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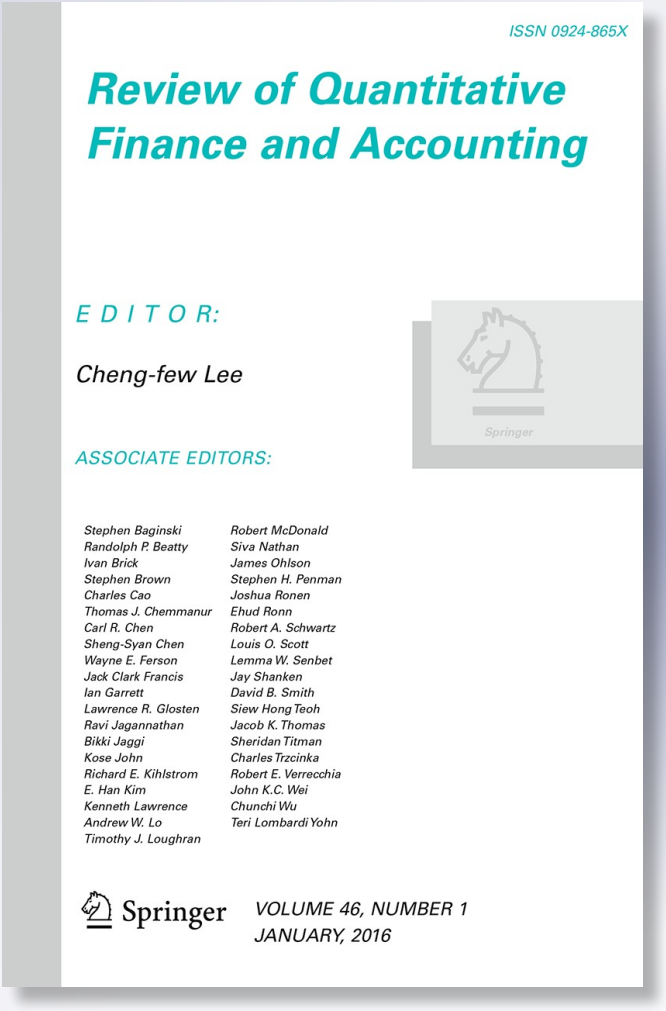

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ORIGINAL RESEARCH

A theory of underwriters' risk management in a firm-commitment initial public offering

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Abstract A cynosure of the academic literature relating to initial public offerings (IPOs) is the question of why they are "mispriced" so frequently. The large and growing literature addressing this question is evidence as to its intractability. This paper develops a theory of underwriters' behavior suggesting that they will exploit their private information to minimize the bilateral risks to themselves of firm-commitment IPOs. That minimization may cause them to knowingly underprice the issue. The main result in this paper is based, in part, on the premise that the random character of the investors' demand for shares in the secondary market, given the spread, is governed by an estimable conditional probability distribution. The underwriters exploit their private knowledge of that probability distribution to influence the number of shares in the offering in such a way as to minimize their expected loss function.

Keywords Firm-commitment IPO · Underwriting risk management · Asymmetric information

JEL Classification G24 · G32 · K22

1 Introduction

Recently a decision in a New York State Appellate Court clarified the legal relationship between the underwriters and the issuer in a firm commitment initial public offering

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(IPO).[1] The court ruled that the lead underwriter in an IPO does not owe a fiduciary duty to the issuer of securities to disclose conflicts of interest in connection with the pricing of the securities, unless the two parties have a distinct relationship of higher trust that arises apart from the underwriting agreement. The Court's decision has immediate practical implications for the apportionment of financial risks between the two entities.

Whether the lead underwriter of a public securities offering is an issuer's fiduciary is a crucial determination because it affects the standard of care owed by an underwriter to an issuer.[2] As a fiduciary, an underwriter would be obligated to act in the issuer's best interest and would owe a heightened level of care and loyalty. Alternatively, if, as the New York Appellate court held, an underwriter is merely the issuer's advisor, the obligations of the underwriter are purely contractual, resulting in a higher threshold for potential liability in the event of a dispute. The subordinate clause in the last sentence will be construed by underwriters to mean that in their negotiations with the issuer concerning the terms of the underwriting contract, they are not required to put the issuer's interests ahead of their own.[3]

The court stated that firm commitment underwriting relationships are inherently adversarial because the underwriter has an incentive to set a lower price (which makes it easier to sell shares in the offering), while an issuer seeks a higher price to maximize its proceeds from the offering. Such an adversarial relationship, the court held, cannot give rise to a fiduciary relationship.

The court's economic reasoning is correct, as far as it goes. However, it does not go far enough; the court's reasoning is biased because it fails to recognize the dual character of the risks assumed by the underwriter in a firm commitment offering.[4] This paper focuses on how information asymmetry can be exploited by underwriters to draft the terms of underwriting agreements in such a way as to minimize the dual risks to themselves of undertaking a firm commitment IPO. The legal decision cited above provides an additional incentive for the underwriters to engage in purely self-interested conduct because, absent a fiduciary relationship, they can do so with legal impunity in New York.

2 Identification of dual risks faced by the underwriters

A cynosure of the academic literature relating to IPOs addresses the question of why they are "mispriced" so frequently. A representative statement (Adams et al. 2008) is: "Why

[1] On December 8, 2011, the New York State Appellate Division, First Department, held in *EBC I, Inc. v Goldman Sachs & Co.* that Goldman Sachs & Co., the lead underwriter for the IPO of common stock by EBC I, Inc., formerly known as eToys, Inc., was not eToys' fiduciary. NY Slip Op. 08839.

[2] "A fiduciary relationship exists between two persons when one of them is under a duty to act for or give advice for the benefit of another upon matters within the scope of the relation." Restatement [Second] of Torts § 874, Comment a.

[3] The New York Court's decision did nothing to change the law that underwriters can be held criminally and/or civilly liable if they engage in acts of fraud or if they make factual misrepresentations or if they conceal significant and relevant facts.

[4] The court's asymmetric reasoning regarding the underwriters' risk and incentive(s) is mirrored by similar reasoning found in the finance literature. For example, Chen and Mohan (2002) stated: "We contend that underwriter spread may represent an explicit pricing of risk for an IPO issue and we find that it is significantly correlated with underpricing, which represents an implicit pricing of risk." That statement recognizes only one source of underwriting risk. Similar opinions are expressed in other publications of the same or later vintage. See Jones and Yeoman (2011).

IPOs are consistently underpriced is a mystery." In a paper published by Chen and Monahan (2002) the following statement appears:

> For over 20 years, researchers investigated the underpricing puzzle associated with initial public offerings (IPOs). Ibbotson (1975), Ibbotson and Jaffe (1975) and Ritter (1991) among others, adduce convincing evidence that initial public offerings are, on average, underpriced.

A representative paper by Baron and Holstrom (1980) suggests the issuer should design an underwriting agreement that nullifies the self-serving conduct of the underwriters to underprice the issue:

> In placing a new security issue, an investment banker has an opportunity to obtain private information by conducting preselling activities during the registration period. The task of the issuer is to design a contract that both induces the banker to use the information to the issuer's advantage and provides a disincentive for the banker to price the issue low in order to reduce the effort required to sell the issue.

The "task" described in the paragraph reproduced above is addressed to the same perception of underwriting risk as was identified by the New York Appellate Court decision; the Court's decision and the published literature fail to recognize that there are really two manifestations of the underwriters' risk.

The most obvious risk is that the underwriter will be unable to sell the entire issue at the offering price. The counterpart risk is manifested whenever there is an upward spike in the market price at the date the issue goes public or very shortly thereafter. In that scenario the underwriter would have realized a larger profit, and the issuer would have realized an increase in its capitalization, if more shares had been issued at the offering price.

3 The significance of information asymmetry in an IPO

Various theories attribute the first-day IPO underpricing to the existence of information asymmetry between parties to the IPO process. The paper by Guo (2005) summarizes the loci and the cause(s) of asymmetric information. Of particular interest is the paper by Baron (1982). He proposed that underwriters know more about capital markets and potential investors than IPO issuers. To the extent that Baron's theory is valid, it can help to explain why underwriters' incentives can be exploited to the detriment of issuers.

Recently a paper by Chen et al. (2010) examined the validity of Baron's model of IPO underpricing. Their paper compared self-marketed underwriters' IPOs with non-self marketed underwriters' IPOs and with IPOs they lead. Their empirical results show that Baron's model of IPO underpricing can be validated when issuer incentives are taken into account. The paper by Nguyen et al. (2010) tested for the role of risk management in alleviating the degree of uncertainty relating to the value of the issuing firm and hence in lowering the underpricing return.

At the antipodal end of the spectrum of information is Rock's theory (1986). It was adumbrated and tested in the paper by Balvers et al. (1993). The theory models underpricing as a necessary compensation to uninformed investors who face an adverse selection risk. The Rock/Balvers theory focusses on the dichotomy between the sub-population of well-informed investors and the complement sub-population of investors who are uninformed. That theory is applicable to the dichotomy between the underwriter(s) and the issuer. The underwriters have undertaken costly research and investigations of the

businesses and the finance of the issuing firm. Moreover, the underwriters' knowledge of the nuances of capital markets is (usually) vastly superior to that of the issuer. There is confirmatory evidence in a recent publication by Chong et al. (2010). That paper carried out an empirical study of H-share IPOs during the 1993–2003 period.[5] The authors concluded: "We show that the degree of IPO underpricing is positively associated with the market conditions prior to issuance."

The theory developed in this paper synthesizes some of the salient elements of the asymmetric distribution of information between the issuer and the underwriter(s).

4 The definition of a *pro-forma* underwriting agreement in a firm-commitment IPO

The terms of the underwriting agreement in this model of underwriters' behavior are assumed to be very simple. A private company decides to issue and sell stock in an IPO. The underwriting syndicate undertakes a so-called a firm-commitment underwriting contract with the issuer. The underwriting agreement provides that the offering price, the underwriters' discount and the number of shares in the issue are determined by negotiations between the parties to the underwriting agreement.

I assume the lead underwriter is a non-fiduciary. The implication of that assumption is that the underwriter has an incentive to draft the terms of underwriting agreement in such a way as to minimize the risk to itself of the sale of the stock to the public. In the negotiations the underwriter has an opportunity to exploit whatever private information accumulates in the "book." As a practical matter, the lead underwriter is assumed to represent the interests of all the members of the distribution syndicate and he is assumed to carry on all the negotiations with the issuer's representative(s).

The salient terms of the agreement are these:

The price at which the syndicate offers the shares to the investing public is symbolized by P_o. The share price paid by the underwriter(s) to the issuer for each share is symbolized by P_i. The underwriters' gross spread is $P_o - P_i$ for each share sold at the offering price in the secondary market.[6] Both prices are fixed in the underwriting agreement. Inasmuch as the underwriting syndicate purchases the entire issue directly from the issuer, that transaction is executed in the primary market.

The total number of shares to be offered to the investing public is symbolized by S. Thus, the putative capitalization of the issuer at the date IPO goes public is P_iS.

If the subscriptions to the IPO at the offering price do not exhaust the offering, the underwriters may have to realize losses. SEC regulations forbid taking unsold shares into the underwriter's trading account for resale in the early aftermarket. The unsold shares must be taken in the investment account and they must be held for at least 1 year.

If the issuer and the lead underwriter reach an agreement on the offering price and the underwriters' discount, the underwriter can exploit his private information to try to influence the number of shares in the issue to mitigate the risks to itself.[7]

[5] A special characteristic of H-shares is that they are shares of companies incorporated in China, but are also listed abroad.

[6] The underwriters' gross spread is usually expressed as a percentage discount of the offering price; e.g. P_i is 95 % of P_o.

[7] This paper does not address underwriting of IPOs which are fully subscribed ab initio. In those kinds of IPOs all uncertainty is eliminated. Sherman (2005) states that those fully-subscribed IPOs have increased worldwide since the early 1990s.

5 The loci and causes asymmetric information

Before the formal registration statement is declared effective by the SEC, the members of the distribution syndicate can engage in preliminary marketing activities. The underwriters can gather "indications of interest" from potential investors. Those are statements by investors as to how many IPO shares they may be interested in buying and the price they are willing to pay. The preliminary marketing may include sales-force calls by underwriters' representatives to investors to educate them about the company. The underwriters set up meetings with senior management of potential investors and conduct a "road show" where the underwriters' representatives travel to key cities across the country making presentations to, and fielding questions from, potential investors. The managing underwriter records all the information gathered in a metaphorical "book" in a process known idiomatically as "book building." Fleuriet (2008) states that the result of these preliminary marketing activities is to create an asymmetry of information between the underwriters and the issuer. The asymmetry can be exploited by the underwriters, but not necessarily in the way suggested by most papers published about IPO pricing.

The risk to the participants in the distribution syndicate is the uncertainty regarding the number of shares that will be sold to the public at the offering price. The underwriters cannot forecast with certainty the latent demand of the investors at the offering price. The "book" they compile during the preliminary marketing is not a perfect forecasting vehicle. The market is not certain about the quality of the IPO. The issuing firm and its underwriters cannot know for certain what the after-market trading price will be in relation to the public offering price.

A problem facing underwriters wanting to collect information useful for pricing the IPO is that potential investors have mixed incentives to truthfully reveal their private information during the pre-marketing phase. Prospective customers can bargain for a lower price, but they have a strong incentive to be at least truthful enough to be among those who will receive an allotment of shares when the offer is made. If they bluff to get a bargain price, they may see the shares go to customers who spoke frankly about their interest.

Benveniste and Spindt (1989) found that for institutional investors to reveal their true interest in the shares, they demand more underpricing. Those investors may make their interest known by specifying the number of shares they would be willing to purchase at the offer price. When investors make their indications known, they must factor in their expectations about the initial market price. From these indications of interest, the underwriter learns positive and negative information to be used to estimate a conditional probability distribution governing investors' the demand for shares. That information helps the underwriters to set the terms of the issue.[8]

One reason why the influence of information in underwriting agreements is of paramount importance is that previously published theories usually assume that the issuer or investors know (or learn) the "true value" of the IPO. For example, a recent publication by Zhang (2012) formulates a model of information "precision" in an IPO. However, the theory developed in his paper ignores the function of underwriters. Zhang's paper states: "The underwriter's role is suppressed: the issuer sells the shares directly to a representative investor." As a practical matter, it is doubtful whether any participant in the IPO knows its "true value", except in greatly delayed hindsight.

[8] There have been extensive studies of the effect of public and private information on the offer price. In addition to the study by Benveniste and Spindt (1989) cited in the text, see Bradley and Jordan (2002), Edelen and Kadlac (2005), Hanley (1993), Loughran and Ritter (2002) and Lowry and Schwert (2002).

The theory developed in this paper explicitly embodies risk management behavior by underwriters precluded by Zhang's theory; namely that the private information gathered by the underwriters during their preliminary marketing activities enables them to influence the terms of the underwriting agreement in such a way as to manage the risks to themselves. I assume they effect this management by negotiating with the issuer to determine the number of shares in the offering.

Underwriters and issuing companies negotiate the number of shares, the offer price and the underwriters' compensation together and sometimes up to the last hours before the underwriting agreement is signed and the SEC declares the registration statement effective. If all is well, the offering "goes out the window" on the first day. By most accounts, the offer price is the last item negotiated within the book building process. However, there have probably been instances where the issuer and the underwriter have become deadlocked on the offer price at the 11th hour. In those instances the underwriter can agree to the offer insisted on by the issuer conditional on lowering the number of shares in the offering.

The underwriters do not have the unilateral power to set the number of shares to be offered. However, if an issuer company adamantly insists on an unrealistically sized issue, in view of the hypothetical offer price and the information acquired by the underwriters while they solicited "indications of interest," the underwriter can be equally adamant or propose a compromise. The underwriter can also walk away if the issuer will not relent or compromise. A distinct feature of the theory in this paper is that the number of shares in the offer is endogenously determined by the influence the underwriters exercise in the determination of the parameters of the IPO.[9]

In light of the imperfect ability of the underwriters to predict the equilibrium trading price, I assume their uncertainty about the demand for shares at the offer price is regarded by the underwriters as a random variable, symbolized by X.

I assume that the book compiled by the participants in the distribution syndicate enables them to establish a continuous conditional probability density function governing the investors' demand in the public market, conditioned on the offering price. The conditional density function governing X is represented as:

$$Prob[X|offering\,price = P_0] = f(X|P_o) \tag{1}$$

For the sake of mathematical simplicity, I assume X is a continuous random variable whose range is defined as: $0 \leq X < \infty$.

6 The dichotomy of the risks assumed by the underwriting syndicate

I assume that the firm commitment underwriting agreement is drafted in such a way that the issuer avoids uncertainty: I assume the entire issue will be sold to the underwriters at a share price determined by the underwriting agreement. However, the virtual impossibility of pricing IPOs precisely in conjunction with the underwriters' proscribed hedging causes underwriters to assume dual risks. Here is a description of those risks considered exclusively from the point of view of the underwriters.

[9] The paper by Zhang (2012) makes the same assumption as to the endogeneity of the size of the IPO. That paper expressly assumes the absence of financial intermediation. Zhang's assumption vitiates the verisimilitude of his theory.

6.1 The risk to the underwriters of underpricing the IPO

One risk to underwriters is the risk that investors' aggregate demand for shares in the public market at the offering price exceeds the number of shares in the issue. It is the market scenario described by the authors of many studies of IPO underpricing (Chen and Monahan 2002; Habib and Ljungqvist 2001; Jones and Yeoman 2011). In that case, the excess demand for subscriptions at the offering price will cause the transaction prices in the after-market to increase rapidly and perhaps very sharply.

The risks associated with underpricing are borne by the issuer as well as the underwriter. The issuer will sustain an obvious loss because its capitalization will be less than what it could have realized from the IPO if they had negotiated a higher price. Adams et al. (2008) estimates that for the 15 year period antedating year 2008, the share price of the typical IPO closed roughly 15 percent above the offer price on the first day of trading. These high initial returns are captured by the original subscribers rather than by the issuer or the underwriters.

The underwriter(s) will sustain an opportunity loss for the same reason. The loss of revenue to the participants in the syndicate is measured by the spread on each share the underwriters could have sold at the offer price, but did not offer.

In an underpriced offering the participants in the underwriting syndicate cannot take advantage of the after-market price increase. An IPO offer price must be fixed, pursuant to Financial Industry Regulatory Authority (FINRA) "Rules of Fair Practice," reflecting the Securities Act of 1933 and the Securities and Exchange Act of 1934 as well as the National Association of Securities Dealers' (NASD) *Rules of Fair Practice.* That rule is embedded in a popular law text-book, Coffee and Sale (2009). The fixed price must be set before the offering goes public. All or part of the shares may be sold for less than the offering price, but shares may not be sold at a higher price. After the issuer and the underwriter agree on the offering price, it cannot be increased if the offering is over subscribed. That rule offers an incentive for the underwriter to negotiate with the issuer for a total number of shares in the issue to match the number of shares the underwriter expects to be demanded at the offering price. This matching objective identifies one of the risks borne by the underwriter.

If the syndicate offers S shares at price P_o, and investors in the public market at the date of the offering demand more than S shares at that price, then $X > S$. The conditional expected opportunity loss sustained by the syndicate if the IPO is underpriced can be calculated as:

$$(P_0 - P_i) \int_S^\infty (X - S) f(X|P_o) dX \tag{2}$$

6.2 The risk to the underwriters of overpricing the IPO.6

The risk to the underwriters of overpricing is the risk that investors' demand for shares at the offer price is less than the number of shares in the IPO. That is not a risk borne by the issuer. If the issue is overpriced the excess supply of shares in the IPO will cause the after-market equilibrium price to be smaller than the offering price. That after-market equilibrium trading price is symbolized by P.

The equilibrium trading price in the after-market at the date of the offering is regarded by the underwriters as a random variable. The information compiled in the book, and known only to the underwriters, allows the syndicate to estimate the conditional density

function governing the after-market trading price of the stock at the date the IPO is issued, given the size of the offer. The conditional density function is represented by $g(P|S)$.

The estimates of the density functions f and g enable the underwriters to calculate a conditional density function governing the after-market price if the IPO is overpriced:

$$Prob[P|X<S;P_o] = \frac{g(P|S)}{\int_0^S f(X|P_o)dX} = g(P|S;P_o) \tag{3}$$

The underwriters can use the conditional density function defined in Eq. (3) to estimate the conditional expected clearing price in the public market if the IPO is overpriced. It is symbolized by $\bar{P}$ and is calculated as:

$$\bar{P} = \int_0^{P_o} Pg(P|S;P_o)dP \tag{4}$$

If the share price paid by the underwriters to the issuer exceeds the conditional expected trading price in the public market, the underwriters can expect to sustain a loss on every share sold in that market. If the condition $X < S$ is satisfied, I assume $\bar{P} < P_i$.

The loss expected by the underwriters if the issue is undersubscribed at the offer price is measured by $P_i - \bar{P}$ for each share sold in the public market. Thus, the total loss expected by the underwriters if the issue is undersubscribed at the offer price is:

$$(P_i - \bar{P}) \int_0^S (S - X)f(X|P_o)dX \tag{5}$$

6.3 The underwriters' expected loss function

The syndicate's dichotomized expected total loss function is symbolized by $E[L]$. It is the sum of Eqs. (2) and (5)[10]:

$$E[L] = (P_o - P_i) \int_S^\infty (X - S)f(X|P_o)dX + (P_i - \bar{P}) \int_0^S (S - X)f(X|P_o)dX \tag{6}$$

7 The management of underwriting risk by a non-fiduciary underwriter

In order to analyze how the syndicate will manage the risks to itself it is necessary to characterize its (collective) attitude toward risk as well as its instrument(s) of control. The simplest attitude to impute to the syndicate, and the attitude adopted in this paper, is risk neutrality. Risk neutrality implies that expression (6) is the syndicate's objective function. I assume lead underwriter will exploit its asymmetric information advantage to draft an underwriting agreement to minimize that function.

Virtually all the published literature known to me suggests that underwriters manipulate the offering price as their instrument of control, viz. after the issuer and the underwriter

[10] The underwriters' expected loss function expressed as Eq. (5) is similar to the so-called "boundary conditions" appearing as expression (2) in Bae and Levy (1990).

determine the number of shares in the offering, the parties determine the offering price and the gross spread. I suggest an alternative theory of underwriter behavior fully consistent with the known characteristics of underwriting agreements.

This paper undertakes an analysis by assuming that the underwriters and the issuer first negotiate to determine the offering price and the gross spread. Having fixed those price parameters of the IPO in the underwriting agreement, the underwriter and the issuer then proceed to determine the "optimal" number of shares to be offered to the public. It is at this juncture in the negotiation of the underwriting agreement that the underwriters bring to bear their private information respecting the investors' latent demand for shares at the offering price. The underwriters can use the private information in their book to influence the offer price and the number of shares in the offering to minimize the total risk to themselves.

Calculations displayed in "Appendix 1" show that the underwriters' expected loss function is minimized with respect to the number of shares in the IPO when equality (7) is satisfied:

$$Prob[X \leq S | offering\ price = P_0] = \frac{P_0 - P_i}{P_0 - \bar{P}} \tag{7}$$

The numerator in expression (7) is the underwriters' gross spread. The denominator is the conditional total unit share loss expected by the syndicate if the issue is undersubscribed. That loss is the sum of the underwriters' opportunity loss per share if the IPO is underpriced (i.e. the gross spread) plus the underwriters' accounting loss in the aftermarket if the IPO is overpriced.[11]

The significance of Eq. (7) is expressed in the following proposition:

Proposition *The expected loss to the underwriters is minimized if the underwriting agreement provides that the number of shares in the issue is such that the conditional probability that no more than that number of shares will be subscribed by investors at the offering price is equal to the ratio of the underwriters' gross spread divided by the expected total loss per share if the IPO is overpriced.*

The optimality condition expressed in Eq. (7) can be analyzed to reveal how the number of shares in the IPO will be affected by changes in the price parameters. Calculations displayed in "Appendix 2" demonstrate the inequality:

$$\frac{\partial}{\partial(P_o - P_i)} Prob[X \leq S | offering\ price = P_0] > 0 \tag{8}$$

The inequality in (8) translates to Corollary 1 of the Proposition:

Corollary 1 *Self-serving behavior of the underwriters implies that the underwriting agreement will be negotiated by them to provide that the number of shares in the IPO is an increasing function of the underwriters' gross spread*

That theoretical result is completely consistent with the microeconomic theory of upward sloping market supply curves.

Calculations displayed in "Appendix 2" show:

[11] Adams et al. (2008) comments that the practitioners' idiom describes the nominal loss as the "haircut" taken by the underwriters.

$$\frac{\partial}{\partial(P_i - \bar{P})} Prob[X \leq S | offering\ price = P_0] < 0 \tag{9}$$

The inequality in (9) translates to Corollary 2 to the Proposition.

Corollary 2 *Self-serving behavior of the underwriters implies that the underwriting agreement will be negotiated by them to provide that the number of shares in the IPO is a decreasing function of the loss the underwriters expect to sustain if the issue is overpriced.*

That result is also completely consistent with the microeconomic theory of market supply curves.

8 A numerical example of the effect on the size of the issue of a change in the price expected in the secondary market

The practical implications of the inequalities in (8) and (9) can be illustrated with a simple numerical example.

The starting point is the underwriters' estimate of the conditional density function governing investors' demand for shares, given an offer price, symbolized by (1). For the sake of computational convenience, I assume the investors' demand for shares at the offering price can take on only integer values such that each value represents a block of 1,000,000 shares.

I assume that the underwriters' estimate of the conditional cdf governing the investors' demand for shares, given the offering price, is a Poisson distribution with a mean of $\lambda(P_o)$.

$$Prob[X \leq S | offering\ price = P_0] = e^{-\lambda(P_0)} \sum_{j=0}^{S} \frac{\lambda(P_o)^j}{j!}$$

The underwriters and the issuer, after preliminary analyses and discussions, agree that the offering price will be \$100 per share and the underwriters' discount will be 5 %. Thus, the share price paid by the underwriters to the issuer is \$95.

Subsequent to these preliminary discussions, but before the terms of the offering are expressed in a formal underwriting agreement and the Registration Statement and the Prospectus are declared effective by the SEC, the participants in the underwriting syndicate (or the lead underwriter) carry out the book building activities.

Potential investors are informed, *inter alia*, that the offering price of the IPO is \$100. The information accumulated in the book is sufficient for the underwriters to estimate the parameter of the cdf governing the demand for shares. I assume the underwriters estimate that at an offer price \$100, the value of $\lambda(\$100) = 10$.[12]

These estimates allow the underwriters to determine that if the offer price is \$100 per share, an issue of 15 million shares will minimize the risks to themselves. The Proposition explains how the size of the issue was determined.

If the 15 million shares are not all sold at the offering price, the underwriters expect the shares will all be sold at a discounted price of \$94.744 per share. Thus, if the IPO is not fully subscribed the nominal loss to the underwriters on every share sold at the market price is \$0.256 per share and the conditional expected loss is \$5.256 per share.

The price parameter assumptions can be substituted into Eq. (7) with the result:

[12] The mean of the Poisson distribution in the example is arbitrary.

$$\frac{P_0 - P_i}{P_0 - \bar{P}} = \frac{\$5.00\,per\,share}{\$5.256\,per\,share} = 0.9513$$

The Proposition in Sect. 7 states that a risk-neutral underwriter will want to negotiate with the issuer for a term in the underwriting agreement providing that the total number of shares in the IPO at an offering price \$100 is the value of S that satisfies Eq. (10):

$$Prob[X \leq S | offering\,price = \$100] = 0.9513 \tag{10}$$

Pursuant to the Proposition, the number of shares in the IPO that minimizes the underwriters' expected loss function is the integer value of S that satisfies Eq. (11):

$$\sum_{j=0}^{S} 10^j \frac{e^{-10}}{j!} = 0.9513 \tag{11}$$

One can find the solution value for S by consulting a table of values for the cumulative Poisson distribution with a mean of 10. The table shows that the value of S corresponding to a cumulative probability of .9513 is 15. That value translates to an IPO of 15 million shares.

Suppose before the terms of the underwriting agreement are fixed, the underwriters change their (collective) expectation about the market-clearing price. Suppose in the new scenario the underwriters' consensus is that if the issue is not fully subscribed at the offering price, the underwriters expect the shares to trade in the after-market at a price of \$94.216. The Poisson cdf value is:

$$\frac{P_0 - P_i}{P_0 - \bar{P}} = \frac{\$5.00\,per\,share}{\$5.784\,per\,share} = 0.8645$$

In the second scenario the lead underwriter will have an incentive to re-negotiate the underwriting contract to fix the number of shares in the issue to satisfy the Eq. (12) :

$$\sum_{j=0}^{S} 10^j \frac{e^{-10}}{j!} = 0.8645 \tag{12}$$

The value of S corresponding to a cumulative probability of 0.8645 is 13. Thus, a relatively small decrement in the price expected by the underwriters if the issue is not fully subscribed should induce the underwriters to revise the underwriting agreement from an offering of 15 million shares to an offering of 13 million shares. This reduction can explain why the issue may be underpriced.

The numerical example presented in Sect. 8 is a special case because it is based on the properties of the Poisson distribution. However, the Proposition in Sect. 7 is general enough to be applied to any conditional cdf governing the demand for IPO shares. The only requirement is the obvious one that the range of the cdf must be non-negative.

In the general case of an estimable discrete conditional cdf, the underwriters can calculate the optimal number of shares in the IPO at the offer price to be the integer value of S that satisfies the binary inequality conditions:

$$Prob[X \leq S | offer\,price = P_o] \leq \frac{P_o - P_i}{P_o - \bar{P}} \leq Prob[X \leq S + 1 | offer\,price = P_o]$$

9 Concluding remarks

My concluding comments refer back to the New York Appellate Court decision adumbrated in the Introduction. The theory of underwriter behavior developed in this paper is consistent with that decision. The factual circumstances in that case are illustrative as well as suggestive of the practical implications of the theory.

In that case, the plaintiff represented the issuer of the IPO, namely eToys. The defendant, Goldman Sachs, was the lead underwriter.[13] The plaintiff alleged that Goldman Sachs was the plaintiff's fiduciary because eToys had relied on Goldman Sachs' expert advice in configuring the terms of its IPO and had placed trust and confidence in Goldman Sachs in doing so.

The following deposition testimony by the plaintiff's chief executive officer summarizes the information asymmetry as well as the manifest imbalance in the negotiating power between the issuer and the underwriter:

Q. *Did you believe on May 19, 1999, that Goldman Sachs was giving you advice with the interest of eToys foremost in their mind* [sic] *?*
A. *Yes*
Q. *Well you relied on them on May 19th ?*
A. *We relied on them and … why did we rely on them?*
Q. *Yeah*
A. *Because they're Goldman Sachs, for crying out loud, and they make a market and they take companies public. They completely control the process. They know how to do it. They get it done. They raise the money for us. They are the experts. They do this every day. We do this once in a life*

The veracity of the testimony reproduced above should not necessarily be accepted at face value. The witness may simply be attempting find someone other than himself to blame for his company's bankruptcy. However, to the extent that the attitude expressed in the witness's testimony is generally an accurate representation of the relationships between IPO issuers and their underwriters, the latter have opportunities as well as economic incentives to configure the terms of firm commitment IPOs in such a way as to minimize the risks to themselves of mispricing the IPO. If issuers cede to underwriters decisions respecting price parameters and the size of the issue, the theory developed in this paper explains how the underwriters can exploit asymmetric information to configure the size of the issue with little (or no) regard to the interests of the issuers. Moreover, they can do so with legal impunity, at least in New York State.

The theory developed in this paper offers an explanation of why well-informed underwriters might exploit their private information to configure the terms of an IPO that result in purposeful underpricing. The testimony reproduced above suggests in vivid terms the opportunities for such exploitation to happen, even if the issuer is reasonably sophisticated in business dealings.

In May 27, 2011, Rule 513(d) of the FINRA meliorated the information asymmetry in IPOs. Pursuant to that rule, the managing underwriter of a new issue must provide to the issuer's pricing committee (or board of directors) a regular report on indications of interest

[13] Technically, the plaintiff was the Official Committee of Unsecured Creditors of eToys, Inc., a bankrupt internet start-up company that was incorporated in 1996. By order of the United States Bankruptcy Court for the District of Delaware, plaintiff was granted standing as a representative of eToys' bankruptcy estate and authorized to prosecute any litigation claim on behalf of eToys and the estate.

including the names of institutional customers. Significantly, FINRA did not impose any fiduciary obligation, but just required the reports as part of its rules of fair practice. Rule 513(d) will not necessarily eliminate all opportunities for underwriters to exploit their private information in the way described in this paper. The Rule will, however, lessen the imbalance in the information which enables that kind of exploitation.

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Appendix 1

Define the symbol θ_1 to represent the underwriters' spread earned on each share sold at the offering price: $\theta_1 = P_o - P_i$.

Define the symbol θ_2 to represent the loss per share, if any, incurred by the underwriters for each share sold in the secondary market expected to be at a price below the price paid to the issuer $\theta_2 = P_i - \bar{P}$.

I assume that the members of the syndicate estimate fixed values of the two parameters θ_1 and θ_2. The expected loss function can be rewritten as:

$$E[L] = \theta_1 \int_S^\infty (X - S) f(X|P_o) dX + \theta_2 \int_0^S (S - X) f(X|P_o) dX \tag{13}$$

The expected loss in (13) is minimized for the numerical value of S that satisfies the equality $\frac{dE[L]}{dS} = 0$ and the inequality $\frac{d^2}{dS^2} E[L] > 0$.

Expression 13 can be decomposed into four integral functions:

$$E[L] = \theta_1 \int_S^\infty X f(X|P_o) dX - \theta_2 \int_0^S X f(X|P_o) dX + S \left[\theta_2 \int_0^S f(X|P_o) dX - \theta_1 \int_S^\infty f(X|P_o) dX \right] \tag{14}$$

Applying the well-known formula for the differentiation of a definite integral with respect to a parameter, we have the result[14]:

$$\frac{dE[L]}{dS} = -\theta_1 \int_S^\infty f(X|P_o) dX + \theta_2 \int_0^S f(X|P_o) dX \tag{15}$$

Expression 15 is simply a weighted sum of the dichotomized cumulative distribution function of $f(X \mid P_o)$. Thus, by the law of total probability, $\int_S^\infty f(X|P_o) dX +$

[14] The general formula for the differentiation of an integral of a function with respect to a parameter, when the limits are also functions of the parameter, is stated below.

If $\varphi(\alpha) = \int_a^b g(x, \alpha) dx$, where a and b are functions of α, and if some general restrictions are placed on $g(x, \alpha)$ and $\partial g(x, \alpha)/\partial \alpha$, then

$\frac{d\varphi(\alpha)}{d\alpha} = \int_a^b \frac{\partial}{\partial \alpha} [g(x, \alpha] dx + g(b, \alpha) \frac{db}{d\alpha} - g(a, \alpha) \frac{da}{d\alpha}$

$\int_0^S f(X|P_o)dX = 1$. The equality allows the substitution $\int_S^\infty f(X|P_o)dX = 1 - \int_0^S f(X|P_o)dX$ into expression 15. The result is:

$$\frac{dE[L]}{dS} = -\theta_1 + \theta_1 \int_0^S f(X|P_o)dX + \theta_2 \int_0^S f(X|P_o)dX \tag{16}$$

$\frac{dE[L]}{dS}$ is equal to zero when

$$\int_0^S f(X|P_o)dX = \frac{\theta_1}{\theta_1 + \theta_2} \tag{17}$$

The definitions of θ_1 and θ_2 imply $\theta_1 + \theta_2 = P_o - \bar{P}$. Substituting these into Eq. 17 produces the result in the body of the text.

Appendix 2

Equation 17 can be written as:

$$Prob[X \leq S|offering\,price = P_0] = \frac{\theta_1}{\theta_1 - \theta_2} \tag{18}$$

Taking the partial derivative of Eq. 18 with respect to θ_1 results in the following inequality:

$$\frac{\partial}{\partial\theta_1} Prob[\cdot] = \frac{\theta_2}{[\theta_1 + \theta_2]^2} > 0 \tag{19}$$

An increase in θ_1 is equivalent to an increase in the underwriting discount. If the price paid by the syndicate to the issuer is fixed and the syndicate has the contractual right to set the offering price, then we have the result:

$$sign\frac{\partial}{\partial\theta_1} Prob[\cdot] = sign\frac{\partial}{\partial P_0} Prob[\cdot] \tag{20}$$

The result in 20 proves Corollary 1.

Calculating the partial derivative of Eq. 18 with respect to θ_2 results in:

$$\frac{\partial}{\partial\theta_2} Prob[\cdot] = -\frac{\theta_2}{[\theta_1 + \theta_2]^2} < 0 \tag{21}$$

For a fixed value of the offer price, an increase in θ_2 is equivalent to a decrease in the conditional price expected in the public market if the issue is overpriced. Thus we infer that a decrease in the price expected in the after-market is associated with a decrease in the numerical value of the cdf governing the demand for shares in the market. If the underwriters' gross spread is fixed, and if the underwriters expect the issue to be overpriced, the

optimal numbers of shares in the offering will likewise diminish. This result proves Corollary 2.

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