The Pricing of Initial Public Offerings:
A Simple Model

by

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Preliminary.

Present draft:
August 9, 1994

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Acknowledgements

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Abstract

This paper presents a simple model that explains a number of empirical observations on initial public offerings. The model assumes that the firm which intends to go public is best informed about the future prospects of the firm. The apparent incentive for the firm to overprice the offering creates a market for an intermediary that can certify the estimated value of the firm. In this paper the decision problem of establishing a proper offer price is condensed into a simple loss-function for the intermediary. The paper shows that under fairly general conditions underpricing will arise. The expected underpricing will be a function of a few simple parameters.

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Introduction

Initial public offerings are rapidly becoming one of the most thoroughly researched topics in empirical finance. An extensive survey of the results obtained for IPOs in different countries can be found in Loughran, Ritter and Rydqvist (1994). The results in these IPO studies confirm the original findings in Ibbotson (1975), and Ritter (1987) that IPOs are underpriced in the short run. The average difference between the price at which the stock starts trading when listed and the subscription price is too large to be explained by the risk characteristics of the firm.

This paper presents a simple model that explains these observations. The model can be seen as a generalisation of the model in Beatty and Ritter (1986). Like in Beatty and Ritter (1986) the pivotal agent in the pricing decision is the underwriter. In this paper the underwriter's decision problem is compressed into a simple loss function which includes the loss of reputation that is playing a crucial role in the Beatty and Ritter (1986) paper. As such the present model also encompasses some other hypotheses that have been advanced to explain the observed pricing of initial public offerings.

In contrast to the Beatty and Ritter (1986) this paper does not rely on a split between informed and uninformed investors. In IPOs differences in opinion in the Harris and Raviv (1993) sense, between investors trying to asses the value of the firm, will play a substantial role. Lacking an observed market price, experts looking at the same firm are highly unlikely to come up with exactly the same estimate of the value of this firm. Thus the abstraction with informed investors that know the true value of the firm and uninformed ones that do not know it, is not a very accurate description of an IPO. This paper substitutes the informed-uninformed split with a simple firm-specific downward sloping uncertain demand curve. In this respect the paper builds on Baron and

Holmström (1980) and Baron (1982) where it is assumed that the underwriter is able to increase the demand for the issue by lowering the price or increasing the selling effort.

In contrast to papers by Allen and Faulhaber (1989), Grinblatt and Hwang (1989), Welch (1989) which also assume that the firm itself is best informed about its future prospects, signalling is not present in this paper. Again, the reason is that the true value of the firm is assumed to be unobservable for all participants in the IPO market. Thus, no easily interpretable signal is available. All participants are forced to base their actions on uncertain estimates of the value of the firm[1].

The outline of the paper is the following: In the next section the general setting for the model is explained. The following section specifies the decision problem faced by the underwriter and derives some general results. The fourth section derives some further results by restricting the demand for the IPO to be log-linear in the offer price. The fifth section summarises the paper.

Background

There are three different groups of participants in the IPO market: 1. the firm that intends to go public, 2. potential subscribers of the initial offering, and finally 3. underwriters. These three groups differ with respect to the information that they posses about the firm but also in their incentives for accepting biased or unbiased estimates of

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[1] In contrast to the paper by Chemmanur (1993), in which underpricing is required to induce investors to collect information about the firm this paper relies heavily on the need for an underwriter. The investor's decision whether to subscribe or not is not explicitly modelled in this paper.

the true value of the firm.[2]

In the following we will assume that the IPO is in the form of new equity intended for new shareholders. The IPO firm is assumed to act as an agent for its old shareholders. Everything else equal, this firm wants to get the highest possible price. In other words, the firm itself has an incentive to accept an upward biased estimate for its value. The potential subscribers, on the other hand, would, everything else equal, like to buy the shares at a price which is as low as possible. These investors have an incentive to accept a downward biased estimate for the value of the firm. Finally, the third group, the underwriters, have to strike a balance between both sides of the market. Thus, they will have an incentive to come up with an estimate which is not, at least obviously, biased in one direction or the other. However, as we shall see they are unlikely to settle for an offer price which equals an unbiased estimate for the value of the shares.

In principle the firm that plans to go public could sell its shares to the public without any intermediation. However, if all firms would do that without exception the market's unbiased estimate of the true value would be the average for these kinds of firms. Going public without intermediation would thus not be worthwhile for firms that are better than the average in their group. Accordingly, the only firms that would like to go public without intermediation would be the ones which are below the average. Since the better firms would drop out, the market would adjust its estimate. This would cause the firms close to the average to drop out inducing a further market adjustment, and so on, ultimately leading to a market failure. Hence, the need for intermediation to reduce the

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[2] This is especially important for the certification role performed by the underwriter. The fact that the certification role is lacking in the Baron and Holmström (1980) and Baron (1982) model allows Muscarella and Vetsuypens (1989) to test the model by comparing cases in which underwriters arrange their own IPOs with cases in which underwriters arrange IPOs for client firms. Their results reveal that these IPOs do not differ with respect to their degree of underpricing leading them to reject the model. However, their results follow naturally the certification role of the underwriter. The underwriter's incentives will be different in its own IPO than in its clients' IPOs. This difference in incentives is obvious to the market. The underwriter is not able to certify its own subscription price and thus a higher degree of underpricing is, ceteris paribus, required when the underwriter arranges its own IPO than when it acts on behalf of a client.

information asymmetry[3] in an IPO.[4]

The task of the underwriter is to reduce the information asymmetry that exists between the firm and the stock market. To accomplish this the underwriter is making a thorough inspection of the firm with the aim producing an unbiased estimate of its true value. On the basis of this estimate the underwriter certifies the offer price. This certified estimate is considered trustworthy by the market mainly because of the repetitive nature of the underwriter's business. The market knows that by accepting biased estimates, in favour of the firms that plan to go public, the underwriter would gradually ruin its reputation among sophisticated investors[5].

The reason why the underwriter is forced to rely on sophisticated investors is the same as the one which drives the IPO firm to use an intermediary. Even an unsophisticated investor realizes that an underwriter that avoids investors who are known to be sophisticated is probably overpricing.

In the following we will assume that the underwriter is facing a downward sloping uncertain demand curve for the issue, that is, the larger the offering the lower the price has to be for the underwriter to obtain enough subscriptions. There are several justifications for this assumption[6].

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[3] The information asymmetry could in principle also be reduced by the existence of a credible signal . The reason why underpricing as such will not work as a signal as suggested by Allen and Faulhaber (1989), Grinblatt and Hwang (1989), Welch (1989) is that the true value is unobservable. See also the empirical results obtained by Jegadeesh, Weinstein and Welch (1993).

[4] See Booth and Smith (1986) for an elaboration of this argument for underwriting in the case of new issues of equity. In Leland and Pyle (1977) this argument is used in a general explanation for why intermediaries are needed to prevent market failure in the raising of new financing by firms.
The basic idea builds on the seminal article by Akerlof (1970).

[5] See Beatty and Ritter (1986).

[6] A survey of arguments and empirical evidence in support of a finite price elasticity for a firm's shares are found in Loderer, Cooney and Van Drunen (1991).

To begin with, if the underwriter's success in selling the issue will depend on the willingness of a small group of sophisticated investors to pick up a significant part of the issue, then a larger issue should require a higher premium to compensate these investors for forgone diversification benefits. This is consistent with the "cascade" theory advanced by Welch (1992): Other investors will wait for a commitment from those investors who are supposed to be most competent in judging the value of the firm. When investors observe that the most competent ones are willing to risk their own money, others will follow.

The second justification for a downward sloping demand curve for the IPO is easily explained in the framework of Merton (1987): The underwriter's task can simply been interpreted as that of inducing enough investors to include the IPO firm in their information sets. By offering a higher expected return, more investors will be persuaded to include the firm in their information sets.

The third justification for a downward sloping demand curve is based on the size of the issue as an important, easily available, piece of information for potential subscribers. If the size of the offering is large compared to the size of the firm, the project for which the funds are needed has to be large compared to the present operations of the firm. This is likely to make sophisticated investors asses a higher probability for a failure than if the investment project would be more reasonably sized.

The Underwriter's Decision Problem

The underwriter's incentive to establish a subscription price which closely corresponds to the true value of the firm, makes the underwriter the pivotal agent in setting the subscription price. In the following the decision problem faced by the underwriter is specified, and the optimal offer price is characterised. It is shown that a rational underwriter is likely to choose an offer price which is below the unbiased estimate for

the value of the firm.

The market for underwriting services is assumed to be atomistic. There is a large number of underwriters which are small relative to the size of the market. This allows us to focus on a representative underwriter. From basic micro economic theory we know that in the long run equilibrium the fees charged by this underwriter will correspond to minimum costs.

The task of the representative underwriter is to determine the per share offer price P_0, the share price, at which the issue is offered to the public[7]. The underwriters relevant conceptions concerning the potential market for the IPO can be summarised by the following subjective demand schedule:

(1) $Q = \Theta (P) + \varepsilon,$

where Q is the quantity that the market will accept, P is the per share price for the new shares, $\Theta' < 0$, and ε is random variable, with an expected value equal to zero.

The dispersion parameter for ε, denoted σ^* for simplicity, will depend on the amount of information (I) that the underwriter is willing to collect about the firm and the potential demand for its IPO:

(2) $\sigma^* = \sigma^*(I), \sigma^{*'} < 0, \sigma^{*''} > 0,$

the negative first derivative $\sigma^{*'}$ meaning that by collecting more information about the firm the underwriter is able to establish a more precise estimate for the demand for this IPO, and the positive second derivative implying a decreasing marginal benefit of

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[7] This is a simplification justified by our focus on the pricing problem. In practice the underwriter is offering advice on a whole package including the size and the timing of the issue, the use of warrants, and other things which may affect the attractiveness of the issue among potential subscribers.

additional information.

The task of the underwriter is to establish, together with the firm, a per share price P_o, at which the issue is offered to the public[8]. Assume that there is a given sum that the firm wants to raise with the issue. Together with the underwriter the firm will decide on a quantity Q^* and a price P_o which enables them to raise this sum. Once this is done and the issue has been offered to the public the market will decide. If the actual demand for the issue at that price turns out to be at least as large as the size of the issue we will call the issue a "success", and if the actual demand falls short of Q^* we will call it a "failure".

Denote the share price on the first day of trading when the firm has been listed by P_m. Making the simplifying assumption that this price reflects the demand during the subscription period, the underwriter's decision problem that was spelled out in terms of the issue size[9] can be rephrased in terms of the share price. $P_m \geq P_o$ would then be a "success", and $P_m < P_o$ would be a failure. Furthermore, the demand schedule (1) transforms the uncertainty concerning the quantity demanded, which is the relevant state variable, to uncertainty regarding the price, which is the decision parameter.

The underwriter's objectives can now be expressed as a function of the pricing error in the form of the following asymmetric loss function, which for simplicity excludes all costs that do not depend on the offer price:

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[8] Note, that size of the issue as such is easily available information for the market. A specified number of shares transmits a more favourable piece of information to the market than leaving the number open. The latter alternative is an obvious indication of over pricing. In the extreme: maximising the number of shares sold would be an optimal policy for the old shareholders only if the shares were overpriced. The practice of announcing certain limits allowing the firm to issue more shares up to a given maximum in the case of oversubscription can be explained by the relatively low marginal cost of this equity once the fixed costs of the issue have been incurred. Thus, it makes sense for the firm to replace some of its planned financing from other sources with this equity if more than the required amount is offered by subscribers.

[9] It is assumed that the price elasticity of demand will never reach or exceed -1. Thus the sum that can be raised in the IPO will increase as the price is lowered.

(3) $L = c_s (P_m - P_o) \mathbf{1}(P_m \geq P_o) + (C_f + c_f(P_o - P_m)) \mathbf{1}(P_m < P_o),$

where

1   - is the indicator function, taking the value 1 if the condition is true, 0 otherwise,

c_s - is the cost parameter connected to a successful public offering, and

C_f, c_f - are the cost parameters connected to a public offering that fails.

For simplicity the cost in case of a success is assumed to be proportional to the difference between the market price and the offer price. The cost consists of two components: firstly, there may be a tangible cost: the reward to the underwriter may be smaller if the offer price is lower, secondly, there is the intangible cost: the reputation of the underwriter will suffer among potential entrants if they think this underwriter is selling the shares to the public too cheaply[10].

The loss in case of a failure consists of two parts: firstly, there is a fixed part (C_f) which corresponds to the loss of reputation, - firms do not want to engage an underwriter in the process of planning an IPO just to experience that it fails[11], secondly, there is the part which is proportional to the overpricing (c_f): if the IPO is overpriced, and the offering is guaranteed the underwriter will be forced to keep the unsubscribed shares. Even in the absence of any guarantees investors will loose their confidence in underwriters who are trying to sell overpriced shares. Furthermore, the more overpriced the issue is, the more

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[10] Beatty and Ritter (1986, p.225) report a significant loss of market share for underwriters with large pricing errors. James (1992) studying the relationship between IPOs and subsequent offerings conclude that: "These results suggest that the deviations from optimal IPO pricing carry a penalty for the underwriter" (p.1865).

[11] This explains why underwriters seem to engage in propping up the price of the stock in cases where the equilibrium price on listing would have been below the subscription price, as documented by Ruud (1993) and Hanley, Kumar, and Seguin (1993), and Schultz and Zaman (1994). Schultz and Zaman (1994) write: "While it is not necessary for a model of IPO underpricing to predict aftermarket support, it is plausible that the same factors that make it desirable for IPO stock prices to rise above their offer prices explain the effort and expense that underwriters incur to maintain prices of IPOs above their offer price." (p.218). Price support can be incorporated in the present model by treating them simply as a method for the underwriter to spread out the losses incurred by overpricing in time.

negative attention the issue is likely to get[12]. The costs for overpricing also include the expected costs of law-suits from dissatisfied investors. Thus the model encompasses the so called law-suit avoidance hypothesis advanced by Tinic (1988).

Given the loss function (3) what remains to be determined by the underwriter together with the firm that intends to go public is the optimal offer price. This decision includes the decision on the optimal risk of a failure.

The optimal offer price is found by minimising the expected loss of the underwriter. Taking expectations on both sides of (3):

$$
(4) \qquad E\{L\} = \int_{P_o}^{\infty} c_s(P_m - P_o) \, f(P_m) dP_m + C_f \int_{-\infty}^{P_o} f(P_m) dP_m + \int_{-\infty}^{P_o} c_f(P_o - P_m) \, f(P_m) dP_m
$$

The distribution function f is obtained by solving expression (1) for P_o. Since θ is strictly monotonic the impact of additional information on this distribution function will be the same as in (2).

Taking the derivative of (4) with respect to P_o yields:

$$
(5) \qquad \frac{dE\{L\}}{dP_o} = C_f f(P_o) = c_f + (c_s + c_f) \int_{P_o}^{\infty} f(P_m) dP_m .
$$

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[12] The actual loss function, especially its tangible part, will depend on the contract between the issuer and the underwriter. That the contract matters is shown by Ritter (1987). He shows that the underpricing in the case of best efforts contracts in the US is higher than in the case of firm commitment contracts. Since the costs for overpricing will be higher for the underwriter in the case of a firm commitment contract than in a best efforts contract this seems to contradict our theory. However, it seems likely that client firms that choose the best efforts contract are the ones that find the firm commitment contract too expensive. By accepting a contract which makes the loss function for the underwriter 'flatter' with respect to overpricing the client obtains a higher offerprice. Consistent with this Ritter (1987) shows that the outcome is more uncertain for the best efforts contract.

The necessary condition for a minimum yields the following expression for the optimal probability of a success:

$$(6) \qquad \int_{P_o}^{\infty} f(P_m)\,dP_m = \frac{C_f f(P_o) + c_f}{c_s + c_f}.$$

As a special case assume that $c_s = c_f$ and that the fixed costs $C_f = 0$. Expression (8) immediately gives us the intuitive result that the offer price should be chosen so as to make the probability of success $= \frac{1}{2}$, that is, the offer price should be set at the median of the probability distribution. If the fixed costs $C_f > 0$ the optimal price will lay below the median even if $c_s = c_f$. Finally if $c_s < c_f$ the optimal offer price will always remain below the median.

The actual size of the parameters in the loss function will depend on the contract between the issuing firm and the underwriter. E.g. if the underwriter guarantees the issue c_f will be higher than if the there is no guarantee. Consequently the required underpricing will, other things equal, be higher when the issue is guaranteed than when it is not.

Institutional settings will also affect the parameters in the loss function. Thus, c_f will be higher in a country where there is a considerable probability that the underwriter will face a law-suit if the IPO fails, than in a country where is this is unlikely. A detailed analysis of differences in the loss functions faced by underwriters in different countries may, in fact, explain a considerable part of the differences in average initial returns reported for 25 different countries in Table 1 of Loughran, Ritter and Rydqvist (1994).

The expression for the optimal probability of a failure is:

$$(7) \qquad \int_{-\infty}^{P_o} f(P_m)\,dP_m = 1 - \int_{P_o}^{\infty} f(P_m)\,dP_m = \frac{c_s - C_f f(P_o)}{c_s + c_f}.$$

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To find an analytical solution for the price in (6) or (7) will be difficult since P_o appears in the limit of the integral on the LHS, as well as in the numerator on the RHS. That a solution actually exists is seen by the fact that LHS will go from 0 to 1 as P_o goes from ∞ to 0, whereas the RHS will converge towards $\dfrac{c_f}{c_f + c_s}$, which is below 1, from above when $P_o \to 0$. Since the LHS is monotonically decreasing in P_o while the RHS is monotonically increasing, in the relevant range, the solution is unique.

Under the fairly general assumption that the distribution function f is unimodal and monotonically increasing below the modal value, and furthermore assuming that the initial optimal P_o will be below the modal value, the comparative statics for an increase in the dispersion in f are easily derived. It turns out that:

$$(8) \qquad \frac{\partial P_o^*}{\partial \sigma} < 0,$$

where P_o^* is the solution to (8). The reason is that an increase in σ will, ceteris paribus, cause a drop in the LHS of (7) while it will increase the RHS. To restore the equality the value of P_o must fall.

The result in (8) is consistent with the empirical observations that the average under-pricing is higher when the offer price is fixed months before the listing than when it is fixed close to the listing (See e.g. Loughran, Ritter and Rydqvist, 1994, Table 2). It also consistent with the finding that the average underpricing is higher for young firms than for old firms (see e.g. Loughran, Ritter and Rydqvist, 1994, Figure 2).

Log-linear demand

By restricting the functional form of the demand function in (2) we may derive some

further results. Assume that the demand is log-linear in the price, that is:

(9) $\ln(Q) = \alpha - \beta \ln(P) + \varepsilon,$

where $-\beta$ is the price elasticity of demand, and ε is assumed to be normally distributed around zero with a standard deviation of σ.

Denote the price at which the expected value of the logarithm of the quantity demanded equals the size of the initial offering by P^*, that is[13]:

(10) $\ln(Q^*) = E[\ln(Q)] = \alpha - \beta \ln(P^*).$

The optimal probability of failure is now given by expression (7). Accordingly the price should be set so that the expected logarithm of the quantity demanded equals:

(11) $\ln(Q^*) + \sigma N^{-1}(\dfrac{c_s - C_f f(P_o)}{c_s + c_f}),$

where N^{-1} is the inverse of the standard normal cumulative density function.

The optimal offer price is the solution to the following equation which is obtained by putting the expectation of the RHS of (9) equal to (11):

(12) $P_o = \exp\left(\dfrac{\alpha - \ln(Q^*)}{\beta}\right) \exp\left(-\dfrac{\sigma}{\beta} N^{-1}(\dfrac{c_s - C_f f(P_o)}{c_s + c_f})\right),$

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[13] At this price the expected value for the quantity demanded will be higher than the size of the initial public offering (Jensen's inequality).

where the RHS contains a product of two expressions, the first one being the price under certainty and the second one the modification imposed by the presence of uncertainty.

A simple solution is obtained if the fixed costs of a failure C_f equals zero. In that case (12) reduces to:

$$(13) \quad P_o = \exp\left(\frac{\alpha - \ln(Q^*)}{\beta}\right) \exp\left(-\frac{\sigma}{\beta} N^{-1}(\frac{c_s}{c_s + c_f})\right).$$

Expression (13) provides us with some further interesting comparative static insights. The offer price will decrease with:
1) an increase in the size of the offering,
2) an increase in the uncertainty concerning the demand,   and as before
3) a decrease (increase) in the costs due to underpricing (overpricing).

An additional interesting conclusion that emerges from (13) is that the required underpricing (given the price under certainty) will increase with a decrease in the price elasticity of the demand. This implies that the required underpricing will be higher in less liquid markets. This in turn is consistent with the observed tendency for IPOs to occur mainly when the market turn-over is high[14].

It is fairly easy to prove that the comparative static results above will hold also when C_f is larger than zero, that is, in the general case of (12), provided that the derivative is taken for an offer price which is below the mean of the distribution. The technical reason is that the additional term, which is not included in (13), will re-enforce the original change. That is, if the price drops when the fixed cost is not taken into account then it has to drop even more to restore the optimum when the fixed cost is included.

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[14] For international evidence see Loughran, Ritter and Rydqvist (1994).

Going back to expression (2) it easily seen that there is a trade-off between underpricing and obtaining a more precise estimate for the value of the firm. More information will reduce σ, and thus through (12) the required underpricing. On the other hand more information will imply larger information costs.

Since the returns to more information in the form of a more precise evaluation of the firm are decreasing there will be a cut-off point where the collection of more information will be unprofitable. Since the cost of collecting information about a firm are in part independent of firm size this point is reached earlier for small firms going for small IPOs than for large firms. This explains why a larger underpricing on an average is observed for small firm IPOs than for large firm IPOs.

Going back to expression (6) it seems clear that underpricing is what we would expect in the case of IPOs. Does this mean that those who subscribe to IPOs are making excess profits? No, because usually when there ex post turns out to be underpricing there will be quantity rationing. Quantity rationing together with a downward sloping demand curve will imply the existence of a winner's curse (Rock, 1986). The winner's curse means that an undiscriminatory subscription policy will yield a large number of shares when the offering is not that popular and a small number when it turns out to be highly popular. As shown by, e.g. Keloharju (1993), the average return for undiscriminatory large scale subscriptions may thus become negative in spite of a significant average underpricing.

Summary

This paper presents a simple model for the pricing of initial public offerings. The model can be seen as a generalisation of the model in Beatty and Ritter (1986). Like in Beatty and Ritter (1986) the pivotal agent in the pricing decision is the underwriter. In this paper the underwriter's decision problem is expressed in the form of a simple loss function. The paper substitutes the informed-uninformed split in Beatty and Ritter (1986)

with a simple firm-specific downward sloping uncertain demand curve.

The optimal offer price is determined by the penalty that the underwriter is facing as a consequence of a pricing mistake. It is argued that pricing errors implying under- or overpricing will always be costly for the underwriter, and that this cost will depend on the size of the pricing error. Obviously, these costs include those that are written into the contract between the client and the underwriter. In addition there are intangible costs like loss of market share due to a battered reputation either among potential IPO firms or among potential subscribers for the IPOs.

It is shown that in the case where these costs ad up to a symmetric loss function with no fixed costs for failure the underwriter would opt for the median of the price distribution. A positively skewed distribution for the price on the day of listing would then be enough to imply an offer price which is below the mean of the distribution, i.e. underpricing.

However, it is unlikely that the loss function is symmetric. The more likely case is that pricing errors that imply overpricing are more costly for the underwriter, and that there may be a fixed cost attached to a failure. In that case the underwriter would opt for an offer price which is below the median, i.e. for deliberate underpricing. The evidence that underwriters engage in price support to prevent the price of the shares to fall below the subscription upon listing as documented by Ruud (1993) and Hanley, Kumar, and Seguin (1993), and Schultz and Zaman (1994) indicate the presence of a fixed cost attached to apparent overpricing, a cost which the underwriter avoids by buying up the excess supply.

Finally, the results from the comparative static analysis showed that the underpricing is expected to increase with, an increase in the size of the offering, an increase in the uncertainty concerning the demand, a decrease in the price elasticity of the demand, and an increase (decrease) in the expected costs due to overpricing (underpricing).

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A challenge for future research is to try to specify the differences in the loss functions that will arise in different institutional settings and when different types of contracts between the issuer and the underwriter are employed. Once these differences are specified the correspondence between the predicted optimal IPO-pricing and observed actual pricing of IPOs can be analysed.

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