The Effect of Uncertainty on the Underpricing of IPOs

Jason Draho*
Department of Economics
Yale University

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Abstract

It is often claimed that uncertainty over the firm value will lead to underpricing in an IPO. Surprisingly, there is little theoretical justification for this conjecture with bookbuilt IPOs. This paper analyzes the effect of uncertainty by developing a model of the IPO process that endogenizes the price setting in both the primary and secondary markets. Underpricing will occur if there is uncertainty over the initial secondary market price. This uncertainty decreases as the quality and quantity of information produced in the primary market increases. In the limit the information generated in the primary market perfectly forecasts the secondary market price and the need to underprice is eliminated, even when there is residual uncertainty about the firm value. When the information production is insufficient, underpricing is the premium paid to investors for insuring the firm against an adverse market outcome. Underpricing will then increase in the ex ante uncertainty over the firm value. The results suggest that IPO mechanisms which generate more precise information about the likely secondary market price will require less underpricing.

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1. Introduction

Uncertainty has a pervasive presence throughout the IPO process. Firm insiders don't know how successful the offering will be or the amount of proceeds that will be generated. Investors aren't sure how the firm will perform in the long run, nor do they know how it will be valued initially by the market. It is quite reasonable then to suggest that uncertainty will affect how the IPO is conducted. One idea widely accepted is that uncertainty over the firm value will result in underpricing, and that the two are positively related.[1]

The uncertainty-underpricing argument was originally put forth by Beatty and Ritter (1986), who extended the winner's curse explanation for underpricing of Rock (1986). Uninformed investors face the risk of receiving large allocations in poor offerings. By intentionally underpricing the IPO their participation constraint is satisfied. Increasing ex ante uncertainty, measured by the spread of the distribution, exposes the uninformed to greater downside risk, increasing the required underpricing. While intuitively reasonable the general applicability of this model is questionable. The result was derived under the assumption that the IPO was a fixed-price offering. If the bookbuilding procedure is used instead it is easy to show that the optimal pricing and allocation rules embed teh winner's curse problem, eliminating the need to underprice due to uncertainty.[2]

The objective of this paper is to determine whether uncertainty will still lead to underpricing in bookbuilt IPOs. In Beatty and Ritter the critical uncertainty was with respect to the firm value. This choice was appropriate because they assumed that the initial secondary market price would be the true value of the firm, and did not derive this as the equilibrium price. This paper endogenizes the secondary market price setting process and produces the more realistic result that the initial secondary price is an aggregate assessment of investor's beliefs, conditional on the available information, for the true value. Thus the relevant ex ante uncertainty associated with participating in the IPO is not over the firm value, but rather over the secondary market price.

[1] Jenkinson and Ljungqvist (1996) provide an extensive review of the empirical evidence on the uncertainty-underpricing relationship. Two approaches are used to proxy fot the uncertainty, the post-issue volatility of the share price and the number of uses for the funds listed in the prospectus. The evidence is overwhelming that underpricing is greater when there is more uncertainty.

[2] Recent papers by Biais, Bossaerts, and Rochet (1999) and Biais and Faugeron-Crouzet (2000) both derive an optimal IPO mechanism and show how the winner's curse problem can be embedded into the mechanism.

In the model all investors are risk averse and symmetric with respect to their private signals for the firm value. The share price that emerges in the secondary market is the Walrasian equilibrium price, which reflects all of the private information. Investors behave competitively and submit orders in the IPO that reveal their private signals. Knowing the secondary market pricing rule the issuer will form an expectation for the secondary price conditional on the revealed signals. The expectation will be noisy if there are investors with private signals who did not participate in the IPO. This leaves residual uncertainty over the secondary market price when the IPO must be priced. As Beatty and Ritter pointed out this risk that leads to underpricing is non-systematic. Investors participating in the IPO are exposed to the one-time uncertainty of learning the market assessment for the firm. The systematic risk associated with the firm's future cash flows will affect the value of the firm, but it does not require underpricing.[3]

Intentional underpricing requires not only uncertainty over the secondary market price, but that it also increases the expected utility of the issuer. This condition will hold if both the firm and underwriter are risk averse. In the absence of a primary market the issue proceeds would be based on the secondary market price. The uncertainty of these proceeds exposes the issuer to a great deal of risk. If the shares are instead sold in the primary market at a price less than the expected secondary market price, the expected issue proceeds are reduced, but the expected utility is increased. The sale of the shares in the IPO represents a transfer of pricing risk from the issuer to the initial investors. Since these investors are also risk averse they will buy only if the offer price is less than the expected secondary price. By acquiring this risk investors insure the issuer against an adverse market outcome, and the premium for this insurance is the underpricing.

By making the dependence of the secondary market price on the private information explicit, the model demonstrates the importance of producing information in the primary market. The more private information that is revealed in the primary market, the lower is the uncertainty over the secondary price. In the limit when all private information is revealed there is no uncertainty and underpricing is not required. This is true even if there is residual uncertainty about the firm value. If the information production is insufficient the required underpricing will

[3]An argument for underpricing as a consequence of risk characteristics was proposed by Mauer and Senbet (1992). The risk profile of the IPO firm had idosyncratic risk that was not spanned by the existing assets in the economy. In addition, only a subset of all investors participated in the offering. The discount rate used to value the firm in the IPO was higher than the secondary market rate because it was decreasing in the number of investors buying the shares. This led to a positive first-day return.

be increase with the ex ante uncertainty over the firm value. The model replicates the original conjecture by Beatty and Ritter, but it also shows that the degree of underpricing has more to do with the information quality than the dispersion in possible firm values.

The relationship between the quality and quantity of information produced in the primary market and underpricing enables a comparison of the efficiency different IPO mechanisms in dealing with uncertainty. Auction-type mechanisms, such as those used in France and the U.K., are open to all investors, who are required to submit price-quantity bids. By constructing an aggregate demand curve the underwriter can form a fairly precise expectation for the secondary market clearing price. In contrast, underwriters do not incorporate the orders by retail investors when setting the offer price for bookbuilt IPOs. Nor are investors required to submit limit prices in their orders (Cornelli and Goldreich (2000)). The conditional expectation for the secondary market price should be less precise for bookbuilt IPOs relative to the auction-type mechanisms, and consequently underpriced more. There is some evidence, based on IPOs in France, that this does happen.[4] Fixed price offerings produce no information prior to setting the price. These offerings should have, and in fact do have, the largest first-day returns.[5]

A large theoretical literature on the issue of underpricing exists.[6] The insurance premium argument proposed in this paper is a complementary, rather than competing, explanation. Underpricing the IPO to compensate regular investors or to signal positive firm information does not conflict with the need to underprice when there is uncertainty over market values. A different insurance motive for underpricing was proposed by Tinic (1988), and later formalized by Hughes and Thakor (1993). The underpricing was an implicit insurance payment by the underwriter and issuing firm to guard against legal action by disgruntled new shareholders upset at the firm's performance.[7] In this paper the underpricing insurance premium buys the issuer the participation of investors in the IPO.

[4]Section (3.1) of the paper has a more detailed discussion of the alternative IPO mechanisms and the effect of uncertainty. Evidence consistent with the conjecture is presented.

[5]Fixed price offerings are more prone to the winner's curse and this may be the reason for the additional underpricing, not the poor information production.

[6]Suggested motives for underpricing include the winner's curse (Rock (1986)); informational rent for informed investors (Benveniste and Spindt (1989)); signalling by good firms (Allen and Faulhaber (1989), Grinblatt and Hwang (1989), and Welch (1989)); to generate information cascades and herding (Welch (1992)); and costs to information production (Chemmanur (1993)).

[7]The evidence on this insurance argument does not support the claim.

The remainder of the paper is as follows. Section 2 describes the information structure and the objectives of the firm and investors in the model. The pricing mechanism in both the secondary and primary markets are developed. The motivation and characterization of the underpricing is derived. A discussion of the effect of uncertainty under alternative IPO mechanisms, the role of the underwriter, and the impact of price stabilization follows in section 3. Section 4 concludes.

2. The Model

A firm about to undertake an IPO is owned by a risk averse entrepreneur. The entrepreneur would like to sell S shares in the offering and will choose an offer price that maxmizes his expected utility of the IPO proceeds.[8] The role of the underwriter is suppressed and the entrepreneur will sell directly to investors. Following the entrepreneur's announcement for the IPO investors acquire a noisy signal for the firm value and submit an order for shares in the offering. The IPO is conducted by the bookbuilding method. The entrepreneur sets the offer price and allocates shares conditional on the submitted demand. Trading begins in the secondary market immediately after the allocation. The time elapsed between the submition of orders and the start of trading is sufficiently short that no new information is revealed in the interim. There is only a single round of trading in the secondary market, after which the firm is shut down and pays a liquidating dividend equal to the value per share.

The true value per share is v, which is unknown to both the entrepreneur and investors. The value v can be decomposed into two parts, an industry parameter θ and a firm-specific value e. This decomposition reflects the fact that firms from the same industry have a common component to their values. The firm value is additive in its two parts

$$v = \theta + e. \tag{2.1}$$

Over the short duration of the IPO process θ can be treated as a known fixed constant. By observing the market prices of other firms from the industry the entrepreneur and investors have some prior information about the firm value.

[8]The entrepreneur's utility may be defined over non-pecuinary benefits as well as monetary payoffs. If the entrepreneur gets private benefits from controlling the firm he may underprice to induce over-subscription by investors to allow for a discriminatory allocation of shares and the optimal ownership structure. (See Brennan and Franks (1997)). Non-monetary factors are not considered in the price setting process.

The uncertainty over v arises from the firm-specific component e. Firm values are normally distributed around the industry average θ, implying that e is distributed

$$e \sim N\left(0, \frac{1}{\rho}\right). \tag{2.2}$$

The entrepreneur does not have any private information about e. From his perspective the private signals that investors receive for e are equivalent to a relative assessment of the firm with respect to the industry average. This information can not be known by the entrepreneur prior to the IPO.

The entrepreneur's entire wealth is tied to the firm. By conducting the IPO he is able to partially liquidate his holdings.[9] Let π equal the proceeds from the IPO, which is a random variable at the start of the IPO process. The entrepreneur's utility function has the negative-exponential form

$$U(\pi) = -e^{-\pi}. \tag{2.3}$$

Given the constraints imposed upon him by the investors and the IPO mechanism, the entrepreneur will choose an offer price p_1 to maximize his expected utility.

2.1. Investors

A total of N investors will participate in the IPO, which is a subset of the total $N + M$ investors who can buy the shares in the secondary market. The number N is a restriction imposed by the entrepreneur, who prefers to sell to a few large institutional investors. No distinction is made between institutional and retail investors, although the limiting case where M goes to infinity implicitly assumes that many small retail investors are taking part.

Every investor has the same negative-exponential utility function

$$u(w^i) = -e^{-w^i}, \tag{2.4}$$

where w^i is the initial wealth of investor i. There are only two assets available for investors, shares in the new firm and a riskless asset. The riskless interest rate is normalized to zero. Prior to the IPO each investor has an initial endowment of the risk free bond equal to w^i. Investors who participate in the IPO can re-balance their portfolio immediately after that in the secondary market.

[9] No assumption is made about the fraction of the total equity sold in the IPO. S is exogenously specified and the entrepreneur will maximize his utility over the sale of these shares, and not chose S to maximize his total wealth.

All investors receive a noisy signal for the value v denoted by s^i. The signal structure is

$$\begin{aligned} s^i &= \theta + e + \omega + \varepsilon^i & (2.5) \\ &\equiv v + \omega + \varepsilon^i, & (2.6) \end{aligned}$$

where ω is a common error observed by all investors and ε^i is an idiosyncratic error specific to investor i. The common error ensures that the price in the secondary market does not fully-reveal v. The error components ω and ε^i, for all i, are independent and normally distributed

$$\omega \sim N\left(0, \tfrac{1}{\beta}\right), \quad \varepsilon^i \sim N\left(0, \tfrac{1}{\lambda}\right). \tag{2.7}$$

With these error components each signal s^i is distributed

$$s^i \sim N\left(v, \frac{1}{\delta}\right) \tag{2.8}$$

where

$$\delta = \frac{\beta\lambda}{\beta + \lambda}. \tag{2.9}$$

Conditional on the signal each investor forms a posterior belief for v

$$E\left[v|s^i\right] = \frac{\rho\theta + \delta s^i}{\rho + \delta} \tag{2.10}$$

with variance

$$Var\left(v|s^i\right) = \frac{1}{\rho + \delta}. \tag{2.11}$$

Investors who purchase shares in the IPO are concerned with the secondary market price p_2 and their payoff from investing in the IPO. Only in the secondary market are the trading decisions made based on the expected dividend payment v. Since p_2 is unknown to investors, and a random variable prior to submitting an order in the primary market, there is risk to participating in the IPO because p_2 may be less than p_1. The exact amount of risk will depend on the distribution of possible firm values and the amount of information produced in the primary market.

When the conditional distributions for p_2 and v in the primary and secondary markets, respectively, are normal, and this will be shown to be true, the negative-exponential utility produces demand functions that are linear and independent of wealth. The general demand function for investor i is denoted x_t^i, conditional on his information I_t^i at time t. The primary (secondary) market is designated $t = 1$ ($t = 2$). The individual demand functions have the form

$$x_t^i = \frac{E[p_{t+1}|I_t^i] - p_t}{Var(p_{t+1}|I_t^i)}, \tag{2.12}$$

where $p_3 = v$ is the liquidating dividend.

2.2. Secondary Market

The demand by an investor in the primary market will depend on his expectation, and the variance, of p_2. The price p_2 will itself depend on the information about v revealed in the primary market. With x_1^i and p_1 both contingent on p_2, which is influenced by the information in p_1, the prices must be solved for recursively. For a set of beliefs, conditioned on the conjectured on the information produced in the primary market, we can solve for the price p_2. The pricing rule derived for p_2 is then imbedded in the price setting process in the primary market. The prices p_1 and p_2 can then be solved for jointly.

To illustrate the pricing rule for p_2 the hypothetical case of an IPO without a primary market is considered. The result is easily generalized to the case with a primary market. The price setting process in the secondary market is a Walrasian equilibrium.[10] Investors submit demand functions conditional on their private signal for v, an equilibrium price is determined, and the shares are allocated at that price. Since the demand functions are independent of wealth, the equilibrium price is not influenced by the allocation of shares that would have occurred in the primary market. The demand for investor i, conditional on p_2, is

$$x_2^i = \frac{\frac{\rho\theta+\delta s^i}{\rho+\delta} - p_2}{\frac{1}{\rho+\delta}} \tag{2.13}$$

$$= \rho\left(\theta - p_2\right) + \delta\left(s^i - p_2\right) \tag{2.14}$$

[10] The use of a Walrasian equilibrium as opposed to a rational expectations equilibrium is justified on the same grounds as in Blume, Easley, and O'Hara (1994). Traders do not know the price at which their order will execute, unless they used unrealistically complex limit orders. Conditioning their trades on contemporaneous prices is not possible, and the usual rational expectations approach is not valid.

The equilibrium price in the secondary market with $N+M$ investors is found by equating aggregate demand and supply

$$(N+M)\,\rho\,(\theta - p_2) + (N+M)\,\delta\,(\overline{s} - p_2) = S, \tag{2.15}$$

which yields

$$p_2 = \frac{(N+M)\,(\rho\theta + \delta\overline{s}) - S}{(N+M)\,(\rho + \delta)}. \tag{2.16}$$

As the number of investors becomes large, $M \to \infty$, the average signal $\overline{s}$ will converge almost surely to $v + \omega$ by the Strong Law of Large Numbers. The price p_2 will converge to a weighted average of the prior belief and the average signal

$$p_2 = \frac{\rho\theta + \delta\,(v + \omega)}{\rho + \delta}. \tag{2.17}$$

Note that this price does not equal the expected value per share conditional on all the private information, which would be $v + \omega$. The reason being that the average investor will have an expection for v equal to p_2 in (2.17). The remaining investors have expectations either above or below p_2 and take long and short positions, respectively, that cancel out.

At the beginning of the IPO process, before investors have received signals for the value, the entrepreneur can form an expectation for the secondary market price. The unconditional expectation for this price prior to the IPO is

$$E\,[p_2] = \frac{\rho\theta + \delta E\,(v + \omega)}{\rho + \delta} = \theta, \tag{2.18}$$

with corresponding variance

$$Var\,(p_2) = \frac{\delta^2 \left(\frac{1}{\rho} + \frac{1}{\beta}\right)}{(\rho + \delta)^2}. \tag{2.19}$$

For notational simplicity define $\phi = Var\,(p_2)$.

In the absence of a primary market the entrepreneur would be faced with considerable uncertainty over the proceeds generated by the sale of the shares. His expected utility from selling the S shares to investors would be

$$E\,[U\,(\pi)] = E\,[-\exp - [Sp_2]]\,. \tag{2.20}$$

The price p_2 is normally distributed which means that the expected utility can be re-written in the certainty equivalent form. Formally

$$E\left[U\left(\pi\right)\right] = -\exp\left[-\left(E\left[Sp_2\right] - \frac{1}{2}S^2 Var\left(p_2\right)\right)\right]. \tag{2.21}$$

Plugging in the expressions from (2.18) and (2.19) into (2.21) yields

$$E\left[U\left(\pi\right)\right] = -\exp\left[-\left(S\theta - \frac{1}{2}S^2\phi\right)\right]. \tag{2.22}$$

The entrepreneur is indifferent between selling the shares directly into the secondary market at an expected price p_2 and pre-selling to N investors at price p_1 if

$$Sp_1 = S\theta - \frac{1}{2}S^2\phi, \tag{2.23}$$

or

$$p_1 = \theta - \frac{1}{2}S\phi. \tag{2.24}$$

The entrepreneur would be willing to pre-sell the shares at a price less than θ, but greater than p_1 in (2.24), because it eliminates the uncertainty in the IPO proceeds. This conclusion will continue to hold when a primary market is added and the entrepreneur can generate information from investors that makes the expectation for p_2 more precise. This result is a necessary condition for underpricing to occur, but it is not sufficient. Whether underpricing has to occur depends on the investors and their willingness to take ownership of the risky shares.

2.3. Primary Market

The entrepreneur will set the offer price p_1 after investors have submitted their application for shares. This allows the price to incorporate the private information of the N investors and reduce the risk to investing in the IPO. Assuming that a price function similar to equation (2.17) holds, an investor's conditional expectation for p_2 will be normally distributed. This assumption ensures that the demand function for investor i will again have the linear form

$$x_1^i = \frac{E\left[p_2|s^i\right] - p_1}{Var\left(p_2|s^i\right)}. \tag{2.25}$$

The variance term $Var\left(p_2|s^i\right)$ will be independent of the signal s^i and depend only on the parameters. If an investor submits a demand function that specifies a quantity for each offer price, or even a single price-quantity pair, and he knows the pricing rule for p_2, the entrepreneur will be able to back out the signal s^i from $E\left[p_2|s^i\right]$. For the entrepreneur to infer the private information an investor must submit an order that truthfully reveals his signal s^i. In order to avoid the additional complications imposed by strategic behavior the investors are assumed to act as price takers, and do not misrepresent their signal to manipulate the offer price or beliefs. This assumption is partly justified by Benveniste and Spindt (1989), who showed that a bookbuilding type of mechanism can truthfully elicit the private information of investors.

Conditional on the private signals from the N investors the entrepreneur will form a posterior belief for v. Defining this expectation to be $\overline{v}$ it equals

$$\overline{v} \equiv E\left[v|s^1, \ldots, s^N\right] = \frac{\rho\theta + N\delta\overline{s}}{\rho + N\delta}, \tag{2.26}$$

where $\overline{s}$ is the average of the N signals. This expectation contains only a subset of all the private information of investors. The remaining information will be revealed in p_2. In order to determine the optimal offer price the entrepreneur must first form an expectation of p_2, conditional on $\overline{v}$. This requires the derivation of a new pricing rule, similar to (2.17). Since the entrepreneur uses $\overline{v}$ to form the expectation and set the offer price, which is observed by investors, the aggregate information produced in the primary market, $\overline{s}$, will be revealed to investors before the start of the secondary market. The primary market information will consequently affect the equilibrium price in the secondary market.

For the N investors who participated in the IPO $\overline{s}$ already reflects their private information, which means their posterior belief for v is $\overline{v}$. With identical information sets the demand from these investors in the secondary market is also identical and equal to x_2^i. The demand is a function of $\overline{v}$ and will be

$$x_2^i = \rho\left(\theta - p_2\right) + N\delta\left(\overline{s} - p_2\right). \tag{2.27}$$

For the remaining M investors each deduces $\overline{s}$ from p_1 and will use this information to update his expectation for v. For investor j out of set M

$$\begin{aligned} E\left[v|\overline{v}, s^j\right] &= \frac{\left(\rho + N\delta\right)\overline{v} + \delta s^j}{\left(\rho + N\delta\right) + \delta} && (2.28) \\ &= \frac{\rho\theta + \left(N+1\right)\delta\overline{s}^j}{\rho + \left(N+1\right)\delta}. && (2.29) \end{aligned}$$

The second equality was found by substituting in for $\overline{v}$. The term $\overline{s}^j$ is the average private signal for the N investors from the primary market and the jth investor from M. The demand by the jth investor in set M will be

$$\begin{aligned} x_2^j &= \rho\left(\theta - p_2\right) + \left(N+1\right)\delta\left(\overline{s}^j - p_2\right) \\ &= \rho\left(\theta - p_2\right) + \delta\left(N\overline{s} + s^j - \left(N+1\right)p_2\right) \end{aligned} \tag{2.30}$$

The equilibrium price is again determined by equating supply and demand. The equilibrium requires

$$Nx_2^i + \sum_{j=1}^{M} x_2^j = S, \tag{2.31}$$

which, by substitution, equals

$$N\rho\left(\theta - p_2\right) + N^2\delta\left(\overline{s} - p_2\right) + M\rho\left(\theta - p_2\right) + M\delta\left(N\overline{s} + \overline{s}^M - \left(N+1\right)p_2\right) = S. \tag{2.32}$$

The term $\overline{s}^M$ is the average signal over the M investors. Solving for p_2 yields

$$p_2 = \frac{\left(N+M\right)\rho\theta + \left(N^2 + MN\right)\delta\overline{s} + M\delta\overline{s}^M - S}{\left(N+M\right)\rho + N^2\delta + M\left(N+1\right)\delta}. \tag{2.33}$$

In the limit economy as M tends to infinity the mean signal for the M group of investors will converge almost surely to $v + \omega$. Dividing both the numerator and denominator in (2.33) by M and letting M go to infinity gives the secondary market price:

$$p_2 = \frac{\rho\theta + N\delta\overline{s} + \delta\left(v + \omega\right)}{\rho + \left(N+1\right)\delta}. \tag{2.34}$$

Compared with the price in (2.17) this price function includes the information produced in the primary market $\overline{s}$. The M investors dominate the secondary market and p_2 will reflect there aggregate beliefs. After the primary market the belief of the M investors for v is $\overline{v}$, which they then update based on their private signal. As with the price in (2.17) the price in (2.34) equals the mean expectation of the M investors.

With knowledge of the pricing rule in (2.34), the entrepreneur can form a conditional expectation for p_2 equal to

$$\overline{p}_2 \equiv E\left[p_2|\overline{s}\right] = \frac{\rho\theta + N\delta\overline{s} + \delta\left(\frac{\gamma\theta + N\lambda\overline{s}}{\gamma + N\lambda}\right)}{\rho + \left(N+1\right)\delta}, \tag{2.35}$$

where

$$\gamma = \frac{\rho\beta}{\beta + \rho}. \tag{2.36}$$

Based on this expectation the entrepreneur can procede to setting the offer price. By assumption the entrepreneur is constrained to setting a price not greater than $\overline{p}_2$. If a sufficient number of investors submit demands based on expectations higher than $\overline{p}_2$ the entrepreneur could sell all the shares to these investors at a price greater than his expectation. But with all private information revealed during secondary market trading investors will learn that the offer price was too large. To avoid the loss to his reputation from following such a strategy, the entrepreneur will set the offer price less than or equal to $\overline{p}_2$. The second constraint on the entrepreneur in setting p_1 is the uncertainty over p_2. The uncertainty is measured by the conditional volatility

$$\sigma_{p_2}^2 = Var\left(p_2|\overline{s}\right), = \frac{\delta^2\left(\frac{1}{\gamma+N\lambda}\right)}{\left(\rho + \left(N+1\right)\delta\right)^2}. \tag{2.37}$$

The pricing function in (2.34) is known to all investors. The price is a function of the private signals of the N primary market investors. For this to be true the investors had to use the linear demand functions in (2.25), which required that p_2 be normally distributed. With p_2 a linear function of $\overline{s}$, v, and w, all normal variables, this condition is met. There are two demand functions that are applicable to the investors in the primary market. The demand in (2.25) is submitted by investors at the start of the primary market, and reveals their signal. Once the entrepreneur aggregates the signals and sets an offer price the investors have a different demand. This new demand reflects the fact that their conditional expectation and volatility are not based on the signal private signal s^i, but rather the aggregate signal $\overline{s}$. The entrepreneur will set p_1 based on these new demands.

For the investors to deduce $\overline{s}$ from the offer price they have to know the pricing rule used by the entrepreneur to set p_1. The optimal pricing policy for the entrepreneur is stated in the next proposition.

Proposition 2.1. *The entrepreneur maximizes his expected utility by underpricing the IPO in the primary market, setting the offer price equal to*

$$p_1 = \overline{p}_2 - \sigma_{p_2}^2\frac{S}{N}, \tag{2.38}$$

and allocating an equal number of shares, S/N, to all N investors.

Proof. See Appendix.

The entrepreneur's willingness to underprice stems from his desire to eliminate the risk of owning shares with an uncertain payoff. By selling the shares in the primary market he transfers the risk of secondary market pricing to investors. A simple comparison shows that underpricing in the primary market increases his utility. This is true if the following inequality holds

$$-\exp-\left[S\left(\overline{p}_2-\sigma_{p_2}^2\frac{S}{N}\right)\right]>-\exp-\left[S\overline{p}_2-\frac{S^2}{2}\sigma_{p_2}^2\right], \tag{2.39}$$

which holds if $N>2$. The term on the left side of the inequality is the utility from selling the S shares at price p_1 from (2.38) in the primary market. The right side is the certainty equivalent of the expected utility from selling directly into the secondary market, with the proceeds determined by p_2.[11]

The underpricing is required because the investors take on the pricing risk. The reallocation of risk is optimal because it is now spread over a large number of investors instead of the single entrepreneur. The investors insure the entrepreneur against an adverse outcome in the secondary market, and the underpricing is the premium required to pay for the insurance.

As more investors participate in the IPO, increasing N, the risk can be spread over a larger group, reducing the amount of underpricing required. There is another effect associated with increasing N on underpricing that is even more important than risk spreading. With a larger pool of investors the information generated becomes more precise. The point is made in the next corollary.

Corollary 2.2. *As the fraction of all investors who participate in the IPO increases the information produced provides a more precise estimate for p_2. The intentional underpricing goes to zero, even if there is residual uncertainty about the firm value.*

Proof. See Appendix.

In the limit, with all investors participating in the IPO, there is no residual uncertainty about the secondary market price. Without any pricing risk for the investors there is no need to underprice. However, since all investors received

[11] Without p_1 to reveal $\overline{s}$ the variance $\sigma_{p_2}^2$ in the right side would be even larger, which makes selling in the primary market even more desirable.

the common error component ω there is still residual uncertainty about the value v. This conclusion does not rely on taking limits, and is not a large sample phenomenon. To illustrate this point consider the case of a finite number of investors. The pricing function in the secondary market will have the form in (2.33). If the total number of investors equals $\overline{N} = N + M$, the price when all investors participate in the IPO, or $M = 0$, will be

$$p_2 = \frac{N\rho\theta + N^2\delta\overline{s} - S}{N\rho + N^2\delta}. \tag{2.40}$$

With all of the private information revealed in the primary market the conditional variance for p_2 is 0 and there is no underpricing.[12] Increasing the percentage of investor participation in the IPO reduces underpricing because it improves the quality of information, even if the risk sharing benefits are unaffected.

The first criteria for this equilibrium result to hold was that investors knew the pricing rule for p_2. They must also know the pricing policy of the entrepreneur for p_1 so they can infer the aggregate information $\overline{s}$. The values for S,N, and $\sigma^2_{p_2}$ are constants and functions of known parameters. By observing p_1 the investors can back out $\overline{s}$ from $\overline{p}_2$. The offer price p_1 can be interpreted as a public signal for the information produced in the primary market.

The optimality of an equal allocation of shares is a consequence of all investors being identical with respect to their risk preferences. Deviating from this allocation would require unnecessary underpricing to induce an investor to purchase additional shares. Relaxing this assumption by allowing for different risk aversion coefficients would result in larger allocations for the least risk averse. The exact effect on underpricing will depend on the profile of risk aversion coefficients across investors. As long as the entrepreneur and investors are risk averse underpricing due to uncertainty will be necessary if there is insufficient information production,and this is independent of other motives for underpricing.

When only a subset of all investors participate in the IPO the amount of underpricing will depend on the conditional volatility $\sigma^2_{p_2}$. This term is a function of the precision of the prior beliefs and the noise in the private signals. The impact of the precision terms is stated in the next corollary.

[12] When N is large enough, and S/N tends to zero the price p_2 will converge to the conditional expected value given all the information. For a finite N the fact that p_2 is less than the expected value is a result of the residual uncertainty due to the common error ω. Each investor takes on a small position in an asset that still has a risky payoff. To clear the market the price is below the expected value.

Corollary 2.3. *Underpricing will increase in the ex ante uncertainty over the firm value and in the variance of the private signals received by investors.*

Proof. See Appendix.

The ex ante uncertainty in the firm value is measured by the precision ρ. A decrease in ρ leads to a greater spread in possible values. The greater variance in possible values increases the uncertainty over the possible secondary market prices, which leads to additional underpricing. Similarly, as the private signals s^i become less precise investors face greater uncertainty over the possible value of p_2, again leading to further underpricing. The model produces the result assumed frequently in the literature, that underpricing increases in the uncertainty in the firm value. However, the effect is only indirect through the precision for p_2. Further, this uncertainty is a necessary condition for underpricing, but it is not sufficient.

3. Discussion

3.1. Alternative IPO Mechanisms

The bookbuilding method for IPOs is only one of a few different mechanisms being utilized in various countries. The fixed price method is common in the U.K. and most Asian countries. Uniform price auctions are used in Isreal, and more recently in the U.S. with the creation of OpenIPO.com. Auction-type mechanisms are used in France and the U.K., called the *Offre à Prix Minimal* and Offer for Sale by Tender, respectively.

The impact of uncertainty on IPO pricing will depend on the specific features of the mechanism. The entrepreneur must have discretion in setting the offer price for there to be intentional underpricing. Underpricing can not occur in uniform price auctions, where the offer price equals the bid of the marginal investor. Uncertainty over the secondary market price may affect the bidding strategy of an investor, but it does not affect the actions of the entrepreneur.[13]

[13] The absence of intentional underpricing does not preclude the possibility of positive first-day returns. Kandel, Sarig, and Wohl (1999) document that IPOs in Isreal conducted as uniform price auctions had significant average first-day returns of 4.5 %. They find that the return is positively related to the elasticity of the demand curve in the auction. This finding does raise the interesting issue of just how much of the initial return is due to underpricing in other IPO mechanisms.

In the auction-type mechanisms investors submit applications for shares that specify both price and quantity. The entrepreneur can then compute the aggregate demand curve, determine the market clearing price, and set the final offer price.[14] These auction-style mechanisms are similar to bookbuilding in that they grant the entrepreneur discretion in setting the offer price. However, they differ in the quality and quantity of information produced in the primary market. The preceding analysis on price setting in bookbuilt IPOs assumed investors submitted demand curves in the primary market, but actual orders are often less informative. "Strike" bids, which specify a number of shares or total dollar amount regardless of the price, are commonly used. These bids provide little information to the entrepreneur about the investor's private valuation. In addition, bookbuilding provides preferential treatment to institutional investors. Shares may be set aside for retail investors, but the retail demand does not factor into the pricing. In contrast, the auction-type method treats bids from retail investors equally with those of institutional investors.

More and better information is generated in the auction-type mechanisms that will indicate the likely secondary market price. The lower uncertainty over the market price dictates that less underpricing is required for these mechanisms. Evidence consistent with this claim is provided in Derrien and Womack (2000). Using a sample of IPOs conducted in France from 1992 to 1998 they compared the first-day returns of 99 IPOs sold through the *Offre à Prix Minimal* (OPM) method and 135 sold by bookbuilding. The average first-day return for the book-built IPOs was 16.9%, compared to 9.7% for the OPM offerings. More telling is the volatility of the initial return, with standard deviations of 24.5% and 12.25% for bookbuilding and OPM, respectively. The greater accuracy that the OPM method achieves in pricing the offering relative to the secondary market price reduces uncertainty for investors. The difference in the initial returns may be explained in part by the reduced underpricing due to lower risk for OPM IPOs.[15]

[14] There is no formal mechanism that maps the market-clearing price to the offer price, which is set at the discretion of the underwriter and firm. The justification for the underpricing is that it is informational rent to investors for revealing their private valuations. See Biais, Bossaerts, and Rochet (1999) and Biais and Faugeron-Crouzet (2000) for an analysis of the optimality of these auction-type mechanisms.

[15] This finding might be influenced by a selection bias in the types of firms choosing each mechanism. The smallest and largest firms used the bookbuilding procedure, whereas medium size firms were more likely to use the OPM method. Derrien and Womack do not provide results on the relationship between the size and underpricing for the bookbuilt IPOs. If the results are weighted more towards smaller firms, and there is greater uncertainty over their value, the

While bookbuilding produces less information than auction-style mechanisms, it certainty produces more than fixed price offerings. By setting the price before investors have applied for shares the private information can not be incorporated. This entails the greatest risk for investors, necessitating the largest underpricing. Although it should be pointed out that this risk also reflects the winner's curse problem investors will face in fixed price offerings. However, the entrepreneur also faces the added risk that the offering will be under-subscribed at a given price. To lower the risk of an unsuccessful offering the entrepreneur is willing to underprice even more. The evidence does show that first-day returns are largest for fixed price offerings.[16]

The primary market for fixed price offerings isn't without information production. Early indications of the demand can leak out through informal chanels to investors. If the early information about demand is favorable, indicating that the offer price may be too low, the number of orders will surge.[17] One justification for the fixed price method is that it can create information cascades, insuring the success of the offering (Welch (1992)). To increase the probability that a positive cascade starts the IPO is underpriced. By waiting investors can reduce the risk of participating in the IPO if there is some information production. By this argument uncertainty leads to underpricing for fixed price IPOs more to insure the success of the offering, than as an insurance premium to investors.[18]

3.2. The Underwriter

The entrepreneur would not be able to undertake the IPO without an underwriter providing advice on the timing and pricing of the IPO and marketing the offering to investors. How the presence of an underwriter affects the pricing when there is uncertainty will depend on the regulatory environment. For both the fixed price and auction-type mechanisms the underwriter has a relatively passive role. It will distribute the prospectus to investors, collect the orders, and allocate the

additional underpricing is consistent with predictions of the model.

[16]See Loughran, Ritter, and Rydqvist (1994) for an international comparison of first-day returns across regulatory environments.

[17]Chowdhry and Sherman (1996) provide convincing evidence that leakages happen quite frequently in Hong Kong. It is not uncommon for offerings to be oversubscribed by four or five hundred times. Word spreads informally that the offer price is set too low, leading to high demand.

[18]In a comparison of bookbuilding and fixed priced methods, Benveniste and Busaba (1997) find that bookbuilding generates larger expected proceeds, but exposes the firm to greater uncertainty.

shares. Its primary function is to certify the quality of the firm, which should reduce the risk investors have over the firm value. This will reduce the necessary underpricing, but does not eliminate it.

For bookbuilt IPOs the underwriter makes a more concerted effort to sell the offering to investors. The same certification role is performed, which will again reduce underpricing. While the entrepreneur was willing to underprice because he was risk averse, it was the risk aversion of investors that made underpricing necessary and determined its amount. Assuming that the underwriter is also risk averse, if not over the proceeds, then over the loss in reputation capital when it underwrites an unsuccessful offering, the required underpricing given by equation (2.38) should continue to hold. Adding an underwriter to model, and assuming no agency conflicts between the entrepreneur and underwriter arise, does not change the general uncertainty-underpricing results.

For bookbuilt IPOs two different contractual arrangements between the entrepreneur and underwriter can be used, best efforts and firm commitment. The responsibility of any unsold shares falls on the entrepreneur and underwriter, respectively, for these methods. The observed difference in initial returns for the two methods, best efforts returns are far larger, can be influenced by uncertainty for two reasons already discussed. First, the underwriter provides a stronger certification signal to investors for firm commitment offerings. Best efforts firms tend to be a biased selection of the riskiest firms that require greater underpricing. Second,the offer price in a best efforts IPO is set two months in advance of the offer date and before investors have submitted orders. Essentially a fixed price offering, best efforts IPOs produce less information and should lead to greater underpricing.

3.3. Price Stabilization

The risk to investors from buying shares in the IPO is that the initial secondary market price will fall below the offer price. It is common for underwriters to provide price support in initial secondary market trading to stabilize the price at the offer price.[19] With no downside risk to investing in the IPO there should be no reason to underprice due to uncertainty. Underwriters have no formal policy as to how they will provide price stabilization, but the support typically lasts for three

[19] Price stabilization activites have been documented by an number of authors, including Ruud (1993), Hanley, Kumar, and Seguin (1993), Schultz and Zaman (1994), and Asquith, Jones, and Kieschnick (1998).

to four weeks after the offer date. Recent studies by Asquith, Jones and Kieschnick (1998) and Krigman, Shaw, and Womack (1999) track the initial four-week return for IPO firms. Both papers find that IPOs which had opening prices at or around the offer price, the likely candidates for price support, produced negative four week returns. Unless the IPO investors are able to sell their allocations at the stabilized offer price, they still face short term downside price risk.[20] The need to underprice due to uncertainty over the market price will still be present, but price stabilization will minimize the required amount.

By artificially supporting the price above its equilibrium level, the underwriter is essentially reacquiring the risk that was shed by selling in the primary market. If the equilibrium price is below the offer price the underwriter will have to buy the excess shares for sale at the stabilized price, and will suffer a loss when he has to sell then later. Benveniste, Busaba, and Wilhelm (1996) suggested that since price stabilization is costly to the underwriter, it can be avoided by underpricing even further. The lower underpricing that would result from investors facing less risk due to stabilization is countered with the additional underpricing the underwriter will choose to avoid having to stabilize. The claim that stabilization is costly to the underwriter was challenged in Ellis, Michaely, and O'Hara (2000). They found that the lead underwriter works as the primary market maker for NASDAQ IPOs, and the profits made on trades, combined with a judicious use of the over-allotment option, meant that aftermarket trading activities could not be viewed as a cost to the underwriter. The net effect that price stabilization should have on the uncertainty-underpricing relationship is to reduce, but not eliminate, the need to underprice.

4. Conclusion

This paper has shown that uncertainty can lead to the underpricing of IPOs. The uncertainty is not with respect to the value of the firm, but rather the initial secondary market price. By agreeing to buy shares in the primary market investors insure the issuing firm against an adverse market response to the offering. As

[20]Krigman, Shaw, and Womack analyzed the patterns of trade on the opening trading day to determine the effect of flippers. They found that large block trades by institutional investors accounted for a larger percentage of the shares traded and the number of transations for IPOs they defined as cold. The order imbalance that suggests these were seller initiated implies that institutional investors were flipping their shares at the stabilized price, which they expected to fall. The extent to which they reduced their exposure to the downside pricing risk is unclear.

compensation the IPO is underpriced, which is equivalent to the premium the firm has to pay for this insurance. The model shows, however, uncertainty over the firm value is a necessary, but not a sufficient, condition to produce underpricing. By increasing the production of information in the primary market a more precise belief about the secondary market price can be formed. As the uncertainty about the price diminishes the need to underprice is eliminated. This result holds even when there is residual uncertainty about the firm value. If the offering must be underpriced the amount will increase in the uncertainty over the value.

The results of the model suggest that IPO mechanisms which maximize the production and transparency of the information in the primary market will lower both uncertainty and underpricing. This can be achieved by requiring orders to specify price and quantity pairs, and by allowing all investors equal access to the offering. If uncertainty is viewed as a significant cost to conducting an IPO an optimal mechanism should incorporate these features.

5. Appendix

Proof of Proposition 2.1. The utility of the entrepreneur is $-\exp-(p_1 S)$. This utility is maximized by setting the price p_1 as high as possible. The constraint on the entrepreneur is to set an offer price that will clear the primary market. Each investor will be able to infer the aggregate signal $\overline{s}$ from the offer price and will have the same individual demand functions. The price p_1 must satisfy

$$N\frac{(\overline{p}_2 - p_1)}{\sigma_{p_2}^2} = S. \tag{5.1}$$

Solving for p_1 yields

$$p_1 = \overline{p}_2 - \sigma_{p_2}^2 \frac{S}{N}. \tag{5.2}$$

Setting a price lower than this will produce excess demand and a lower utility for the entrepreneur. Each investor will be allocated the same number of shares, S/N. Deviating from this allocation rule lowers the entrepreneur's utility. For one investor to accept a larger allocation the price must be lowered. But at least one other investor is taking a smaller position. At the margin this other investor would be willing to pay more for additional shares than the investor with the larger allocation.

Proof of Corollary 2.2. The conditional variance has the form

$$\sigma_{p_2}^2 = \frac{\delta^2\left(\frac{1}{\gamma+N\delta}\right)}{\left(\rho+(N+1)\,\delta\right)^2}. \tag{5.3}$$

As N increases the numerator decrease and the denominator increases. Together $\sigma_{p_2}^2$ will decrease as the entrepreneur incorporates more signals into the expectation for p_2.

Proof of Corollary 2.2. It must be shown that $\sigma_{p_2}^2$ is inversely related to ρ. Taking the first order condition

$$\frac{d\gamma}{d\rho} = \frac{\beta^2}{(\beta+\rho)^2} > 0. \tag{5.4}$$

The variance term $\sigma_{p_2}^2$ has the form

$$\sigma_{p_2}^2 = \frac{\delta^2\left(\frac{1}{\gamma+N\delta}\right)}{\left(\rho+(N+1)\,\delta\right)^2}. \tag{5.5}$$

As ρ increases γ increases and the numerator decreases. The denominator is strictly increasing in ρ. As the precision of the firm value increases, the conditional volatility of p_2 decreases, which reduces underpricing. Taking the first order condition of δ with respect to β gives

$$\frac{d\delta}{d\beta} = \frac{\lambda^2}{(\beta + \lambda)^2} > 0. \tag{5.6}$$

The variance $\sigma_{p_2}^2$ is decreasing in δ. An increase in the precision in the common signal ω will lower the conditional volatility, and underpricing. The same result holds for the idiosyncratic noise terms ε^i.

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