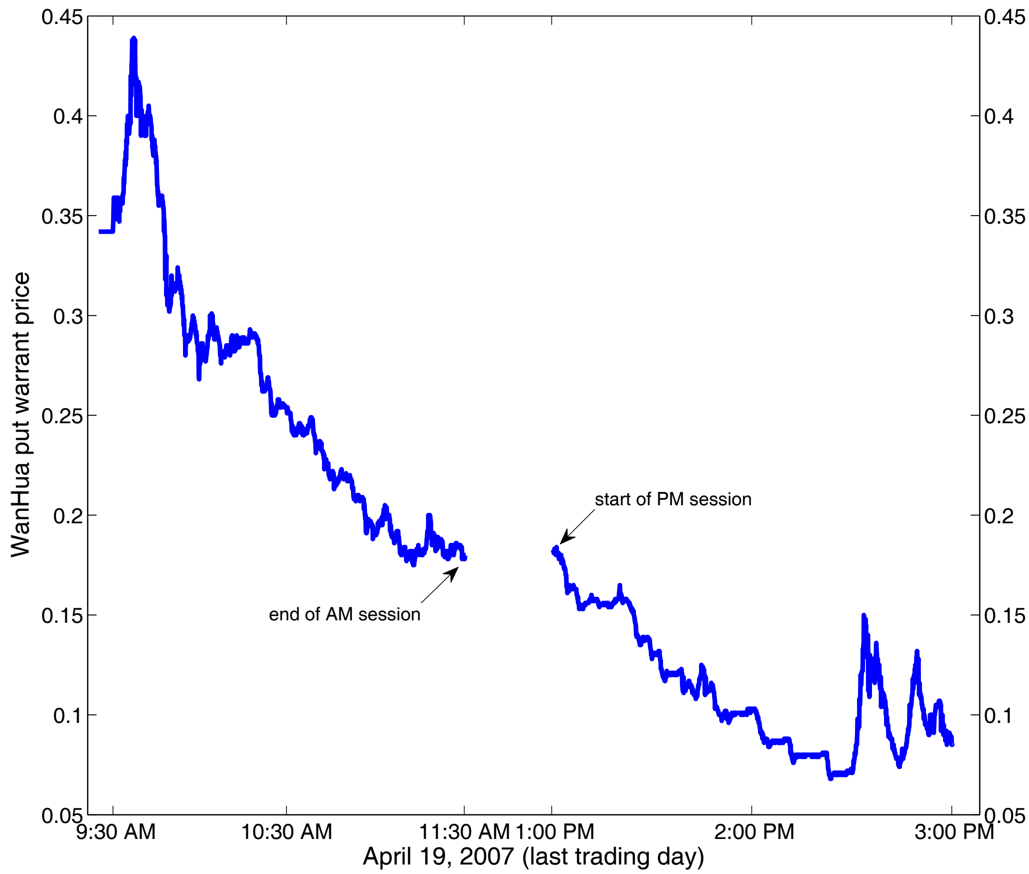

Figure 5. Average warrant price drop

This figure shows the daily percentage drop of the average warrant price, along with its scaled versions (scaled by the average daily warrant turnover and the average 5-minute warrant return volatility (annualized), respectively), against the number of trading days remaining for the 16 put warrants in their respective zero-fundamental periods. The averaging is across all warrants with a given number of trading days remaining.

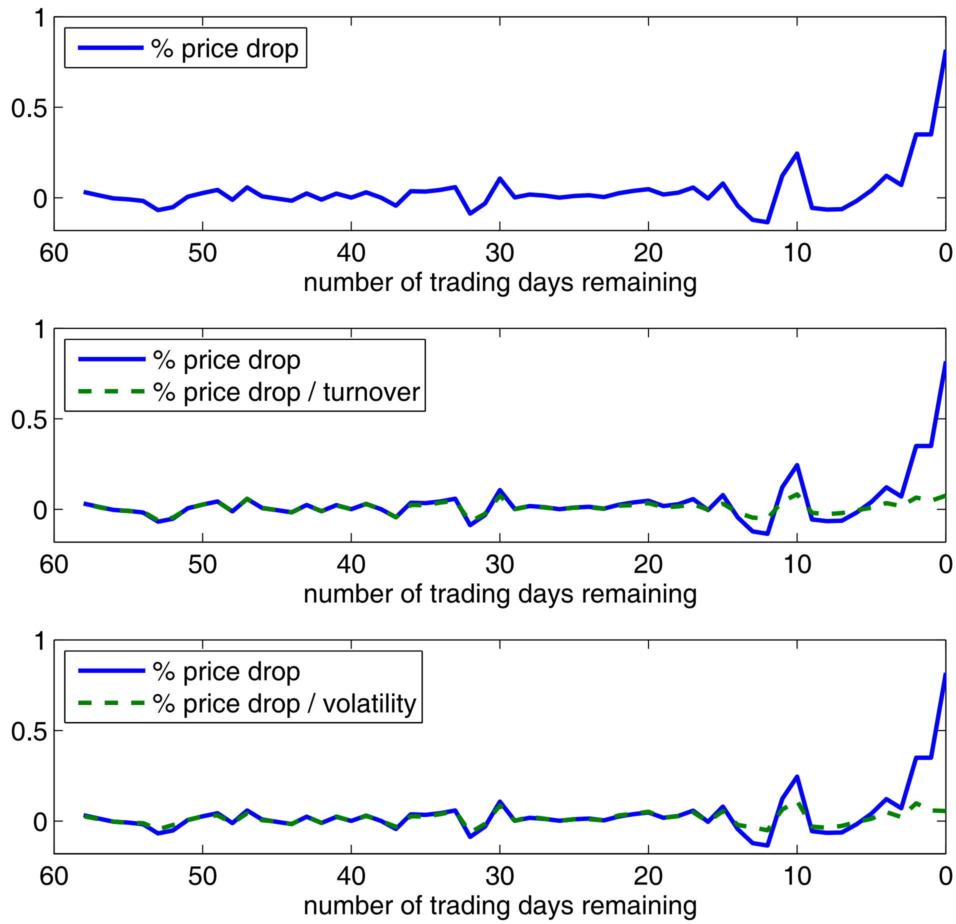

Table 1. Summary information of the 16 put warrants

This table shows, for each put warrant, its ticker, name, exchange (Shenzhen or Shanghai), total shares outstanding of the warrant and the underlying stock at the start of warrant trading, trading period, and exercise period. This table also shows the closing price of the underlying stock, along with the warrant strike price and exercise ratio (number of underlying stocks per warrant) on the first and the last day of the warrant trading period. The warrants are sorted according to the expiration date of their exercise periods.

					Initial Information			Trading Period		Exercise Period		End Information		
Ticker	Name	Exchange	Warrant amount (million shares)	Stock amount (million shares)	Stock Price	Strike Price	Exercise Ratio	Begin	End	Begin	End	Stock Price	Strike Price	Exercise Ratio
38002	WanKe	Shenzhen	2140	2673	3.78	3.73	1	12/5/2005	8/28/2006	8/29/2006	9/4/2006	6.79	3.638	1
580999	WuGang	Shanghai	474	2370	2.77	3.13	1	11/23/2005	11/15/2006	11/16/2006	11/22/2006	3.35	2.83	1
580998	JiChang	Shanghai	240	476	6.77	7	1	12/23/2005	12/15/2006	3/23/2006	12/22/2006	7.94	6.9	1
580994	YuanShui	Shanghai	280	684	4.27	5	1	4/19/2006	2/5/2007	2/6/2007	2/12/2007	6.54	4.9	1
580996	HuChang	Shanghai	568	901	11.85	13.6	1	3/7/2006	2/27/2007	3/6/2007	3/6/2007	25.52	13.36	1
580995	BaoGang	Shanghai	715	1843	2.1	2.45	1	3/31/2006	3/23/2007	3/26/2007	3/30/2007	5.7	2.37	1
580993	WanHua	Shanghai	85	328	16.42	13	1	4/27/2006	4/19/2007	4/20/2007	4/26/2007	38.75	9.22	1.41
38001	GangFan	Shenzhen	233	875	3.3	4.85	1	12/5/2005	4/24/2007	5/8/2007	5/8/2007	10.72	3.16	1.535
580991	HaiEr	Shanghai	607	742	4.74	4.39	1	5/22/2006	5/9/2007	5/10/2007	5/16/2007	15.79	4.29	1
580992	YaGe	Shanghai	635	907	6.8	4.25	1	5/22/2006	5/14/2007	5/17/2007	5/21/2007	26.44	4.09	1
580990	MaoTai	Shanghai	432	302	48.39	30.3	0.25	5/30/2006	5/22/2007	5/29/2007	5/29/2007	94.84	30.3	0.25
38008	JiaFei	Shenzhen	120	336	20.3	15.1	1	6/30/2006	6/22/2007	6/25/2007	6/29/2007	45.21	15.1	1
580997	ZhaoHang	Shanghai	2241	4705	6.37	5.65	1	3/2/2006	8/24/2007	8/27/2007	8/31/2007	39.04	5.45	1
38006	ZhongJi	Shenzhen	424	606	13.98	10	1	5/25/2006	11/16/2007	11/19/2007	11/23/2007	24.11	7.302	1.37
38003	HuaLing	Shenzhen	633	880	3.64	4.9	1	3/2/2006	2/22/2008	2/27/2008	2/29/2008	12.45	4.718	1
38004	WuLiang	Shenzhen	313	893	7.11	7.96	1	4/3/2006	3/26/2008	3/27/2008	4/2/2008	25.92	5.627	1.402

Table 2. Market dynamics of the 16 put warrants during their zero-fundamental period

This table shows, for each warrant, the sample period of zero fundamental value defined by its Black-Scholes value at the end of each trading day being less than 0.0005 Yuan (half of the minimum trading tick). The Black-Scholes value is computed using the previous one year's daily return volatility. This table reports, for each warrant in its zero-fundamental period, the time-series average/maximum of its daily closing price, daily turnover, daily trading volume (in million Yuan), and daily 5-minute return volatility (annualized). For each warrant in its zero-fundamental period, this table reports the pairwise correlation between the daily warrant return and the daily return of the underlying stock, along with the p-value for the null hypothesis that the correlation is zero. This table also reports, for each warrant, the daily return skewness coefficient and the p-value for the null hypothesis of zero skewness (the p-value is calculated using the Pearson Type VII curve approximation in D'Agostino and Tietjen (1973) which requires at least 8 daily return observations). Cross-sectional averages for all warrants, for the first 8 warrants, and for the last 8 warrants are reported along with the differences between the averages of the first 8 and the last 8 warrants and the p-values for testing the null hypothesis of no difference between the first 8 and last 8 warrants.

					Warrant Price		Daily Turnover		Yuan Volume (mil)		Daily Volatility (annualized)		Corr(stock ret, put ret)		Skewness(put ret)	
Ticker	Name	First Obs	Last Obs	# Days	Avg	Max	Avg	Max	Avg	Max	Avg	Max	Corr	p-value	Skewness	p-value
38002	WanKe	8/3/2006	8/28/2006	17	0.055	0.09	178%	547%	176	317	306%	1139%	-0.424	9.00%	-1.879	0.001
580999	WuGang	11/6/2006	11/15/2006	7	0.188	0.281	765%	1695%	756	1,451	763%	2297%	0.045	92.50%	0.931	
580998	JiChang	12/6/2006	12/15/2006	6	0.721	0.96	378%	725%	767	1,334	278%	414%	0.383	45.40%	-0.899	
580994	YuanShui	1/24/2007	2/5/2007	9	0.379	0.562	510%	1471%	711	2,589	397%	1362%	-0.166	66.90%	-0.292	0.613
580996	HuChang	1/10/2007	2/27/2007	30	0.586	0.924	264%	991%	751	2,162	214%	1309%	0.46	1.10%	-2.461	0
580995	BaoGang	2/13/2007	3/23/2007	24	0.448	0.588	296%	1406%	1,000	2,621	165%	1019%	-0.082	70.40%	-2.891	0
580993	WanHua	1/9/2007	4/19/2007	67	1.014	1.39	183%	1438%	299	1,700	133%	1772%	-0.035	77.70%	-2.757	0
38001	GangFan	3/13/2007	4/24/2007	27	0.843	1.25	237%	1316%	364	881	173%	1438%	-0.435	2.30%	-3.069	0
580991	HaiEr	12/4/2006	5/9/2007	89	0.614	0.826	96%	1072%	353	1,280	100%	1620%	-0.021	84.40%	-4.945	0
580992	YaGe	2/12/2007	5/14/2007	55	0.544	0.749	145%	972%	433	1,250	122%	1433%	0.006	96.70%	-3.747	0
580990	MaoTai	4/16/2007	5/22/2007	19	0.41	0.71	289%	815%	523	1,875	316%	2112%	-0.142	56.10%	-1.452	0.006
38008	JiaFei	4/9/2007	6/22/2007	44	1.97	6.07	363%	1741%	1,285	7,990	300%	1669%	0.003	98.30%	1.703	0
580997	ZhaoHang	12/18/2006	8/24/2007	165	0.628	3.269	180%	1198%	6,384	45,683	153%	1872%	-0.11	15.80%	4.861	0
38006	ZhongJi	5/22/2007	11/16/2007	111	3.034	7.12	312%	1662%	3,680	17,053	180%	1150%	-0.052	58.70%	-0.766	0.002
38003	HuaLing	9/13/2007	2/22/2008	40	1.768	3.87	246%	1306%	1,428	3,907	242%	1384%	-0.013	93.80%	-1.181	0.003
38004	WuLiang	7/23/2007	3/26/2008	150	2.815	5.218	210%	1841%	1,286	4,974	131%	1475%	0.094	25.10%	-2.954	0
Average				54	1.001	2.117	291%	1262%	1,262	6,067	248%	1467%	-0.031	60.3%	-1.362	0.037
Average(first 8 puts)				23	0.529	0.756	351%	1199%	603	1,632	304%	1344%	-0.032		-1.665	
Average(last 8 puts)				84	1.473	3.479	230%	1326%	1,922	10,502	193%	1589%	-0.029		-1.060	
Diff				61	0.944	2.723	-121%	127%	1,319	8,870	-111%	246%	0.002		0.605	
p-value				0.010	0.032	0.010	0.140	0.526	0.099	0.120	0.179	0.286	0.984		0.628	

Table 3. Violations of the fundamental upper bound by the 16 put warrants

This table shows, for each warrant, the number of days its closing price is higher than the fundamental upper bound computed by assuming its underlying stock price drops 10% every day before expiration (maximum daily drop allowed in China's stock market). Also reported is the time-series average/minimum/maximum of the dollar amount that the closing price surpasses the upper bound when the bound is violated. This table also shows the number of days that a put warrant's closing price is above its strike price. Cross-sectional averages for all warrants, for the first 8 warrants, and for the last 8 warrants are reported along with the differences between the averages of the first 8 and the last 8 warrants and the p-values for testing the null hypothesis of no difference between the first 8 and last 8 warrants.

Ticker	Name	# of Days in Violation	Magnitude of Violation			
			Average	Min	Max	# of Days with Price > Strike
38002	WanKe	1	0.001	0.001	0.001	0
580999	WuGang	0				0
580998	JiChang	0				0
580994	YuanShui	0				0
580996	HuChang	3	0.319	0.015	0.5	0
580995	BaoGang	5	0.225	0.006	0.491	0
580993	WanHua	9	0.527	0.087	0.828	0
38001	GangFan	2	0.153	0.01	0.295	0
580991	HaiEr	7	0.266	0.001	0.48	0
580992	YaGe	11	0.295	0.002	0.491	0
580990	MaoTai	7	0.123	0.003	0.299	0
38008	JiaFei	8	2.564	0.107	4.9	0
580997	ZhaoHang	13	0.264	0.002	0.673	0
38006	ZhongJi	8	0.216	0.01	0.438	0
38003	HuaLing	8	0.256	0.01	0.561	3
38004	WuLiang	16	0.261	0.004	0.447	2
Average		6	0.421	0.020	0.800	0.3
Average(first 8 puts)		3	0.245	0.024	0.423	0
Average(last 8 puts)		10	0.531	0.017	1.036	1
Diff		7	0.286	-0.006	0.613	1
p-value		0.001	0.469	0.761	0.412	0.159

Table 4. Market dynamics on the last trading day and irrational warrant exercises

This table reports, for each warrant that is certain to expire out of money on its last trading day (13 such warrants in total, as shown in Table 3), the open/close/average/minimum/maximum of its intra-day transaction price and the daily turnover, trading volume (in million Yuan), and 5-minute warrant return volatility (annualized). The highest unfilled bid at trading close and the total value of unfilled bid (in thousands Yuan) are reported, along with the fraction of warrant exercised and the total exercise loss (in thousand Yuan, assuming the exercise price equals the closing price on the last trading day) for each put warrant. Cross-sectional averages for all warrants, for the first 5 warrants (which belong to the first 8 of our full sample), and for the last 8 warrants (which correspond to the last 8 in our full sample) are reported along with the differences between the averages of the first 5 and the last 8 warrants and the p-values for testing the null hypothesis of no difference between the first 5 and last 8 warrants.

Ticker	Name	Intra-day price					Turnover	Volume	5min volatility	Unfilled bid at trading end			Exercise	
		Open	Close	Avg	Min	Max		(million Yuan)	(annualized)	Time	Highest bid	Value (000 Yuan)	Exercised	Loss (000 Yuan)
38002	WanKe	0.018	0.001	0.011	0.004	0.019	547%	98	1139%	2:11:57 PM	0.004	3,824	0.08%	50
580996	HuChang	0.418	0.015	0.209	0.013	0.426	991%	1089	1309%	3:00:14 PM	0.016	134	0.05%	38
580995	BaoGang	0.249	0.006	0.124	0.005	0.266	1406%	1215	1019%	3:00:08 PM	0.005	1,308	0.47%	111
580993	WanHua	0.342	0.087	0.187	0.068	0.439	1438%	482	1772%	3:00:15 PM	0.08	1,316	0.32%	114
38001	GangFan	0.291	0.01	0.147	0.01	0.315	1316%	422	1438%	3:00:32 PM	0.01	152	0.27%	73
580991	HaiEr	0.1	0.001	0.049	0.001	0.108	1072%	340	1620%	3:00:07 PM	0.001	453	0.83%	581
580992	YaGe	0.057	0.002	0.024	0.002	0.059	972%	159	1433%	3:00:19 PM	0.002	728	1.18%	1667
580990	MaoTai	0.04	0.003	0.017	0.002	0.041	801%	103	2112%	3:00:11 PM	0.003	904	0.20%	141
38008	JiaFei	0.42	0.107	0.601	0.1	0.93	1741%	1250	1639%	3:00:24 PM	0.107	1,232	0	0
580997	ZhaoHang	0.161	0.002	0.069	0.001	0.174	968%	3036	1872%	3:00:11 PM	0.001	2,027	0.02%	163
38006	ZhongJi	0.104	0.01	0.076	0.01	0.107	1662%	469	1150%	3:00:32 PM	0.01	581	0	0
38003	HuaLing	0.11	0.01	0.093	0.01	0.15	1306%	648	1340%	3:00:23 PM	0.01	1,057	0	0
38004	WuLiang	0.08	0.004	0.054	0.01	0.08	1841%	285	1475%	2:56:56 PM	0.004	608	0	0
Average		0.184	0.020	0.128	0.018	0.240	1235%	738	1486%		0.019	1,101	0.38%	326
Average(first 5 puts)		0.264	0.024	0.136	0.020	0.293	1140%	661	1335%		0.023	1,347	0.24%	77
Average(last 8 puts)		0.134	0.017	0.123	0.017	0.206	1295%	786	1580%		0.017	949	0.28%	319
Diff		-0.130	-0.006	-0.013	-0.003	-0.087	156%	125	245%		-0.006	-398	0.04%	242
p-value		0.115	0.761	0.893	0.871	0.566	0.502	0.797	0.180		0.778	0.496	0.856	0.379

Table 5. Determinants of the size of the warrants bubble

This table includes the regression results of daily warrant closing prices on TURNOVER (daily warrant turnover) in column (1), on VOL (5min warrant return volatility) in column (2), on FLOAT (the total number of warrants outstanding, in billions) in column (3), and on TURNOVER, VOL, and FLOAT together in column (4). The regressions use the zero-fundamental sample (defined as Black-Scholes value less than 0.0005, half of the minimum trading tick) and include warrant maturity fixed effect. The t-statistics, in the parentheses, are adjusted for heteroskedasticity and correlation within a trading day.

	(1)	(2)	(3)	(4)
TURNOVER	0.201			0.158
(t-stat)	(8.97)			(5.39)
VOL		21.17		14.24
(t-stat)		(5.33)		(2.95)
FLOAT			-0.302	-0.324
(t-stat)			(12.61)	(12.28)

Table 6. Issuance

Panel A shows, for each warrant on the Shanghai stock exchange, the time-series average and maximum of BROKERAGEISSUE (net total warrant issued by brokerage firms) in the zero-fundamental sample period. BROKERAGEISSUE on day t = BROKERAGEISSUE on day (t-1) + number of warrants issued on day t – number of warrants cancelled on day t. The zero fundamental sample includes those trading days when a warrant's Black-Scholes value at the end of trading day is less than 0.0005 Yuan (half of the minimum trading tick). For comparison, Panel A shows FIRMISSUE (which denotes the total amount of warrants issued by the underlying firm from Table 1). FIRMISSUE remained constant throughout the sample. The sum of FIRMISSUE and BROKERAGEISSUE is FLOAT in Table 5. Panel B includes the regression results of daily warrant closing prices on FIRMISSUE and BROKERAGEISSUE, with and without controlling for TURNOVER (daily warrant turnover) and VOL (5min warrant return volatility). The regressions in Panel B use the zero-fundamental sample and include warrant maturity fixed effect. FIRMISSUE and BROKERAGEISSUE are in billions in the regressions. The t-statistics, in the parentheses, are adjusted for heteroskedasticity and correlation within a trading day.

Panel A. Net total warrant issuance by brokerage firms during the zero-fundamental sample period

		BROKERAGEISSUE (millions)		FIRMISSUE
Ticker	Name	Avg	Max	(millions, from Table 1)
580999	WuGang	0	0	474
580998	JiChang	35	42	240
580994	YuanShui	80	81	280
580996	HuChang	18	25	568
580995	BaoGang	119	119	715
580993	WanHua	101	104	85
580991	HaiEr	158	160	607
580992	YaGe	94	99	635
580990	MaoTai	331	334	432
580997	ZhaoHang	1276	4292	2241

Panel B. Issuance and the size of the warrants bubble

	(1)	(2)
FIRMISSUE	-1.306	-1.266
(t-stat)	(24.93)	(23.45)
BROKERAGEISSUE	0.498	0.421
(t-stat)	(15.78)	(12.59)
TURNOVER		0.103
(t-stat)		(3.70)
VOL		14.46
(t-stat)		(3.11)

Table 7. Feedback dynamics

This table shows the regression results of RET/ΔTURNOVER/ΔVOL on lagged RET, RET+, ΔTURNOVER, and ΔVOL. RET is warrant return, RET+=max(0,RET), ΔTURNOVER is proportional change in warrant turnover, ΔVOL is proportional change in warrant volatility (measured from 1min return). The regressions use the zero-fundamental sample (defined as Black-Scholes value less than 0.0005, half of the minimum tick). The regressions include warrant fixed effect and maturity fixed effect. The sampling frequency goes from 1 minute to 1 day. The t-statistics are adjusted for heteroskedasticity and correlation within trading day.

Panel A. RET

Sampling frequency	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Lag RET	0.016	0.134	0.176	-0.043	-0.052	0.069	-0.077
	(0.47)	(2.29)	(2.61)	(0.41)	(0.40)	(0.51)	(0.53)
Lag RET +	0.063	-0.099	-0.106	0.166	0.172	-0.175	0.215
	(1.09)	(1.21)	(1.07)	(1.29)	(1.16)	(0.95)	(1.18)
Lag ΔTURNOVER	-0.000	0.000	-0.001	-0.001	0.004	-0.006	-0.013
	(0.73)	(0.68)	(1.71)	(0.77)	(0.61)	(0.83)	(1.90)
Lag ΔVOL			0.001	-0.001	0.001	-0.005	0.010
			(2.13)	(1.01)	(0.69)	(0.54)	(0.90)

Panel B. ΔTURNOVER

Sampling frequency	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Lag RET	0.933	1.168	0.995	1.250	1.189	0.234	-0.435
	(2.07)	(3.47)	(4.60)	(4.53)	(4.20)	(0.69)	(0.86)
Lag RET +	-1.693	-1.419	-0.892	-1.373	-1.743	-0.182	0.867
	(2.38)	(2.16)	(3.17)	(3.88)	(4.78)	(0.54)	(1.31)
Lag ΔTURNOVER	-0.113	-0.145	-0.197	-0.175	-0.203	-0.180	-0.107
	(13.05)	(9.61)	(23.99)	(12.52)	(8.31)	(3.78)	(2.53)
Lag ΔVOL			0.006	0.008	0.042	0.010	-0.102
			(1.07)	(1.58)	(7.94)	(0.16)	(1.29)

Panel C. ΔVOL

Sampling frequency	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Lag RET			0.571	0.635	0.931	-0.061	-0.306
			(1.14)	(2.07)	(2.90)	(0.18)	(0.53)
Lag RET +			-0.155	-0.265	-1.246	0.185	0.516
			(0.22)	(0.48)	(2.09)	(0.44)	(0.81)
Lag ΔTURNOVER			-0.036	-0.046	-0.057	0.003	-0.002
			(1.24)	(1.19)	(1.05)	(0.12)	(0.09)
Lag ΔVOL			-0.175	-0.091	-0.064	-0.196	-0.158
			(2.65)	(2.27)	(5.80)	(5.30)	(2.33)

Table 8. Momentum profits

This table shows the ex-post returns of warrant portfolios sorted on lagged returns for warrants with the same number of trading days remaining during the zero-fundamental sample (defined as Black-Scholes value less than 0.0005, half of the minimum trading tick). Ex-post returns are reported for warrants whose lagged returns are above/below median (panel A), in the top/bottom quartiles (panel B), and positive/negative (panel C). In panel C, those sorts when all lagged returns are positive/negative are excluded. The return horizon ranges from 1 minute to 1day. The t-statistics are adjusted for heteroskedasticity and correlation within trading day.

Panel A. Return of portfolios sorted on lagged return (top half vs. bottom half)

Return horizon	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Winner	0.0001	-0.0005	-0.0001	-0.0012	-0.0026	-0.0031	-0.0058
(Top half)	(2.77)	(1.95)	(0.13)	(0.74)	(0.96)	(0.67)	(0.68)
Loser	-0.0003	-0.0004	-0.0015	-0.0029	-0.0057	-0.0108	-0.0178
(Bottom half)	(3.59)	(1.32)	(2.80)	(2.39)	(2.44)	(2.67)	(2.36)

Panel B. Return of portfolios sorted on lagged return (top quartile vs. bottom quartile)

Return horizon	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Winner	0.0002	-0.0004	0.0002	-0.0006	-0.0011	-0.0019	-0.0046
(Top quartile)	(2.85)	(1.72)	(0.28)	(0.30)	(0.38)	(0.40)	(0.50)
Loser	-0.0002	-0.0003	-0.0017	-0.0033	-0.0059	-0.0085	-0.0146
(Bottom quartile)	(3.07)	(1.03)	(3.27)	(2.72)	(2.60)	(1.95)	(1.58)

Panel C. Return of portfolios sorted on lagged return (positive vs. negative lagged return)

Return horizon	1 min	5 min	10 min	30 min	1 hour	2 hour	1 day
Winner	0.0002	-0.0005	-0.0005	-0.0007	-0.0023	-0.0037	-0.0130
(Positive return)	(2.56)	(2.54)	(0.76)	(0.36)	(0.74)	(0.70)	(1.30)
Loser	-0.0003	-0.0005	-0.0017	-0.0034	-0.0072	-0.0118	-0.0199
(Negative return)	(3.54)	(1.38)	(2.61)	(2.19)	(2.84)	(2.69)	(2.02)