The Impact of Information Uncertainty and Asymmetry on IPO Underpricing

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Abstract. We employ an option pricing framework to extend the winner's curse model developed by Rock (1986) and Beatty and Ritter (1986). We allow the true IPO value to follow a continuous time process and use an option pricing approach to calculate its offer price. In our framework, the uncertainty of information and the time elapsed between the initial offering and the listing of the stock are positively related to the underpricing of the issue. These relationships are confirmed by analyzing a dataset of Chinese fixed-price offerings for the period 1993-2002. On the basis of the estimated level of informed demand it is shown that actual underpricing levels are consistent with very high levels of information asymmetry.

EFM classification: 230, 350

Keywords: IPOs, winner's curse, underpricing

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Introduction

Research on Initial Public Offerings (IPOs) has long attracted the interest of academics and practitioners. Starting with Logue (1973) and Ibbotson (1975), several empirical studies have shown that shares are sold on the first day of trading at a significantly lower price compared to their issue price. For example, Ritter and Welch (2002) examined 6,249 IPOs that took place in the US between 1980 to 2001 and found that the average first day return, defined as the percentage difference between the initial offer price and the closing market price on the first day of trading, was 18.8%. Ljungqvist *et al*. (2000) analyzed 2,051 IPOs by issuers outside the US and found a similar level of average underpricing around 20%. Loughran *et al*. (1994) confirmed the IPO underpricing phenomenon in 25 countries and found that issues in more developed markets of their sample tended to exhibit lower levels of underpricing. This strikingly consistent empirical pattern has inspired a large literature seeking to explain theoretically and validate empirically why IPOs are underpriced in various stock markets.

The present paper focuses on the fixed price mechanism of going public in the context of the winner's curse model of asymmetric information developed by Rock (1986). In this model underpricing compensates uniformed investors for being relatively more rationed when good shares are issued rather than when bad shares are issued. When good shares are issued and there are informed investors in the market who are able to identify the quality of the issue and therefore submit more or bigger orders, uninformed investors will be allocated proportionately less shares. When bad shares are issued, the demand of informed investors will be much lower (or even zero) and uninformed investors will get most or all of the shares, hence the winner's curse. Beatty and Ritter

(1986), have shown that the greater the *ex ante* uncertainty about the true value of the shares, the greater the expected level of underpricing. The main hypotheses of the winner's curse model are as follows. First, uninformed investors earn zero initial returns after adjusting for rationing while informed investors gain conditional returns that just cover their costs of becoming informed. Second, underpricing is lower as information homogeneity among investors increases. Third, the expected underpricing increases with the *ex ante* uncertainty. The third hypothesis has received the most empirical support and attention, since it is easier to test than the other two and is a central premise of most asymmetric information models.

Research so far has clearly demonstrated that under conditions of uncertainty and rationing, the optimal offer price deviates from the expected terminal value of the share at the end of the first trading day. However, no pricing model has yet been developed linking explicitly the expected underpricing level with the specific characteristics of the issue. Thus, the first main contribution of this paper is to extend the asymmetric information model developed by Rock (1986) and Beatty and Ritter (1986) and derive a pricing formula that is able to yield the expected level of underpricing. More specifically, the model is extended in three main ways. First, we link the expected level of underpricing with the *ex ante* uncertainty over the true price of the issue, and this is measured by the daily volatility of the price during the period between the offering and listing. Of course, this is not an observable measure since the stock has not begun trading yet. Following Ritter (1984, 1987), among others, we employ the *ex-post* volatility as a proxy for the *ex ante* volatility.

Second, we account for the dynamics of information uncertainty over the unusually long time that elapses between when the offer price for Chinese IPOs is set and the first trading day. In our model, this time is a parameter that is allowed to vary across issues and to affect the optimal underpricing level. As the time period increases so does the level of information that might accrue and the more likely it is that unfavorable news regarding the issue may be released. Using a different approach, a similar argument regarding the time lag between offering and listing was been made by Chowdhry and Sherman (1996). However, their argument is based on the fact that extensions in the time lag are associated with a higher likelihood of information leakage and therefore greater underpricing is necessary. In this manner, the time period is a proxy for the extent of information leakage and does not affect underpricing directly while in our model the time period enters explicitly in the pricing formula.

Third, we allow the true value of an IPO issue to follow a continuous time process and employ the Black-Scholes option pricing formula to compute the expected underpricing level. This framework is consistent with the main premise of the winner's curse model that the expected level of underpricing is positively related to the proportion of informed investors. Informed investors invest in IPOs according to the probability that the IPO after-market price will increase beyond the offer price. Thus, we expect the level of informed trading to be higher in IPOs with greater underpricing.

We collect a unique dataset on 956 fixed-price IPOs from the Chinese stock market for the period 1993-2002 to test the empirical validity of the proposed model. This is the second main contribution of the paper. China has attracted much attention recently in the empirical literature due to the growth of this market. Moreover, exceedingly high levels of average underpricing have been found by various studies in this market ranging between 178% and 948.6% (see Mok and Hui, 1998; Su and Fleisher, 1999; Chan *et al*., 2004). It must be noted that these are much higher than those reported for other developing markets (e.g., Aggarwal *et al.*, 1993, found an abnormal return of 78.5% for Brazil while Kim *et al.*, 1995, estimated the abnormal return at 57.56% for IPOs from Korea). Another advantage of using Chinese data is that IPOs in this market have a relatively large time lag between offering and listing (see Su and Fleisher, 1999; Mok and Hui, 1998). This means that the relationship between time lag and underpricing may be easier to uncover. Indeed, Mok and Hui (1998) and Chan *et al.* (2004) have reported a positive such empirical relationship on a descriptive basis without any theoretical justification.

Our results lend support to the empirical validity of the proposed model since we find that higher stock price volatility and longer time periods between offering and trading lead to higher levels of underpricing. Our model also allows us to estimate the implied level of informed demand at different underpricing levels which is found at around 70% when a 5-day proxy for volatility is used. Finally, we also examine the intertemporal underpricing of Chinese IPOs. The main result is that in periods of higher uncertainty, as the Asian crisis and the internet bubble, underpricing tends to increase mainly due to an increase in volatility. Moreover, a weak growth in informed demand of around 0.82% per annum is observed which has risen from around 68.2% in 1993 to 77.3% in 2002.

1. Theories of Underpricing and Testable Hypotheses

This section contains a brief discussion of the main theories that have been proposed to explain IPO underpricing (for a comprehensive treatment see Ritter and Welch, 2002) under various market settings. There are three main mechanisms for going public, namely, fixed-price offering, bookbuilding and auctions. According to the first, which used to be the most common practice in Europe, the offer price of the IPO is set prior to the submission of requests for shares. In the case of excess demand, shares are rationed on a pro rata or lottery basis.

Alternatively, other practices seek to assess market conditions before pricing. In bookbuilding, typically used in the USA, the underwriter conducts road shows and solicits indications of interest from investors. Information garnered during the registration period also affects the offer price. Negative information and public data about a company are typically fully incorporated into the offer price whereas private information is only partially accounted for. In general, the more information that is uncovered during the roadshow and built into the offering price, the more accurate that price will be. The initial prospectus issued includes only a suggestive offer price range while the final price may or may not remain in this range depending on investor feedback during the price discovery process (Ritter, 1987; Hanley, 1993).

Although bookbuilding methods have the obvious attraction of conditioning the final issue price on market demand conditions, fixed-price methods were predominant outside the USA before the 1990s. Over the last decade bookbuilding has been introduced around the world and indeed, in many countries, is now established as the default mechanism for conducting an IPO (e.g., see Ritter, 2003). Germany, for example, used the bookbuilding method in over 90% of IPOs that took place between January 1992 and July 1999, whereas over 80% of UK offerings in the same period used fixed-price mechanisms (Ljungqvist *et al*., 2000). The direct costs of bookbuilding have been found to be twice as high as those in fixed-price offerings (Ljungqvist *et al*., 2000) but it has lower indirect costs associated with underpricing (Loughran *et al*., 1994; Ljungqvist *et al*., 2000).

Finally, in auctions, a market-clearing price is set, i.e., the price which equalizes demand and supply. The main difference between auctions and the other two mechanisms of going public is that the offer price in auctions is actually determined by investors who submit bids rather than by the issuing firm. The issuing firm at the time the price is set is only partially or not at all aware of the investors' interest in the issue. The most significant implication of the above is that once the issuing firm and the investment bank set the offering price, any excess demand for the issue creates a situation of quantity rationing, rather than further adjustment of the offering price.

Several theories have been put forward to explain underpricing. One way of classifying them is based on whether asymmetric or symmetric information is assumed. In the former category, we have signaling theories, the winner's curse model and information revelation theories. Examples of theories based on symmetric information include those that emphasize the institutional environment or corporate control motives, as well as behavioral theories.

If the issuer is more informed than investors, then underpricing occurs because good quality issuers set deliberately a lower price to signal their quality (see Welch, 1989). Thus, they are willing to sacrifice some of the IPO proceeds with the expectation of recouping them later in future issuing activity. If investors are more informed than the issuer, then the winners' curse problem (Rock, 1986; Beatty and Ritter, 1986) or theories of informational cascades have been used to explain underpricing (Welch, 1992). In an informational cascade, investors attempt to judge the interest of other investors. Benveniste and Spindt (1989) model the bookbuilding process and argue that IPOs should be deliberately underpriced to reward investors for accurately revealing information during the pre-selling period.

At this point it is necessary to emphasize the difference in the drivers of underpricing in the fixed-price and the bookbuilding methods. Both methods require that money be left on the table for investors in the form of underpricing. However, underpricing is needed for different reasons in each case. In fixed price offerings, underpricing is needed in order to compensate the uninformed investors for the winner's curse they face as informed investors crowd them out of good IPOs (Rock, 1986). By contrast, the winner's curse is not a concern in bookbuilding, since the underwriter solicits investor information prior to price setting. Nevertheless, a discount is still required to reward investors for surrendering information (Benveniste and Spindt, 1989).

Underpricing compensates uniformed investors for being relatively more rationed when good shares are issued rather than when bad shares are issued in Rock's (1986) winner's curse model. When good shares are issued and there are informed investors in the market who are able to identify the quality of the issue and therefore submit more orders, uninformed investors will be allocated proportionately less shares. However, if bad shares are issued, the demand of informed investors will be much lower and uninformed investors will get most or all of these shares. Beatty and Ritter (1986) have shown that the expected level of underpricing increases with the magnitude of *ex ante* uncertainty about the true value of the shares.

Several studies have attempted to test some key aspects of the winner's curse model. Koh and Walter (1989) assume information rationing and find that an uninformed strategy in Singapore indeed just about broke even. More recently, Coakley *et a*l. (2007) show that allocation weighting in Chinese IPOs causes a dramatic drop in initial abnormal returns leading to a median return of only 0.51% for uninformed investors participating in all IPOs. Whether the conditional underpricing return of informed investors just covers the cost of information gathering is hard to test in the absence of data on the cost of becoming informed. In line with the implication that underpricing decreases as information becomes more homogeneous across investors, Michaely and Shaw (1994) show that underpricing tends to be lower for IPOs that do not include Master Limited partnerships. The reason is that that institutional investors who are considered to be more informed tend to avoid MLPs IPOs for tax reasons and thus, investors are more homogeneous.

A large number of studies has investigated if there exists a significant positive relationship between *ex ante* uncertainty and the level of underpricing. The various proxies for uncertainty that have been used in the literature fall into three main groups: a) company characteristics, such as the age of the firm at the time of offering (e.g., Ritter, 1984, 1991; Megginson and Weiss, 1991) or measures of the firm size such as log sales (e.g., Ritter, 1984), b) offer characteristics, such as the number of uses of IPO proceeds (e.g., Beatty and Ritter, 1986) or the number of risk factors as disclosed in the prospectus (e.g., Beatty and Welch, 1996; Ljungqvist and Wilhelm, 2003), the size of offering (e.g., Su, 2004), and, c) aftermarket variables, such as trading volume (Miller and Reilly, 1987) or volatility (e.g., Ritter, 1984, 1987; Coakley *et al*., 2007). The problem with using aftermarket variables is that they rely on information that was not available at the time the IPO was priced.

2. The Asymmetric Information Model of Underpricing Revisited

The model adopted in this paper is an extension of the one originally developed by Rock (1986). In this framework, the issuing firm sets an offer price (*OP*) for a specific amount of shares (*n*) and then asks for orders from the public. Given that both the price and quantity of the shares issued are fixed at the time the offer is made, demand at the end of the offering can exceed supply. In this case, only a fraction of the orders will be filled meaning that the probability of receiving an allocation of the IPO may be less than one. Moreover, it is assumed that allocations are done on a lottery basis. Under this rationing mechanism the probability of obtaining an allocation of the IPO is independent of the order size.

As in Rock (1986), it is assumed that oversubscription results from the participation in the IPO of the informed investors who have favorable information about the offering. Compared to uninformed investors, informed investors can be viewed as individuals that are skilful in assimilating information. The release of good news regarding the prospects of the offering results in a greater number of informed investors and hence, lowers the probability of an order being filled. As informed investors do not participate in "bad" issues, the probability of an order being filled given that the issue is a bad one is greater than the probability of an order being filled given that the issue is a good one. The main intuition of the model developed by Rock is that underpricing compensates uninformed investors for this bias in the probability of receiving an allocation of an IPO.

Some additional assumptions are necessary before we proceed:

i. There is uncertainty about the true value of the share, which reflects the uncertainty over the flow of information. Each share is worth P_t which follows a stochastic process, in our case Geometric Brownian Motion (GBM).

ii. The number of informed and uninformed investors in the market is I and N, respectively.

iii. The time period between when the *OP* is set and trading begins is denoted by T.

iv. Informed investors have perfect information about P_t. They place their orders only if they expect a positive return, i.e., only if P_t exceeds *OP*.

v. The informed investors place orders to the full extent of their wealth (equal to 1), thus informed demand is I.

vi. The uninformed investors cannot condition their demand on P_t and therefore participate indiscriminately in all IPOs. Moreover, each uninformed investor submits the same fraction of his wealth T for a new issue.

As in Rock, we let the probability of a good (bad) order being filled be denoted by b (b'):

$$b = \min\left(\frac{OPn}{nT + I}, 1\right) \tag{1}$$

$$b' = \min\left(\frac{OPn}{nT}, 1\right) \tag{2}$$

The smallest probability an uninformed investor will tolerate before withdrawing from the IPO is found by assuming that the expected profit of uninformed investors is equal to zero:

$$E(\Pi_U) = e^{-rT}\left(b'(NT)p(P_T < OP)E(P_T - OP \mid P_T < OP) + b(NT)p(P_T > OP)E(P_T - OP \mid P_T > OP)\right) \quad (3)$$

or,

$$E(\Pi_U) = e^{-rT}\left(b'(NT)\int_0^{OP}(P_T - OP)f(P_T)dP_T + b(NT)\int_{OP}^{\infty}(P_T - OP)f(P_T)dP_T\right) \quad (4)$$

Assuming that bad shares are not rationed, i.e., *b*’ = 1, yields:

$$\int_0^{OP}(P_T - OP)f(P_T)dP_T + b\int_{OP}^{\infty}(P_T - OP)f(P_T)dP_T = 0 \quad (5)$$

or,

$$b_0 = \frac{\int_0^{OP}(OP - P_T)f(P_T)dP_T}{\int_{OP}^{\infty}(P_T - OP)f(P_T)dP_T} \quad (6)$$

The issuer on the other hand wants to set the offer price which maximizes the proceeds from the IPO, $OP \cdot n$, ensuring however that the issue will be fully subscribed in every state of the world. Therefore, the full subscription price is the price which sets total uninformed demand equal to the market value of the issue:

$$OP_f n = NT \quad (7)$$

In this manner we have,

$$b = \frac{OPn}{OPn + I} \tag{8}$$

Therefore, the full subscription price is the solution of:

$$\frac{OPn}{OPn + I} = \frac{\int_0^{OP} (OP - P_T) f(P_T) dP_T}{\int_{OP}^{\infty} (P_T - OP) f(P_T) dP_T} \tag{9}$$

We can also obtain:

$$E(P_T) - OP_f = \frac{I}{U} \int_0^{OP} (OP - P_T) f(P_T) dP \tag{10}$$

where $U = OP_f n$. The integral in this equation is the future price of a put option, *P*, with underlying asset the true price of the share, strike price *OP* and time to maturity *T*. Denoting the ratio of informed to total demand by *a*, we obtain:

$$E(P_T) - OP = \frac{a}{1 - a} e^{rT} P \tag{11}$$

where $a = \frac{I}{I + U}$. Under put-call parity we have $P + OPe^{-rT} = C + E(P_T)e^{-rT}$. Substituting in equation (11) for the price of the put option, *P*, we obtain:

$$E(P_T) - OP = ae^{rT} C \tag{12}$$

Allowing for the true price of the share to follow a GBM, the Black-Scholes formula can be used to compute the call option price:

$$C = P_0 N(d_1) - OPe^{-rT} N(d_2) \tag{13}$$

where

$$d_1 = \frac{\ln\left(P_0/OP\right) + \left(r + \sigma^2/2\right)T}{\sigma\sqrt{T}}$$
$$d_2 = \frac{\ln\left(P_0/OP\right) + \left(r - \sigma^2/2\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

$N(x)$ is the cumulative probability distribution function for a variable that is normally distributed with a mean of zero and a unitary standard deviation. The level of underpricing can now be calculated as:

$$UP = \frac{P_T - OP}{OP} \tag{14}$$

From equations (12), (13) and (14), we obtain:

$$\begin{aligned} UP &= a\left[(UP+1)N(d_1) - N(d_2)\right] \\ d_1 &= \frac{\ln\left((1+UP)e^{-rT}\right) + \left(r + \sigma^2/2\right)T}{\sigma\sqrt{T}} \\ d_2 &= d_1 - \sigma\sqrt{T} \end{aligned} \tag{15}$$

Therefore, solving equation (15) yields the optimal underpricing level. Note that both the volatility of the true price of the issue and the time lag between offering and trading are used to determine the optimal IPO underpricing level. If the firm wishes to attract a particular level of informed demand, then given the expected volatility and *T*, the optimal underpricing is given by (15).

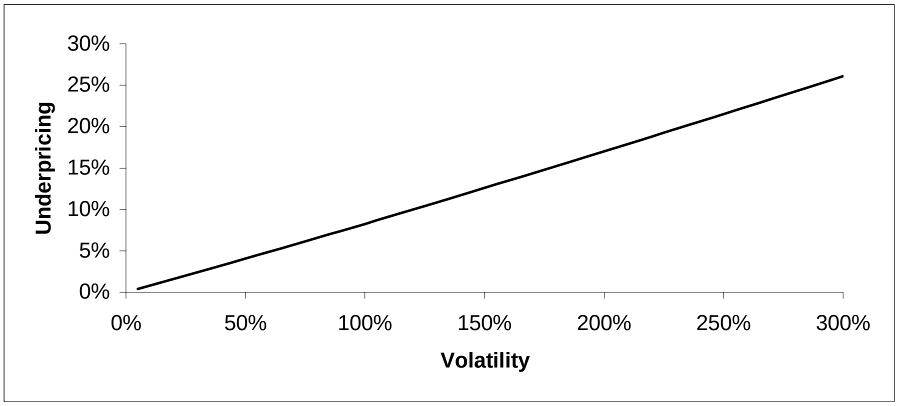
3. Comparative Statics

It is well known in the option-pricing literature that the value of an option increases with the uncertainty over the true price of the share and with the time to maturity, respectively. In the case where there is no uncertainty, or, when *T* goes to zero, the value of the option goes to zero and hence the offer price becomes equal to the true price of the share at the time when the offering price is set. In other words, if there is no uncertainty about future information, or, if there are no informed investors in the market, then the offer price should coincide with the initial true price of the share. Thus, the level of underpricing has the following properties:

$$\frac{d(UP)}{da} > 0, \frac{d(UP)}{d\sigma} > 0, \frac{d(UP)}{dT} > 0$$

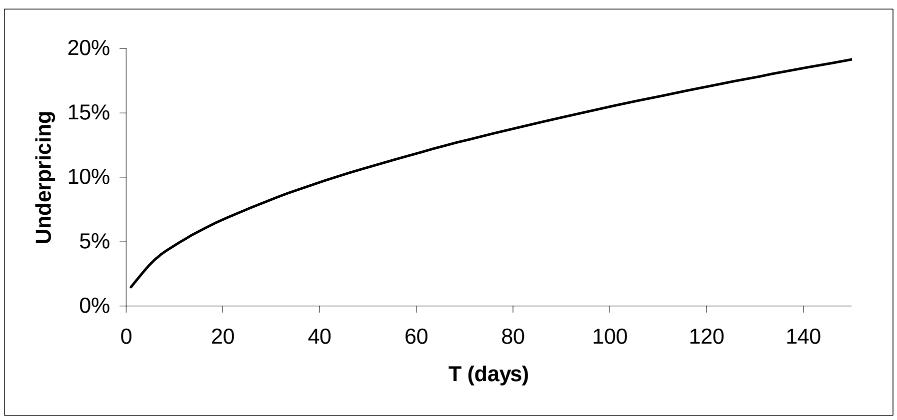
The remainder of this section will demonstrate some comparative statics of the model. As shown in an example depicted in Figures 1, 2 and 3 the optimal level of underpricing increases with the level of uncertainty, the time to maturity and the level of informed demand, respectively. Moreover, as shown in Figure 3, up to a particular level of informed demand, in our example around 80%, underpricing increases almost linearly with informed demand. However, further increases in informed demand lead to abrupt increases in the level of underpricing with the effect being highly non-linear.

Figure 1. Optimal underpricing as a function of annualised volatility



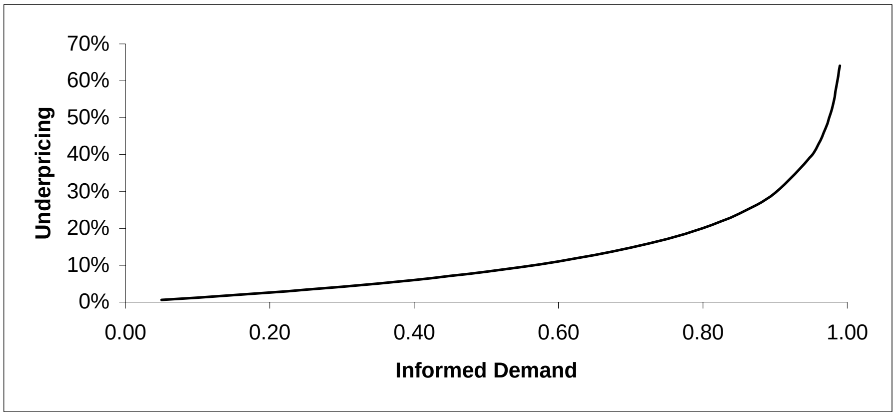
The calculations assume annual risk-free rate 3%, time to maturity 30 days and informed demand 0.5 of the total demand.

Figure 2. Optimal underpricing as a function of the time to maturity



The calculations assume annual risk-free rate 3%, annual volatility 100% and informed demand 0.5 of the total demand.

Figure 3. Optimal Underpricing as a function of the level of informed demand



The calculations assume annual risk-free rate 3%, annual volatility 100% and time to maturity 30 days.

4. Empirical Results

Our initial sample contains 1,160 IPOs for A-share issues from the period 1993-2002. A-shares are traded in domestic currency and are intended exclusively for domestic investors. Out of the 1,160 IPOs, 1,121 were issued through a fixed-price mechanism. The other 39 were issued through bookbuilding and are thus excluded from the analysis. Finally, we exclude 158 IPOs whose price was set by the authorities resulting in an extremely high degree of underpricing, or around 1,160% on average. We also eliminate 7 issues as outliers which had abnormal initial returns over 550%. The final sample thus consists of 956 IPOs.

Before proceeding with the analysis, we first define underpricing since two main definitions exist in the literature. According to the first, underpricing is the percentage difference between the first-day closing price and the offer price. This can be obtained by our theoretical model and is referred to hereafter as the underpricing level. According to the second definition, it is the initial return in excess of the corresponding market return.

As in Coakley *et al*. (2007), we call this initial excess or abnormal return. This approach, widely adopted in the IPOs literature, assumes that all firms have the same systematic risk as the market portfolio. The returns according to each definition can be calculated as:

Underpricing level:

$$UP_j(\%) = \left(\frac{p_{j,1}}{OP} - 1 \right) \times 100\% \qquad (16)$$

Initial excess return:

$$IR_j = \left(\frac{p_{j,1}}{OP} - \frac{p_{m,1}}{p_{m,0}} \right) \times 100\% \qquad (17)$$

where $p_{j,1}$ is the closing price of the new issue *j* on the first trading day and $p_{m,0}$ and $p_{m,1}$ are the market index on the offer date and first trading date, respectively.

Figure 4 shows the distribution of initial excess returns for the issues in our sample. Two points are of particular interest. Firstly, only 7 issues have negative excess initial returns and this is consistent with the extant studies of Chinese IPOs. Secondly, it is evident that returns are skewed to the right which reflects the presence of a number of highly underpriced issues.

Figure 4. The distribution of the initial excess return in Chinese IPOs.

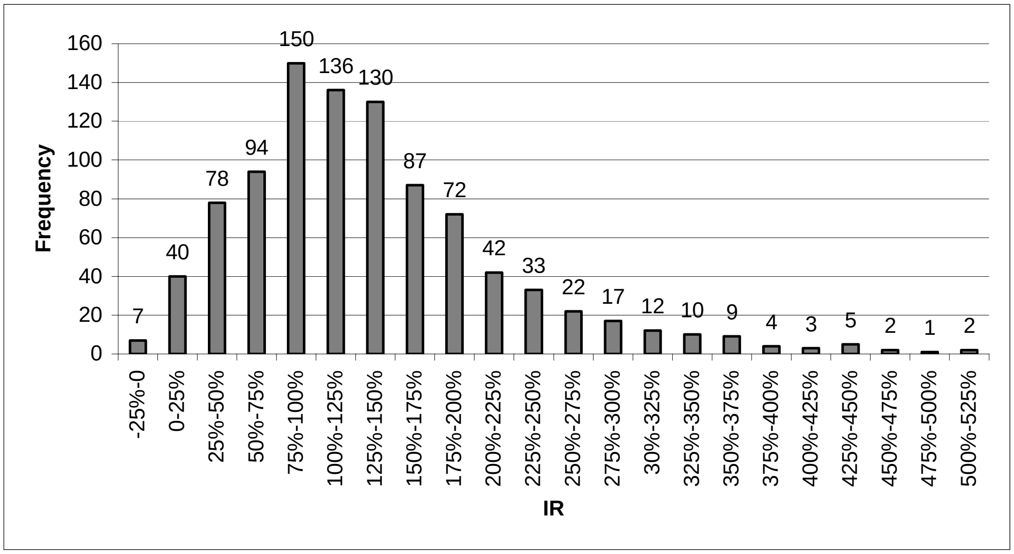


Table 1 provides descriptive statistics on the level of underpricing and initial excess returns.

Table 1. Descriptive Statistics of IPO underpricing

Variable	Mean	Median	Standard deviation	Minimum	Maximum
UP	135.37%	121.69%	85.65%	-15.31%	519.05%
IR	134.25%	120.26%	84.19%	-18.35%	515.68%

In order to test our model we examine whether the level of underpricing is positively related to the stock price volatility ($stdev_j$) and time lag (T_j) between offering and trading for each issue, respectively. The volatility *stdev* is defined as the standard deviation of the five aftermarket daily logarithmic returns. This variable is used as a proxy of the *ex ante* uncertainty over the true value of the issue. The return on day *j* is defined as $R_j = \ln\left(p_j / p_{j-1}\right)$ and in order to calculate the return on day 1, we take $p_0 = OPe^{\mu(T-1)}$, where μ is the average daily equity premium for that period of 0.13% (Su and Fleisher, 1997).

This last expression gives the expected price on the day before the first trading day and it assumes that the stock price increases by an average rate of μ. Thus, the first day return is the percentage difference of the stock price on the first trading day from the expected stock price on the previous day. Compared to other measures of standard deviation that have been used in the literature, the one employed here has the advantage of incorporating the uncertainty before trading commences. The descriptive statistics for the volatility and time lag are given in Table 2.

Table 2. Descriptive statistics for the explanatory variables of underpricing

Variable	Mean	Median	Standard deviation	Minimum	Maximum
Stdev	0.427	0.355	0.347	0.012	2.475
T	44.77	29	49.60	8	635

The effect that these two variables have on underpricing is then examined in a regression framework with underpricing as the dependent variable.

The following cross-section regression is estimated (*t*-statistics in brackets calculated using White's heteroskedasticity-consistent standard errors)**:**

$$UP_j = \underset{(17.965)}{1.042} + \underset{(4.553)}{0.529}\, stdev_j + \underset{(2.131)}{0.002}\, T_j + \varepsilon_j$$

Both variables are found to be significantly positively related to underpricing at better than the 5% level. While the coefficient on volatility is also significant in economics terms (it exceeds its mean level), that on time elapsed is extremely small. A relatively low value of R^2 = 5.8% indicates that the actual return on an offering is only partially predictable on the basis of the volatility and time lag and is likely affected by other, possibly unsystematic variables. Note however that the low R^2 value is consistent with Beatty and Ritter (1986) who point out that the theory predicts a relationship between ex ante uncertainty and expected rather than actual initial return.

We calculate the level of informed demand for those IPOs with positive underpricing, a total of 953, by applying equation (15). Figure 5 shows the distribution of informed demand for each one of the issues which has an average of around 70%. We observe a very high skewness to the right which suggests that most IPOs are underpriced with a high level of informed demand. As shown in Figure 6, this high level of informed demand occurs at very high degrees of underpricing.

Figure 5. Distribution of implied informed demand measures (*a*)

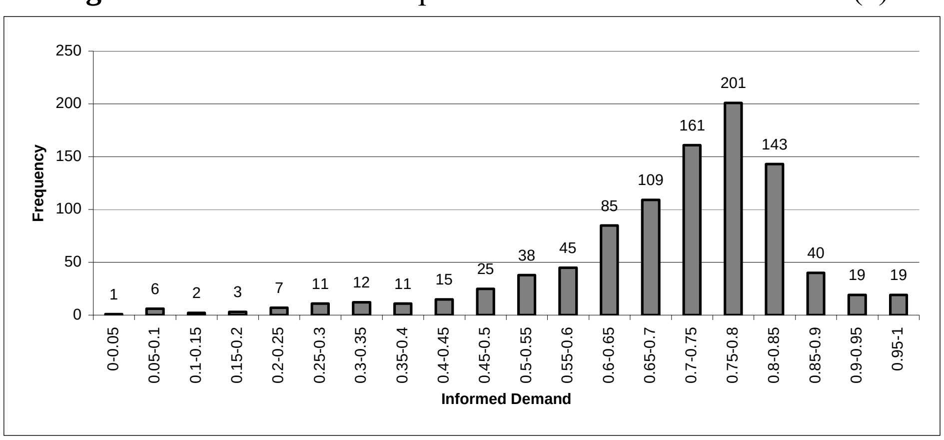
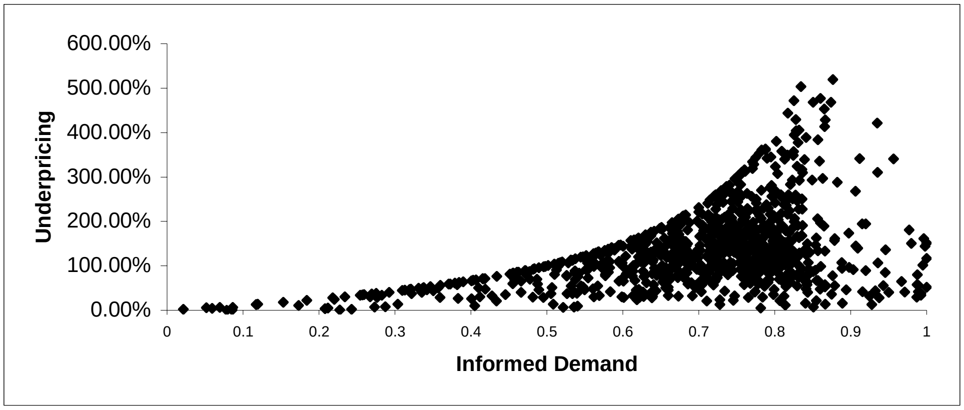


Figure 6. Relationship between informed demand and underpricing



The estimates of informed demand obtained when applying the model are biased upwards since the model gives the informed demand under the assumption that the offer price set is optimal, i.e., guaranteeing full subscription of the issue. However, there is evidence that in China IPOs are sold at a price much lower than the full subscription price, which explains the high levels of oversubscription (see Coakley *et al*., 2007). An interesting measure of informed demand has been proposed by Su (2004) as the sum of government shares, management and employee shares, and legal entity shares divided by total shares. In an empirical analysis of 587 firm commitment offerings in China held between 1994 and 1999, Su (2004) found an average initial abnormal return of 128.2% and an average level of informed demand of 35.7%. The standard deviation, minimum and maximum of the informed demand were estimated at 61.6%, 11.4% and 84.2%, respectively. Although these estimates are much smaller than those found in our study, it must be emphasised that the informed demand measure proposed by Su is clearly a lower bound since private investors may also be informed.

Finally, Table 3 shows for each year in the sample under study the averages with respect to the level of underpricing, the standard deviation, the time period between offering and trading and finally the computed level of informed demand, *a*. Volatility and underpricing both peak in 1997 and 2000 following the Asian crisis and the internet bubble, respectively. This pattern is consistent with the premise that, in periods of higher uncertainty firms tend to underprice more in order to avoid failure of the issue. Despite annual variations, a gradual increase in informed demand can be also observed from 68.2% in 1993 to 77.3% in 2002, implying an annual growth rate of 0.82%.

Table 3. Intertemporal variation in underpricing and model variables

Year	*UP*	*Stdev*	*T*	*a*	Issues
1993	193.13%	49.70%	85.02	0.682	65
1994	115.66%	35.69%	113.15	0.572	88
1995	105.08%	26.86%	66.30	0.689	10
1996	114.89%	38.01%	21.75	0.755	160
1997	149.21%	45.02%	24.03	0.752	190
1998	132.08%	42.50%	51.85	0.639	95
1999	108.94%	41.52%	58.79	0.626	97
2000	151.63%	48.08%	35.76	0.714	136
2001	141.23%	42.28%	32.12	0.702	66
2002	127.63%	44.12%	18.37	0.773	46
Total	**135.83%**	**42.71%**	**44.75**	**0.699**	**953**

5. Conclusions

This paper has extended the asymmetric information model developed Rock (1986) and Beatty and Ritter (1986). The proposed model uses an option pricing setting to calculate the optimal underpricing level, i.e., the level of underpricing which guarantees full subscription to the issue, with respect to the volatility of the true value of the issue, the time period between offering and trading and the level of informed demand. In an empirical application with 956 Chinese offerings between 1993 and 2002, we find conclusive evidence of a positive relationship between the level of underpricing, volatility and time lag. The model is also used in deriving an average degree of informed trading which is estimated at around 70%.

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