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International differences in oversubscription and underpricing of IPOs

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Abstract

We argue that when the offer price of an initial public offering (IPO) is set many days before the issue closes for bidding by investors, relevant price information leaks and becomes public knowledge before investors have finished bidding for firm's shares. Consequently, there are instances when all investors realize ex ante that the offer price is 'too low' and we observe a large oversubscription for the firm's shares, as well as instances when the investors realize that the offer price is 'too high' and the issue fails. If failure is costly, then the offering is underpriced in order to reduce the likelihood that the issue will fail. This is in addition to the underpricing, as suggested in Rock (1986), to compensate the uninformed investors for the adverse selection problem they face in the allocation of shares. Our argument thus explains why underpricing may be larger in situations when there is information leakage.

We further argue that if the issuer collects the interest float on checks deposited by investors for shares they bid, this interest revenue reduces the cost associated with underpricing and thus provides an incentive to underprice the issue further. Our analysis explains some stylized facts about differences in oversubscription and underpricing across countries and allows us to explore some empirical and policy implications. For instance, we show that the method used in the United Kingdom and in most Asian countries may lead to

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more underpricing and more extreme levels of oversubscription than the method used for firm commitment offerings in the United States.

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1. Introduction

It is now well documented – for instance in a comprehensive article, Loughran et al. (1994) (henceforth, LRR) [1] – that initial public offerings (IPOs) of common stock, for all 25 countries for which data are available, are underpriced. [2] LRR notes that the "degree of underpricing varies enormously across countries, however." What explains such a large variance in underpricing across countries? One might suspect, as suggested in LRR, that differences in contractual mechanisms employed across countries help explain differences in the degree of underpricing.

LRR notices that underpricing is smaller when the offer price is set after ascertaining information about the state of demand for a firm's shares. For instance, in the U.S., the offer price for firm commitment offers is "determined only at the pricing meeting, which usually occurs the day before the offer" (Ritter, 1987). In contrast, in many countries, such as Hong Kong, Singapore, Thailand and the United Kingdom (offer for sale), the offer price is set two weeks to two months in advance, before much information is collected about the demand for a firm's shares (see Table 1).

Larger underpricing for IPOs when the offer price is set well in advance of the consummation of the offering is consistent with the argument suggested in Rock (1986): uninformed investors face higher ex ante uncertainty and therefore need to be compensated more since they face higher adverse selection costs. However, larger underpricing in such a case should not necessarily lead to high level of oversubscription since uninformed investors expect only to break-even on average. But it has been observed that in many countries IPOs also are associated with extremely large levels of oversubscription. For instance, for a sample of 68 IPOs from 1986 to 1989 in the U.K., Brennan and Franks (1994) document that 40% of offers were oversubscribed more than 16 times with some as high as 50 times (see Table 2).

McGuinness (1992) documents similar oversubscription levels in Hong Kong for the period of 1980 to the beginning of 1990 (see Table 3).

[1] The article provides references for specific studies for different countries.

[2] The measure of underpricing we have in mind is the size of initial returns. In this paper we are not concerned with the long-run performance of IPOs that is discussed in Ritter (1991) and Section 4 of LRR.

Table 1

Elapsed time [a]	Discretionary allocation		Non-discretionary allocation	
	Underpricing	Country	Underpricing	Country
0 days	16%	Chile		
1 day	12%	US (firm commitment)	4%	France
			4%	Netherlands (tender)
			29%	Portugal (auctions)
			2%	UK (offer by tender)
2 days	8%	Belgium	11%	Belgium (tender)
5 days	15%	UK (placing)		
10 days	9%	Canada		
2 weeks	11%	Germany	11%	UK (offer for sale)
	15%	Japan (post-April 1, 1989)		
	42%	Japan (pre-April 1, 1989)		
1 month	12%	Australia	18%	Hong Kong
	78%	Brazil	27%	Singapore
	60%	Korea (post-June 1988)	45%	Taiwan
	36%	Switzerland		
2 months	36%	Sweden	135%	Portugal
	42%	US (best efforts)	58%	Thailand
3 months	55%	Finland	12%	Finland
	28%	Italy		

[a] 'Elapsed time' refers to the typical time period from the setting of the offer price to the issue date. *Source:* Loughran et al. (1994, Table 2).

Oversubscription rates of 200 to 300 times are not uncommon in many countries. In one issue in Hong Kong, Denway Investment, the offering was oversubscribed 657 times! [3] Such enormous oversubscription levels indicate that even uninformed investors, in such cases, are able to correctly guess that the offer price was 'too low'.

We argue that the phenomenon of extremely high levels of oversubscription can be understood by noticing that, under some contractual arrangements, there is a substantial information leakage about market demand that occurs after the offer price has been set and before the issue closes for bidding by investors. As a result, after the information leakage, investors (including the previously uninformed ones), sometimes realize that the offer price is 'too low'.

One implication of our argument is that, because of information leakage after the offer price has been set, not only is it more likely that extremely high levels of oversubscription will be but also that it is more likely that the offer will fail (i.e., the issuer is not able to sell all shares in the initial offering) – this happens when

[3] Securities Journal (1993).

Table 2

Level of underpricing (u)	Number of issues	Oversubscription (no. of times)
$u < 0$	20	0.49
$0 < u < 5\%$	11	6.84
$5\% < u < 10\%$	7	16.34
$10\% < u < 20\%$	17	18.55
$20\% < u < 30\%$	7	23.75
$30\% < u < 40\%$	3	50.59
$40\% < u < 50\%$	3	34.58

Source: Brennan and Franks (1994, Table 4).

Table 3

Year	No. of IPOs	Average subscription rate
1980	5	12.83
1981	12	5.03
1982	2	2.70
1983	4	9.72
1984	8	18.13
1985	4	17.24
1986	5	14.06
1987	15	52.83
1988	19	59.54
1989	5	16.52
1990	1	5.80

Source: McGuinness (1992, Table 1).

investors, after the information leakage, realize that the offer price is 'too high'. If failure of an offering is sufficiently costly for the firm, it may choose to underprice the issue to reduce the possibility of failure. [4] Thus we are also able to explain

[4] There seems to be no clear answer in the literature for why a failed offering is costly. If failure of an offering isn't costly, a mechanism employing a Dutch auction, for instance, may be optimal and there may not be a need for underpricing an IPO to ensure that it is fully subscribed. The literature on IPOs, nevertheless, seems to be sympathetic to the assumption that the failure of an offering is costly. Perhaps a loss of reputation associated with a failed offering or an attempt to prevent a negative cascade from starting (see Welch, 1992), can explain the costs associated with failure. We thank Jay Ritter for suggesting these reasons.

On the other hand, Sherman (1992) suggests that failure may be desirable in some cases. She shows that, if the market has information that the issuer does not have, then a best efforts offering has an advantage over a firm commitment offering, because it allows issuers to back out of bad projects after getting feedback through market demand. Nevertheless, the fact that more firms in the US choose firm commitment than best efforts offerings seems to indicate that the cost of failure, whatever it is, outweighs the advantage of market feedback.

why offerings in such scenarios may on average be underpriced more compared to situations in which there is little or no information leakage (keeping the underpricing due to the adverse selection cost faced by uninformed investors identical in the two cases).

There is an incentive to underprice IPOs further because of another distinct contractual mechanism. In the U.K. and in most Asian countries [5] investors are required to send in a check in advance for all shares for which they bid. [6] Only a fraction (if any) of the shares for which an investor bids may eventually be allocated to the investor, while the money for shares not allocated is then refunded to the investor. We argue that the interest earned on the subscription funds decreases the cost of underpricing. In most cases where investors pay in advance for their subscription, the issuer earns an interest float for one to two weeks on all money deposited with the bidding applications by investors. [7] In the case of very high oversubscriptions, this interest float can be a substantial part of the overall proceeds. Consider the following back-of-the-envelope calculation. If the annual interest is 5%, a two-week interest float on an offering that is oversubscribed 50 times yields roughly 10% of overall revenues in interest float alone! This creates an incentive to underprice the offering even more since part of the cost of underpricing is recovered in the form of interest revenues on the float.

The information leakage about market demand occurs in many ways. For instance, rumors spread about the number of applications that were picked up on any given day. Newspapers and news magazines often carry stories about investor sentiment towards a given issue. For instance, the day before the subscription period began in the already-mentioned Denway case, a newspaper claimed that ''New public offers Tackshin and Denway Investments are expected to steal the show, with some analysts predicting Tackshin to be oversubscribed 552 times and Denway Investments even higher'', while during the subscription period it reported that ''would-be shareholders... were dropping their forms into the box at quite a brisk rate in the old Bank of China Building yesterday morning''. [8]

One of the more important channels through which information about market

[5] When we refer to the UK method, we mean a UK Open Offer or Offer for Sale at a Fixed Price. Other methods available in the UK are an Offer for Subscription, an Offer for Sale by Tender, Placing and Introduction. The Asian countries requiring payment *in advance* include Australia, Hong Kong, India, Indonesia, Malaysia, Singapore and Thailand, among others.

[6] The average length of time between the setting of the offer price and the consummation of the offering in the best efforts type contracts in the U.S. is also about two months (see Table 1). But it is this feature, advance payment for all shares one is bidding for, that differentiates contractual arrangements for IPOs in these countries from the best-efforts type contracts in the U.S.

[7] See Woods (1993). The primary exception to this is Singapore, where investors usually must pay by a bank draft or cashier's check, but the issuer is not allowed to cash the checks and earn the interest.

[8] South China Morning Post (1993a) and South China Morning Post (1993b).

demand becomes public is as follows. In order to pay for large subscriptions, investors often borrow from banks. An article, Far Eastern Economic Review (1993) states:

''IPOs create a snowball effect in Hongkong [sic]. Once word gets out that an offer will be popular, investors are forced to apply for many more shares than they want and usually have to borrow money for the application.''

Information about the number of investors who apply for bank loans in order to apply for shares thus leaks out. The aggregate demand for loans related to the offering becomes public knowledge and 'word gets out' about whether or not the offering is attractive. In the case of the Denway offering mentioned earlier, it ''tied up funds equivalent to 40% of the colony's 1991 GDP, about 150% of the Hongkong [*sic*] dollar M1 money supply and nearly five times the amount of Hongkong [*sic*] banknote in circulation'' (Far Eastern Economic Review, 1993). Even small, uninformed investors may have access to the information from borrowing levels, since many banks adjust the interest rate and the required margin for IPO loans based on the popularity of the issue. During the subscription period for Denway, some banks were requiring a margin of only 5% for Denway loans while they required a minimum deposit of 20% for Kosonic, another offering at around the same time. [9]

In some cases the information leakage may be even greater. Hong Kong has grey markets for IPO shares that sometimes begin trading during or even before the subscription period (see Harrison, 1994, p. 273). [10] According to Harrison, because of these grey markets, ''it becomes apparent whether or not the stock is a good buy at the offer price. Consequently, issues tend to either flop or to be massively oversubscribed''.

Other reasons have been suggested in the literature for large oversubscription of IPOs. One is that firms face binding regulatory constraints on how high an offer price they are allowed to set. Indeed, in countries such as Malaysia, Korea (before the 1988 reforms) and (until 1992) India, such regulatory constraints were prevalent. Thus, if a binding regulatory constraint forces a firm to set an offer price that is 'too low', it will result in an extremely high level of oversubscription. However, that does not explain why extremely high oversubscription rates are observed even in countries such as the U.K. and Hong Kong, where no regulatory constraints restrict the level of offer price. [11]

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[9] South China Morning Post (1993c).

[10] Some countries (for example, Singapore) have grey or 'when issued' markets that begin trading shortly *after* the end of the subscription period; our argument is *not* about such information leakage that occurs after the subscription period is over.

[11] LRR, Table 2, Panels A–D, provides a list of countries without binding government regulations on offer price and Panel E provides a list of countries with binding government regulations.

Another reason, suggested in LRR and Brennan and Franks (1994) is that a small offer price and the consequent large oversubscription level may be because of a deliberate attempt by the issuing firm to create a widespread ownership of the firm. A large oversubscription for firm's shares allows the firm to achieve widespread ownership by engaging in a discriminatory allocation scheme that favors smaller investors. [12] LRR suggests that this could possibly be to create a more liquid market for the firm's shares. Brennan and Franks (1994) focus on corporate control issues to motivate this behavior.

However, one would imagine that liquidity and corporate control issues are perhaps important in all countries. The relative prevalence of extremely high oversubscription levels in countries such as the U.K. and Hong Kong and the relative absence of such high levels of subscription in countries such as the U.S. suggests to us that yet some other differences in the contractual arrangements across countries are key in understanding these patterns. [13] Moreover, hostile takeovers are virtually unheard of and often impossible in most Asian countries, since it is common for one person, family or corporation to own the majority of shares in the issuer. The 'free float' tends to be relatively small, and therefore corporate control is usually not an issue.

In the next section, we develop a model to formalize our intuition and to carefully derive its implications.

2. The model

Let NV denote the true value of the firm, where N denotes the total number of shares the firm wishes to issue. Let N_I be the number of informed investors and N_U be the number of uninformed investors in the market. For simplicity, we assume that all investors are risk-neutral. Following Rock (1986), we assume that the number of informed investors N_I is not enough to buy up all the N shares offered for sale and therefore the issue must be priced such that the uninformed investors are also induced to bid for the firm's shares. We assume that the uninformed investors, if they choose to bid at all, bid at least a minimum of one share each and that $N_U \geq N$ so that if the uninformed bid for the firm's shares, the issue will be fully subscribed.

The sequence of events is as follows.

[12] See Far Eastern Economic Review (1993).

[13] Jay Ritter has pointed out to us that it is not clear that underpricing is necessary to ensure a wide distribution of ownership. Closed-end funds are sold with no underpricing, and yet they are diffusely held. Marketing effort seems to be an alternative to underpricing as a means of generating demand.

• Date 0: The issuer sets the initial offer price P_0 given a prior distribution of V with mean $\overline{V}$ and variance σ_V^2.[14]

The informed investors receive a qualitative signal, 'Good' or 'Bad', about the value of the firm. Let $\theta(V)$ denote the fraction of the informed investors who receive the 'Good' signal as a function of the true value of the firm. We assume that the fraction of informed investors who receive the 'Good' signal is increasing in V, i.e., $\theta'(V) > 0$. This formulation captures the idea that the value of the firm, as is the case in Rock (1986), depends on the 'aggregate demand'. No informed investor knows this aggregate demand individually – he or she only observes a signal that is correlated with it – but together, all informed investors carry the relevant information about the aggregate demand.

• Date 1: All investors observe a signal, $X = V + \epsilon$, where ϵ is drawn from an independent distribution with mean 0 and variance σ_ϵ^2. Based on this signal they form a posterior distribution of V. This is a simple way of formalizing the intuition that some relevant information about aggregate demand becomes public knowledge and can now be observed by all investors. This could, as discussed in the introduction, happen by observing the demand for bank loans generated by the issue. It is reasonable to expect that investors will not be able to perfectly discern the information about aggregate demand. We capture this by assuming that investors only observe a noisy signal.

To simplify the analysis, we now assume that both V and ϵ are independently and Normally distributed. Under these assumptions the posterior distribution of V, conditional on observing X, is also Normal with mean

$$\mu = \alpha X + (1 - \alpha)\overline{V} \tag{1}$$

and variance

$$\sigma^2 = (1 - \alpha)\sigma_V^2 \tag{2}$$

where

$$\alpha \equiv \frac{\sigma_V^2}{\sigma_V^2 + \sigma_\epsilon^2}.$$

The coefficient α is thus a measure of how informative the signal X is. If the signal is perfectly informative (complete information leakage), $\alpha = 1$. If, on the other hand, the signal is completely uninformative, then $\alpha = 0$. A higher value of α represents a higher degree of information leakage.

An investor bidding for K_1 shares must deposit a check for $K_1 P_0$ dollars with the firm. Each uninformed investor chooses $K_1 \geq 1$ such that the expected profit,

[14] Since the focus of this paper is not on the role of the underwriter or the possible conflicts of interest between the underwriter and the issuer, we do not complicate the analysis by modelling the underwriter and issuer separately.

conditional on the information at date 1, is equal to zero.[15] The informed investor also bids for K_1 shares each if and only if his signal is 'Good'.[16]

Thus, all N_U uninformed investors and $\theta(V)N_I$ informed investors who privately receive a 'Good' signal, bid for K_1 shares each, if $K_1 \geq 0$, and deposit a check for $K_1 P_0$ with the firm. Therefore, the number of investors who wish to subscribe for firm's shares is thus equal to

$$N_S(V) \equiv N_U + \theta(V) N_I.$$

Clearly, N_S is strictly increasing in V, i.e., $N_S'(V) > 0$.

Let r denote the interest rate for this period. Also let rt denote the transactions costs associated with bidding an amount equal to $K_1 P_0$. Thus, the total cost of bidding for K_1 shares equals $K_1 P_0 r(1+t)$. The issuer deposits all these checks in a bank.

If the signal $V + \epsilon$ that all investors observe on date 1 is low enough that $K_1 < 1$, the issue fails.

- Date 2: If the offering is oversubscribed, each investor is allocated shares on a *pro rata* basis and receives $N/N_S(V)$ shares. Since the allocation is strictly decreasing in V, the value of each share of the firm is perfectly revealed to everyone when the shares are allocated. The true after-market value of the stock thus becomes public knowledge.

If $K_1 \geq 1$, then the offering is fully subscribed and the issuer raises NP_0. In addition, the issuer raises $N_S(V) K_1 P_0 r$ in the form of interest earned on the total amount of checks deposited in the bank. A total of N shares are allocated, with each investor receiving shares on a *pro rata* basis, and the remaining amount, for shares not allocated, is refunded. The total amount of funds thus raised by the firm is equal to

$$NP_0 + N_S(V) K_1 P_0 r.$$

[15] The assumption of a minimum bid of one share is purely arbitrary, of course; any restriction on the minimum bid size would suffice for our analysis. A small fixed cost associated with bidding is sufficient to guarantee the optimality of a minimum bid size. We assume it exogenously in order to simplify the analysis.

[16] If the informed investor's expected profits from bidding, conditional on receiving even a 'Bad' signal, are non-negative, then they will always choose to bid for the shares of the company. In such a case, the uninformed do not face any adverse selection costs and therefore need not be compensated in any way (such as through underpricing) to ensure their participation in the bidding.
The assumption that informed investors do not bid for more than K_1 shares each could be justified by arguing that if an informed were to bid more than K_1, the issuer would recognize it as an informed bid and may discriminate when allocating shares; see Far Eastern Economic Review (1993). However, it would not affect our results if informed investors ordered some multiple of the uninformed investors orders. For simplicity, we are abstracting away from issues relating to the design of the optimal allocation mechanism; see Benveniste and Spindt (1989), Benveniste and Wilhelm (1990) and Benveniste and Busaba (1994).

If, however, $K_1 < 1$, the offering fails and the firm is worthless. We make this assumption to capture the intuition that a failed offering is costly. The assumption that the firm is worth *nothing* if the offering fails is stronger than is necessary and is made only for simplicity and analytical tractability.

If the offering is successful, then for any given realization of the true value of the firm's stock V, the capital gain realized by each investor is equal to $N/N_S(V)$. The cost of bidding for K_1 shares is $K_1 P_0 r(1+t)$. The uninformed investors' net expected profits from bidding equal zero if

$$\mathrm{E}_X\left[\frac{N}{N_S(V)}(V-P_0)\right] = K_1 P_0 r(1+t) \tag{3}$$

where $\mathrm{E}_A[.] \equiv \mathrm{E}[.|A]$ denotes conditional expectation.

The first thing to note about Eq. (3) is that it depends on the information leakage, since the expectation is conditioned on X. When uninformed investors observe a high X, their estimate of V is higher but their estimate of the aggregate order size, $N_S(V)$, is also higher. Notice the role interest float plays in our model in determining the optimal order size for each investor in equilibrium. When investors decide how many shares to ask for, they naturally take any expected rationing into account. If they think that demand will be high and that they will only get a fraction of their order, they will adjust their order upward accordingly. The clearest evidence that this occurs in practice is the fact that investors sometimes order more shares than the issuer is trying to sell. For instance, in the already-mentioned Denway case that was oversubscribed by 659 times, the orders for more than 100% of the shares available accounted for 270 times of the oversubscription. In the U.S. type system where ordering shares means simply reporting a number to one's broker over the phone, there is no cost to *ordering* a larger number of shares (although there is of course a potential cost to being allocated more shares). In a pay in advance system, ordering twice as many shares means paying *in advance* for twice as many shares, the cost of which is reflected in the term on the right-hand side of Eq. (3). Moreover, the fact that they expect other investors to order more increases the expected cost of getting a certain number of shares (since there will be more rationing). It is the cost of ordering shares, due to the pay in advance feature, that pins down the optimal order size in this model.

The offering is successful if and only if $K_1 \geq 1$. Let $\hat{X}$ be the critical value of X such that $K_1 = 1$. Substituting in Eq. (3), we get

$$E_{[X=\hat{X}]}\left[\frac{N}{N_S(V)}(V-P_0)\right] = P_0 r(1+t).$$

It follows that the offering is successful if and only if $X \geq \hat{X}$.

The issuer's maximization problem can be stated as follows:

$$\mathrm{Max}_{P_0}\mathrm{E}\left[\int_{\hat{X}}^{\infty}\{NP_0 + N_S(V)[K_1 P_0 r]\}f(x)\mathrm{d}x\right]$$

where $f(x)$ denotes the density function for X. Substituting for $K_1 P_0$ from Eq. (3), the maximization problem can be restated as

$$\mathrm{Max}_{P_0} R \equiv \mathrm{E}\left[\int_{\hat{X}}^{\infty}\left\{NP_0 + \frac{1}{1+t}N_S(V)E_X\left[\frac{N}{N_S(V)}(V-P_0)\right]\right\}f(x)\mathrm{d}x\right]. \tag{4}$$

We first analyze the case where there are no transactions costs associated with bidding for the firm's shares in order to understand the intuition behind various tradeoffs that are involved in choosing the optimal offer price.

Lemma 1. If there are no transactions costs ($t = 0$) *and the issuer collects revenues on the interest float* ($r > 0$), *then the issuer will choose an offer price of* $P_0 = \delta$, *where* δ *is positive but arbitrarily close to* 0.

Proof. See the appendix.

The intuition for the above result is as follows. First, lowering the issue price has the advantage that it reduces the probability that the issue would fail. Of course, a smaller offer price means that funds raised directly through the issue (NP_0) are smaller, but this negative effect on revenues is more than offset by the fact that interest revenues are now sufficiently larger. This is because the uninformed investors, since they expect to make larger capital gains on shares issued at a smaller offer price, bid for a larger number of shares such that the interest cost on the larger amount they must post with the issuer equals the increase in the expected capital gain. Furthermore, this has the added advantage that the revenues raised and collected by the issuer depend more directly on the value of the firm V because the number of informed investors who bid for the firm's shares is increasing in V. So, in effect, the firm is able to obtain an effective price for its shares that is conditional on ex post information (V), which has the advantage that it reduces the surplus that is captured by informed investors. [17]

To understand this intuition further, consider the extreme case in which the signal received by all investors on date 1 is perfect ($\epsilon = 0$). In this case the uninformed investors do not face any adverse selection problem, consequently, the informed investors do not receive any surplus. Conditional on the offering being successful, the reduction in revenues from lowering the offer price, in this case, is

[17] See Ritter (1987). This insight is also developed in Chowdhry and Nanda (1996) in which it is argued that *ex post* price stabilization dominates *ex ante* underpricing.

exactly offset by the increase in interest revenues. But because lowering the offer price decreases the probability that the issue would fail, it makes sense to choose an offer price that is as low as possible.

Now consider the other extreme case in which the signal received by investors on date 1 is completely uninformative ($\sigma_\epsilon^2 \to \infty$). The uninformed investors do face an adverse selection problem. As long as the issuer chooses a price that ensures that the uninformed investors expected capital gains are non-negative, the issue will be successful with probability one. It pays to choose a lower offer price which reduces the revenues raised directly (NP_0) but on the other hand increases the revenues collected in interest. Since the interest revenues depend directly on the number of investors bidding for the issue, which is increasing in the value of the firm V, the issuer is able to obtain an effective price that is conditioned on the ex post information.

If there are transactions costs, however, then it is inefficient to raise revenues in the form of interest. Here again, consider the extreme case in which the signal received by investors on date 1 is completely uninformative. For sufficiently large transactions costs if the offer price is lowered then conditional on the offering being successful, the tradeoff between reduction in revenues raised directly (NP_0) and increase in revenues raised in interest ($N_S(V)K_1P_0r$) is such that the net revenues decrease. In this case, the issuer will choose the offer price to be as high as possible subject to the constraint that the uninformed investors' expected capital gains are non-negative. The offering will then be successful with probability one.

For the analysis in the rest of the paper, we assume that transactions costs are large enough that, in a case of no information leakage (completely uninformative signal), the issuer will optimally choose the largest incentive compatible offer price (i.e., the highest price that induces uninformed investors to bid for the firm's shares). In that case, there is an interior solution to the general maximization problem in (4) since on the one hand, lowering the issue price decreases the net revenues raised conditional on the offering being successful; on the other hand, it decreases the probability that the offering will fail.

2.1. *Differences in oversubscription and underpricing*

Our goal is to understand how different contractual arrangements in different countries result in systematic differences in oversubscription and underpricing of IPOs. In terms of our framework, different contractual arrangements are characterized by different values of exogenous parameters r, t, α, $\bar{V}$ and σ_V^2. We focus our analysis on differences in r, t and α, and assume that the prior mean $\bar{V}$ and the posterior variance σ^2 are identical across all regimes. Intuitively, by keeping the posterior mean identical across all regimes, we are abstracting away from effects caused by differing levels of adverse selection problem faced by the uninformed investors. This allows us to focus purely on effects caused by differences in contractual arrangements. To be specific, we are assuming that in a regime in which prior variance σ_V^2 is high (possibly because the offer price is set many days before the bidding period closes), the leakage of information is also high, characterized by high α (precisely because there are many days over which the information leakage takes place).

2.1.1. *Comparing oversubscription across regimes*

In a regime with no information leakage ($\alpha = 0$), the condition for uninformed investors to participate is

$$\mathrm{E}\left[\frac{N}{N_S(V)}(V - P_0)\right] \geq K_1 P_0 r(1+t).$$

The optimal offer price in this case is the largest price such that the above condition is satisfied. Clearly, $K_1 = 1$ and the issue is successful with probability one.

In a regime with information leakage ($\alpha > 0$), the condition for uninformed investors to participate is

$$\mathrm{E}_X\left[\frac{N}{N_S(V)}(V - P_0)\right] \geq K_1 P_0 r(1+t).$$

Uninformed investors participate if and only if the signal $X \geq \hat{X}$. When $X = \hat{X}$ then by definition $K_1 = 1$. But for $X > \hat{X}$, $K_1 > 1$. So, on average, conditional on the offering being successful, $K_1 > 1$. This gives us the following proposition.

Proposition 1. The average level of oversubscription, conditional on the issue not failing, is higher in regimes that have information leakage ($\alpha > 0$) than in those with no information leakage ($\alpha = 0$).

Information leakage not only increases the average level of oversubscription, it also increases the chance of observing an extremely high order level, such as those that have attracted headlines and debate in Hong Kong. From (1) and (2), it is easy to see that

$$\mathrm{E}\mu = \bar{V},$$

$$\mathrm{Var}\,\mu = \alpha\,\sigma_V^2 = \frac{\alpha}{1-\alpha}\sigma^2.$$

An extremely large value of μ implies an extremely large value for

$$\mathrm{E}_X\left[\frac{N}{N_S(V)}(V - P_0)\right]$$

which implies an extremely large value for K_1 from Eq. (1), which implies an extremely large value, on average, for the oversubscription level. Suppose we were trying to find the probability of an issue being more than L times oversubscribed, where L is some large number. Prob[$\mu > L$] increases with Var μ, which in turn is increasing in α. We therefore get the following proposition.

Proposition 2. The probability of observing an extremely high level of oversubscription increases with the information leakage (α) *between the date when the offer price is announced and the date when the investors must bid for the firm's shares.*

2.1.2. Comparing underpricing across regimes

Let us consider the following two regimes:

1. $\alpha = r = 0$. This is the regime that corresponds most closely to the contractual arrangements for firm commitment offers in the U.S. The length of time between the setting of the offer price and the consummation of the offering is very short, $\alpha = 0$ (Ritter, 1987; Loughran et al., 1994). Also, investors do not pay in advance for shares they bid. So no interest float is collected, $r = 0$.

Let $P_0^{*\,\mathrm{US}}$ denote the optimal offer price in this regime.

2. $r > 0$ and $\alpha > 0$. This regime corresponds to the contractual arrangements in the U.K. and in many Asian countries. The length of time between the setting of the offer price and the consummation of the offering is relatively long ($\alpha > 0$) (Loughran et al., 1994). Also, investors do have to pay for shares they bid in advance, and the issuer collects the interest revenues on the float ($r > 0$).

Let $P_0^{*\,\mathrm{UK}}$ denote the optimal offer price in this regime.

The following propositions hold for any set of exogenous parameter values that imposes the mild restriction that the probability of the offering failing is less than 50%.

Proposition 3. The optimal offer price is higher in regime 1 (US) than in regime 2 (UK), i.e.,

$$P_0^{*\,\mathrm{US}} > P_0^{*\,\mathrm{UK}}.$$

Proof. See the appendix.

The intuition for this result is as follows. First, information leakage increases the probability that the issue will fail. Since failure of an issue is costly, it makes sense to reduce the offer price in order to reduce the probability of the issue failing. Second, making investors pay in advance for shares bid imposes a cost associated with bidding. This also increases the probability of failure and the incentive to underprice further. Third, if the issuer collects the interest float on checks deposited, it reduces the cost associated with underpricing and hence increases the incentive to underprice further.

We now obtain the following comparative statics result which provides a testable empirical proposition.

Proposition 4. The optimal offer price in the U.K. type regime, $P_0^{*\,\mathrm{UK}}$, *is decreasing in the interest rate r.*

Proof. See the appendix.

The intuition for this result is that a higher interest rate increases the cost associated with bidding for the firm's shares. Since this increases the probability of failure for the issue, the issuer underprices the issue more to reduce the probability of failure.

2.2. Optimal contractual mechanism

We now address the issue of which contractual arrangement is optimal. [18] If we define the optimal contractual arrangement as one that maximizes the expected proceeds received by the issuer, then the following comparative statics results are helpful in understanding this issue.

Proposition 5. The total proceeds R^* *from the offering are:*
1. *decreasing in the leakage parameter* α.
2. *decreasing in the interest rate r.*
3. *decreasing in the posterior variance* σ^2.

Proof. See the appendix.

The intuition for this result is straightforward. An increase in the leakage parameter α or the interest rate r or the posterior variance σ^2 is associated with an increase in the probability of the issue failing, which is associated with a smaller level of expected proceeds from the offering.

This allows us to make a comparison between the U.S. type of contractual arrangement and the U.K. type of contractual arrangement. First notice that because the information signal $X = V + \epsilon$ is correlated with the true information V, it mitigates the adverse selection problem faced by uninformed investors. One must keep in mind, however, that information leakage probably occurs even in the U.S. type firm commitment offers in which the offer price is set *after* the underwriting investment bank has tried to estimate demand by soliciting bids from their regular customers (see Benveniste and Spindt, 1989). If we were to assume that the posterior variance is identical under the two arrangements, then the U.S.

[18] Also, see Benveniste and Busaba (1994).

type of arrangement dominates the U.K. type of arrangement since in the latter because the offer price is set *before* the information leakage occurs, it is associated with both higher leakage and higher cost associated with bidding.

It is possible, however, that the U.K. type mechanism that we discuss in our paper leads to more information being revealed before the end of the subscription period. This is plausible, since information about aggregate demand should be more credible when investors are required to pay in advance for shares they wish to bid for. [19] Thus an advantage of the U.K. type of system, in our framework, arises from the possibility that it may lead to a smaller posterior variance resulting in smaller adverse selection cost for uninformed investors. [20]

The choice between the two systems, then, depends on the tradeoffs between these costs and benefits of the two systems.

3. Conclusion

We argued that when the offer price of an IPO is set many days before the issue closes for bidding by investors, there is a possibility that information about aggregate investor demand – which would be crucial in determining the initial price at which the issue would trade in the secondary market – may leak and become public knowledge before investors have finished bidding for firm's shares. Consequently, there will be instances when all investors would know ex ante that the offer price is 'too low' and a large oversubscription for firm's shares would be observed. On the other hand, there will also be instances when investors would realize that the offer price is 'too high' and the issue would fail. If failure is costly, in order to reduce the likelihood of instances in which the issue would fail, the issue may have to be underpriced more compared to the situations in which there is no information leakage. We further argued that if the issuer collects the interest float on checks deposited by investors for shares they bid, this interest revenue reduces the cost associated with underpricing and thus provides an incentive to underprice the issue further.

We are thus able to explain why, under such contractual arrangements, we observe (i) larger underpricing on average; (ii) larger oversubscription levels on average, conditional on the offering being successful; and (iii) a larger probability of observing extremely high levels of subscription (which may appear to be absurdly high, at first blush) compared to issues in which the offer price is set only

[19] The Economist (1993) raises concerns about 'the genuineness of the bids' in the U.S. type of book-building mechanism.

[20] Benveniste and Busaba (1994) finds that the U.S. type of book-building mechanism "generates higher expected proceeds but exposes the firm to greater uncertainty".

days prior to consummation of the offer. We also obtain the empirical implication that underpricing is higher in periods when interest rates are high.

The formal optimization problem in our framework allows us to explore the proceeds maximization solution for the contract design choice. We argued that a higher information leakage and the costs associated with bidding for shares in advance in the U.K. open offer type of contractual mechanism makes it less attractive compared to the book-building type of mechanism employed in the U.S. A possible advantage, however, is that since investors are required to pay in advance for shares they bid for, the information about market demand for the issue is more credible. This reduces the adverse selection problem faced by uninformed investors. It is important to understand and quantify the costs and benefits of the two contractual mechanisms in order to analyze relevant policy implications. In Hong Kong (which uses the U.K. mechanism), for instance, a great debate has ensued among the regulatory institutions as well as the financial institutions involved in IPOs, after the spectacular Denway issue, about whether the contractual arrangements concerning IPOs should be altered. [21] Also, in the U.K., the trend seems to be in favor of the U.S type of book-building mechanism. The following quote from The Economist (1993) reflects this sentiment [22]:

''... market professionals think that all global equity issues will in future be sold through open book-building. It seems, for instance, to have displaced Britain's practice of underwriting privatisations''.

Benveniste and Busaba (1994) notes that the policy issue of an optimal contractual mechanism is complex because there may be motives other than expected proceeds' maximization that are in conflict. In particular, the choice of a contractual mechanism also seems to be tied to the mechanism for allocating shares. The U.S. type of book-building mechanism employs a discretionary allocation mechanism. One of the important reasons for choosing the U.K. type of contractual mechanism might be that a non-discretionary allocation mechanism or an allocation mechanism that favors smaller investors could be employed. [23] Benveniste and Busaba (1994) notes that government policy in the U.K. required that IPOs related to the privatization of nationally owned firms distributed the issues to the public in an evenhanded manner which precluded the option of building a book. A more complete analysis of the policy issues relating to the choice of contractual mechanism will require incorporating these alternative allocation mechanisms into our analysis. We leave these issues for future research,

[21] See Securities Journal (1993), Hanson (1993) and Yam (1993).

[22] This reference was brought to our attention by Benveniste and Busaba (1994).

[23] In the U.K. (see Brennan and Franks, 1994) and in Singapore (see Far Eastern Economic Review, 1993), for instance, the allocation mechanism favors investors with smaller bids. See Chowdhry and Sherman (1996) for an analysis of how allocation mechanisms that favor smaller bids may mitigate the adverse selection problem.

hoping that our analysis has provided a step towards understanding these issues more clearly.

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Appendix A

We will use the following lemma in some of the proofs that follow.

Lemma 2.

$$\frac{\partial \hat{X}}{\partial P_0} > 0, \quad \frac{\partial \hat{X}}{\partial \alpha} > 0, \quad \frac{\partial \hat{X}}{\partial r} > 0, \quad \frac{\partial \hat{X}}{\partial \sigma^2} > 0, \quad \frac{\partial}{\partial r}\left[\frac{\partial \hat{X}}{\partial P_0}\right] > 0.$$

Proof. Since $(N/N_S(V))(V - P_0)$ is assumed to be increasing and concave in V, and is decreasing in P_0, we can write (see Ingersoll, 1987, pp. 95–97)

$$\mathrm{E}_{[X=\hat{X}]}\left[\frac{N}{N_S(V)}(V-P_0)\right] = H(\hat{\mu}, \sigma^2; P_0)$$

where

$$\hat{\mu} \equiv \mathrm{E}_{\hat{X}} V = \alpha\hat{X} + (1-\alpha)\bar{V},$$
$$H_1 > 0, \quad H_{11} < 0, \quad H_2 < 0, \quad H_3 < 0.$$

We know that

$$\mathrm{E}_{[X=\hat{X}]}\left[\frac{N}{N_S(V)}(V-P_0)\right] = P_0 r(1+t).$$

Therefore,

$$\frac{\partial \hat{X}}{\partial P_0} = \frac{r(1+t) - H_3}{\alpha H_1} > 0.$$

Also,

$$\frac{\partial \hat{X}}{\partial \alpha} = \frac{\bar{V} - \hat{X}}{\alpha} > 0,$$

$$\frac{\partial \hat{X}}{\partial r} = \frac{P_0(1+t)}{\alpha H_1} > 0,$$

$$\frac{\partial \hat{X}}{\partial \sigma^2} = \frac{-H_2}{\alpha H_1} > 0.$$

Since $H_{11} < 0$, $\hat{\mu}$ is increasing in $\hat{X}$, which in turn is increasing in P_0, it follows that

$$\frac{\partial}{\partial r}\left[\frac{\partial \hat{X}}{\partial P_0}\right] > 0.$$

Proof of Lemma 1

Differentiating (4) with respect to P_0 and simplifying, we get

$$\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0} = \mathrm{E}\left[\int_{\hat{X}}^{\infty}\left\{1 - \frac{1}{1+t}\left[N_S(V)\mathrm{E}_X\frac{1}{N_S(V)}\right]\right\}f(x)\mathrm{d}x - \frac{\partial \hat{X}}{\partial P_0}P_0\left(1 + r\frac{N_S(V)}{N}\right)f(\hat{X})\right].$$

The above expression can be rewritten as

$$\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0} = \mathrm{E}\left[\pi(\hat{X})\mathrm{E}_{[X \geq \hat{X}]}\left[1 - \frac{1}{1+t}N_S(V)\mathrm{E}_X\frac{1}{N_S(V)}\right] - \frac{\partial \hat{X}}{\partial P_0}P_0\left(1 + r\frac{N_S(V)}{N}\right)f(\hat{X})\right]. \tag{A.1}$$

where $\pi(\hat{X}) = \int_{\hat{X}}^{\infty} f(x)\mathrm{d}(X)$. Substituting $t = 0$ in (A.1), we get

$$\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0} = \mathrm{E}\left[\pi(\hat{X})\mathrm{E}_{[X \geq \hat{X}]}\left[1 - N_S(V)\mathrm{E}_X\frac{1}{N_S(V)}\right] - \frac{\partial \hat{X}}{\partial P_0}P_0\left(1 + r\frac{N_S(V)}{N}\right)f(\hat{X})\right]. \tag{A.2}$$

Notice that the second term on the RHS of above equation is negative. We will now show that the first term is not positive.

$$E_{[X \geq \hat{X}]}\left[1 - N_S(V)E_X \frac{1}{N_S(V)}\right] = 1 - E_{[X \geq \hat{X}]}[N_S(V)]E_{[X \geq \hat{X}]}\left[\frac{1}{N_S(V)}\right] - \mathrm{Cov}_{[X \geq \hat{X}]}\left[N_S(V), E_X \frac{1}{N_S(V)}\right].$$

The LHS in the above expression is largest when the covariance term on the RHS is the smallest. The covariance term is smallest when the signal X is perfect, i.e., when $X = V$. In that case, the LHS in the above equation equals 0 which implies that the first term in the RHS of Eq. A.2 equals zero. Since the maximum possible value for the first term in the RHS of $\mathrm{d}R/\mathrm{d}P_0 < 0$. This means that, at any positive issue price, the issuer would prefer a lower price. The limit would be an issue price of zero, but there are obvious problems with this, since the issuer cannot earn float on checks for $0. Therefore the issuer will choose the smallest possible positive price (such as the equivalent of one tick on the local exchange).

Proof of Proposition 3

$P_0^{*\,US}$ satisfies the following incentive compatibility condition:

$$E\left[\frac{N}{N_S(V)}\left(V - P_0^{*\,US}\right)\right] = 0. \tag{A.3}$$

Consider another regime with $r = 0$ and $\alpha \geq 0$ (let's call it regime US′). Now suppose that we chose the same price as above, $P_0^{*\,US}$, also under this regime. The uninformed investors will bid with this initial price only if the signal $X > \hat{X}$ where $\hat{X}$ satisfies the following:

$$E_{\hat{X}}\left[\frac{N}{N_S(V)}\left(V - P_0^{*\,US}\right)\right] = 0. \tag{A.4}$$

Notice that the above expectation is taken with respect to the distribution of V which has the same variance as in regime 1 (US), but has mean equal to $\alpha\hat{X} + (1 - \alpha)\bar{V}$. Since this expectation is increasing in the mean, which in turn is increasing in $\hat{X}$, comparing Eq. (A.4) to Eq. (A.3) where the mean is equal to $\bar{V}$, we know that $\hat{X} = \bar{V}$.

What that implies however is that in regime US′, if the offer price is chosen to be $P_0^{*\,US}$, the issue will fail whenever the signal $X < \bar{V}$ which happens with probability one half. However, if the exogenous parameters are such that the probability of failure is less than 50%, then $P_0^{*\,US}$ can't be the optimal choice in regime US′. Moreover, since at the optimum, the probability of failure is less than

50%, the optimal value of $\hat{X}$ must be less than $\overline{V}$. This in turn implies that the optimal offer price in regime US′ is such that $P_0^{*\,\mathrm{US}'} < P_0^{*\,\mathrm{US}}$.

$P_0^{*\,\mathrm{US}'}$ satisfies the following first-order condition:

$$\mathrm{E}\left[\pi(\hat{X}^{*\,\mathrm{US}'}) - \frac{\partial \hat{X}}{\partial P_0} P_0^{*\,\mathrm{US}'} f(\hat{X}^{*\,\mathrm{US}'})\right] = 0.$$

Evaluating $(1/N)(\mathrm{d}R/\mathrm{d}P_0)$ for regime UK, at $P_0 = P_0^{*\,\mathrm{US}'}$, we get

$$\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0} = \mathrm{E}\left[\pi(\hat{X}) - \frac{\partial \hat{X}}{\partial P_0} P_0^{*\,\mathrm{US}'} f(\hat{X})\right]$$
$$- \mathrm{E}\left[\pi(\hat{X})\mathrm{E}_{[X \geq \hat{X}]}\left[\frac{1}{1+t} N_\mathrm{S}(V) \mathrm{E}_X \frac{1}{N_\mathrm{S}(V)}\right]\right.$$
$$\left. + \frac{\partial \hat{X}}{\partial P_0} r P_0^{*\,\mathrm{US}'} \left(\frac{N_\mathrm{S}(V)}{N}\right) f(\hat{X})\right] < \mathrm{E}\left[\pi(\hat{X}) - \frac{\partial \hat{X}}{\partial P_0} P_0^{*\,\mathrm{US}'} f(\hat{X})\right].$$

From Lemma 2, $\hat{X}$ is larger in regime UK which implies that $\pi(\hat{X})$ is smaller and $f(\hat{X})$ is larger. Also, from Lemma 2, $\partial \hat{X}/\partial P_0$ is larger. This implies that $\mathrm{d}R/\mathrm{d}P_0$ is negative for regime UK, if evaluated at $\mathrm{P}_0^{*\,\mathrm{US}'}$ which can't be optimal. Therefore the optimal offer price for regime UK is such that $P_0^{*\,\mathrm{UK}} < P_0^{*\,\mathrm{US}'}$.

Proof of Proposition 4

If there is an interior solution to the maximization problem, then we know that

$$\mathrm{Sign}\left[\frac{\mathrm{d}P_0^*}{\mathrm{d}r}\right] = \mathrm{Sign}\left[\frac{\partial}{\partial r}\left\{\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0}\right\}\right]$$

where P_0^* denotes the optimal issue price. Let $\hat{X}^*$ denote the corresponding value of $\hat{X}$.

$$\frac{\partial}{\partial r}\left\{\frac{1}{N}\frac{\mathrm{d}R}{\mathrm{d}P_0}\right\} = -\mathrm{E}\left[\frac{\partial \hat{X}^*}{\partial r}\left(1 - \frac{1}{1+t} N_\mathrm{S}(V) \mathrm{E}_X \frac{1}{N_\mathrm{S}(V)}\right) f(\hat{X}^*)\right]$$
$$- \mathrm{E}\left[\frac{\partial}{\partial r}\frac{\partial \hat{X}}{\partial P_0} P_0^* \left(1 + r\frac{N_\mathrm{S}(V)}{N}\right) f(\hat{X}^*)\right]$$
$$- \mathrm{E}\left[\frac{\partial \hat{X}}{\partial P_0} P_0^* \frac{N_\mathrm{S}(V)}{N} f(\hat{X}^*)\right]$$
$$- \mathrm{E}\left[\frac{\partial \hat{X}}{\partial P_0} P_0^* \left(1 + r\frac{N_\mathrm{S}(V)}{N}\right) f(\hat{X}^*) \frac{\partial \hat{X}^*}{\partial r}\right].$$

The fact that there is an interior solution guarantees that the first term in the RHS above is negative. The second and third are clearly negative. To see that the last term is also negative notice that $f'(\hat{X}^*)$ is positive for $\hat{X}^* < \bar{V}$ and is negative for $\hat{X}^* > \bar{V}$. Since we have assumed that the probability of issue failing is less than 50%, the result follows.

Proof of Proposition 5

The expected proceeds raised by the issuer at the optimal issue price P_0^* are given by the following:

$$R^* = \mathrm{E}\left[N\int_{\hat{X}*}^{\infty}\left\{P_0^* + \frac{1}{1+t}N_S(V)\mathrm{E}_X\frac{1}{N_S(V)}(V-P_0^*)\right\}f(x)\mathrm{d}x\right],$$

$$\frac{\mathrm{d}R^*}{\mathrm{d}\alpha} = \frac{\partial R^*}{\partial\alpha} = -\mathrm{E}\left[N\frac{\partial\hat{X}^*}{\partial\alpha}P_0^*\left(1+r\frac{N_S(V)}{N}\right)f(\hat{X}^*)\right],$$

$$\frac{\mathrm{d}R^*}{\mathrm{d}r} = \frac{\partial R^*}{\mathrm{d}r} = -\mathrm{E}\left[N\frac{\partial\hat{X}^*}{\partial r}P_0^*\left(1+r\frac{N_S(V)}{N}\right)f(\hat{X}^*)\right],$$

$$\frac{\mathrm{d}R^*}{\mathrm{d}\sigma^2} = \frac{\partial R^*}{\mathrm{d}\sigma^2} = -\mathrm{E}\left[N\frac{\partial\hat{X}^*}{\partial\sigma^2}P_0^*\left(1+r\frac{N_S(V)}{N}\right)f(\hat{X}^*)\right].$$

Since from Lemma 2, we know that $\partial\hat{X}^*/\partial\alpha > 0$, $\partial\hat{X}^*/\partial \mathrm{r} > 0$, $\partial\hat{\mathrm{X}}^*/\partial\sigma^2 > 0$, the results follow.

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