The Role of Uninformed Investors in an Optimal IPO Mechanism

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Abstract

This paper explores optimal ways for a firm to sell its initial public offering (IPO) to a mix of informed and uninformed investors through an intermediary. I argue that uninformed investors provide a benchmark for informed investors, resulting in an endogenous constraint that affects the issuer's revenue. I conclude that higher revenues are achieved with higher numbers of uninformed investors participating in an IPO. Furthermore, the intermediary serves as the only credible provider of information about uninformed investors' realized demand to informed investors. This increases the issuer's expected revenue, and provides a rationale for substantial payments to the intermediary.

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1 Introduction

Consider a firm going public for the first time. It has some information about its products and technology and how they compare to competition. However, it possesses neither precise information about financial conditions, nor detailed information about competitors, as well as the product market. Therefore, the firm does not know the stock price that the market is willing to bear at the time of the initial public offering (IPO).

There are two kinds of potential IPO investors. The first kind, associated with financial companies, may have information that the issuing firm does not. That could be, for example, information about competitors, future regulatory reforms, and the general conditions of the economy and financial markets. These types of information allow them to better assess the long-term value of the firm, resulting in asymmetric information in the IPO process. However, these informed investors may have neither the interest nor the cash to purchase the entire IPO. The second type of investors are uninformed, say private individuals. Collectively, uninformed investors have sufficient funds to purchase the entire offering, but may be unwilling to participate due to adverse selection problem, i.e. they fear that they might have access to only low profit or unprofitable offerings.

The importance of informed investors is clear. They hold pivotal information about the value of the IPO, and their participation in the IPO serves as a credible "certification" to the uninformed investors that the IPO is a fair deal.

The objective of this paper is to highlight the role of uninformed investors as drivers of an information extracting IPO mechanism. Its main contribution is to consider uninformed investor's profit as a benchmark for informed investor's profit. Naturally, informed investors must profit no less than uninformed investors, since otherwise they have an option not to reveal their information, and participate in the IPO process as uninformed investors. Hence, uninformed investors play an important role as providers of the "outside option" benchmark for informed investors. This results in an endogenous incentive constraint for informed investors to reveal their information, that leads to limitations on informational surplus extraction from informed investors. I argue that the issuer's potential to extract the surplus from informed investors increases with the number of uninformed investors participating in the IPO. This explains why the issuer must rely on an investment bank as an intermediary to sell the shares, since the issuer does not have direct access to the pool of uninformed investors. Moreover, the intermediary is essential to the IPO process as the only agent who can truthfully and credibly signal the information about the value of informed investors' outside option, as determined by uninformed investors' realized demand.

I explore the effectiveness of information extraction from informed investors in the framework of optimal mechanism design under the assumption of collusion among informed investors. This assumption highlights and also increases the difficulty of information extraction from informed investors.[1] I restrict attention to uniform price mechanisms, since IPO regulations in many countries require that a security should be offered to all investors at the same price. For example, in the U.S., the National Association of Securities Dealers (NASD) Rules of Fair Practice stipulate that a fixed offer price should be established and maintained over the offering period. The implementation of the optimal uniform price mechanism can be described as follows. An intermediary solicits information about IPO quality from informed investors, simultaneously announcing the allocation and price schedule for reported values. IPO shares are then allocated and the price is set according to the announced schedule and information received from informed investors. No shares are allocated if no information is revealed. In the end, the optimal mechanism guarantees fair pricing for uninformed investors, and fully reveals the information about the IPO value, which facilitates a robust aftermarket without the handicap of asymmetric information.

The main results of this paper are as follows.

First, I argue that the issuer's potential to extract the surplus from informed investors increases with the number of uninformed investors participating in the IPO. An uninformed investor's profit serves as an outside option for an informed investor, which limits the issuer's information extraction efforts. The higher the level of participation of uninformed investors, the lower each uninformed investor's profit. This results in a lower value of the outside option for informed investors. Hence the issuer achieves higher revenues with larger numbers of uninformed investors participating in an IPO.

Second, I provide new insights about the role of the intermediary in the IPO process

[1] Otherwise it is possible to completely extract informational surplus (see, for example, Crémer and McLean (1988)).

by arguing that the intermediary serves as the only credible provider of information about uninformed investors' realized demand to informed investors. The intermediary's credibility is based on the fact him being a repeat player in the IPO process, coupled with the fact that his actions are ex-post observable. The intermediary's signaling uninformed investors' demand to informed investors increases the issuer's expected revenue, and also provides a rationale for substantial payments from the issuer to the intermediary.

Third, I consider a continuous information structure that allows deriving comparative statics with respect to the full range of potential IPO values. I conclude that distributing the entire IPO to the informed investors is a robust outcome over a substantial range of high-valued IPOs, and that uninformed investors' participation in the IPO process does not guarantee them positive allocations. However, the fraction of valuations, for which uninformed investors are excluded, declines as the level of interest from uninformed investors increases. This means that higher levels of participation by uninformed investors lead to higher probabilities of positive allocations to each uninformed investor.

The rest of this paper is organized as follows. The next section provides the connection to the existing IPO literature. The model is introduced in section 3. Section 4 describes a motivating example. Analysis of the optimal uniform price mechanism is performed in section 5. Section 6 concludes.

2 Relation to Existing Literature

There has been extensive research into various pricing schemes under asymmetric information in the IPO process over the last twenty years. The two most important papers in this stream are Rock (1986) and Benveniste and Spindt (1989). In both papers, a group of potential investors of an IPO offering (usually large institutional investors) have superior information about the value of the IPO because of their private research and knowledge of market conditions.

Rock (1986) showed how underpricing can be a consequence of information asymmetry in the posted price IPO mechanism. He argued that since uninformed investors are at an informational disadvantage compared to informed investors, they would end up with a disproportionately large share of bad deals. Compensation through an underpricing of IPOs enables uninformed investors to break-even on average. The question of how IPO shares are to be allocated between informed and uninformed investors was not examined. Rock (1986) assumed that all investors are rationed in the same proportion, and was silent on the role of an intermediary or uninformed investors in the IPO process.

Benveniste and Spindt (1989) focused on the relationship between an intermediary and informed long-term investors. In their paper, individual allocations for the long-term informed investors depend on their reports to the intermediary, which allows for partial information surplus extraction from informed investors. The IPO shares unsold to informed investors were assumed to be sold to uninformed investors at the full-information price. Benveniste and Spindt argued that this mechanism resembled the IPO bookbuilding process. Underpricing was also one of the model's results. Benveniste and Spindt also showed that IPO underpricing could be alleviated with a long term relationship between an investment banker and informed investors.

Since Benveniste and Spindt (1989) it has become common to interpret bookbuilding as a mechanism for extracting information from informed investors. This interpretation of information extraction and advantages of bookbuilding were further explored in Spatt and Srivastava (1991), Benveniste and Busaba (1997), Sherman (2000), Biais and Faugeron-Crouzet (2002), Sherman (2005), and Yung (2005). Recently, the information extraction view of bookbuilding was empirically supported in Cornelli and Goldreich (2001) and Cornelli and Goldreich (2003).

It is natural that a issuer's expected revenue in any mechanism depends on the effectiveness of information extraction from informed investors. Benveniste and Wilhelm (1990) studied the effects of uniform-price and uniform-allocations restrictions on the relative costs of information extraction vs. adverse selection in IPO process. They emphasized that uniform-price restrictions lead to the loss of revenue in information extracting mechanisms, due to loss of the issuer's discretion over the use of the information extracting "tools", as well as the fact that uninformed investors would be needlessly rewarded by underpricing, which was necessary for the information extraction from informed investors.

In this paper I study the effectiveness of information extraction in the framework of optimal mechanism design. I develop an IPO model with a continuous information structure, where potential IPO values belong to a bounded interval. I assume risk-neutral informed investors, who receive a perfect signal about the IPO value, and behave in a collusive way, i.e. that they disclose their information only together as a group. One of the objectives of this approach is to highlight the difficulties of issuer's revenue maximization in the absence of uninformed investors. I develop an optimal IPO mechanism that deals with the issue of asymmetric information in the uniform price setting. The model provides a new insight about the role of the intermediary as credible provider of information about uninformed investors' demand to informed investors. The intermediary is also essential in providing the issuer with the access to the pool of uninformed investors, and soliciting information about the IPO value from informed investors.

The optimal mechanism design approach has been applied to IPOs in Biais, Bossaerts, and Rochet (2002), Maksimovic and Pichler (2004) and Bennouri and Falconieri (2004).

Biais, Bossaerts, and Rochet (2002) developed an optimal IPO mechanism for a model where an intermediary and informed investors collude. In this paper I assume that the intermediary acts in the best interests of the issuer, while informed investors collude.

Maksimovic and Pichler (2004) studied optimal IPO mechanisms under the assumption of a discrete information structure, and also considered the effect of allocation or participation constraints on IPO underpricing. One of the key conclusions in Maksimovic and Pichler (2004) was that an optimal IPO mechanism results in zero expected underpricing in the absence of constraints on investors' returns and allocations. Maksimovic and Pichler (2004) interpreted underpricing as a result of exogenous constraints on investors' returns and allocations.

Bennouri and Falconieri (2004) developed an optimal IPO mechanism in a model where risk averse informed investors receive independent signals about the IPO value, and the aftermarket value of the shares is the average of informed investors' signals. They did not assume the uniform price constraint, but concluded that an optimal IPO mechanism could be implemented through a uniform price offering. Bennouri and Falconieri (2004) also found that if informed investors are risk-neutral, the issuer can implement a full extracting mechanism that allocates the entire issue to uninformed investors. Their uniform price optimality result relies on informed investors' risk aversion to quantity, and on the Bayesian incentive compatibility nature of the mechanism, that uses the expected utility with respect to other informed investors' signals. In this paper, I assume risk-neutral investors, and develop mechanisms that do not require the use of Bayesian incentive compatibility, since all information in the model is communicated through the mechanism. Another important feature of this paper is that all mechanisms provide strictly positive participation incentives for all investors, while the full extracting mechanism with risk-neutral informed investors in Bennouri and Falconieri (2004) presents a corner solution, in which informed investors do not receive any allocation in return for the provided information, and have no positive incentives to participate.

A common feature of the above papers is the lack of attention on the role of uninformed investors as drivers of information extracting mechanisms, as well as the absence of guarantees that informed investors profit at least as much as uninformed investors. I introduce an endogenous incentive constraint for informed investors that requires that they receive at least as much profit as uninformed investors. This constraint provides intuition about why the issuer's revenue depends on the number of uninformed investors participating in the IPO process. The endogenous nature of the above constraint differs from Benveniste and Wilhelm (1990) and Maksimovic and Pichler (2004) consideration of exogenous constraints and their adverse effects on the issuer's revenue. The use of a continuous information structure differs from a discrete information structure in Benveniste and Wilhelm (1990) and Maksimovic and Pichler (2004), and enables me to consider comparative statics of the region of IPO values for which the entire allocation goes to informed investors on the uninformed investors' participation levels.

In this paper, I concentrate on the optimal uniform price mechanism, and find pricing and allocation implications that are consistent with the theoretical framework developed in Benveniste and Spindt (1989), Benveniste and Wilhelm (1990), and also with the existing empirical IPO literature:

1) The amount of underpricing increases with the quality of the IPO. This was first documented by Hanley (1993) as the partial adjustment phenomenon, and also confirmed by Ljungqvist and Wilhelm (2002).

2) The positive relationship between IPO prices and informed investors' allocations was identified in Ljungqvist and Wilhelm (2002) by findings of positive relationship between institutional allocations and price revisions.

3) The positive relationship of IPO profitability and informed investors' allocations is consistent with Aggarwal, Prabhala, and Puri (2002) findings of the positive relationship between institutional allocations and day one IPO returns.

In addition, I find new testable implications that both underpricing and informed investors' allocations decrease in response to higher uninformed investors participation.

3 Model Description

I consider a model with an IPO issuer, an intermediary and two groups of investors: informed and uninformed. A firm has a fixed quantity of shares to sell in a firm commitment IPO.[2] The firm uses an intermediary, who sells the shares to two categories of investors: informed (i.e. large investment management firms, or professional investors), and uninformed (i.e. retail investors). I assume that the intermediary acts in the best interests of the issuer. Without loss of generality the quantity of shares is normalized to 1. The market valuation of the shares, v, is distributed over a bounded interval $[\underline{v}, \bar{v}]$. There are N informed investors who know the realization of v, and have sufficient funds to buy as much of the IPO as available if the offering price is less than v. Each uninformed investor has available funds in the amount of m. Without loss of generality assume $m = 1$. Denote the total number of uninformed investors as θ, interpreting it as a measure of uninformed demand that may be willing to participate in an IPO. Assume that θ is distributed over a bounded interval $[\underline{\theta}, \bar{\theta}]$, such that $\underline{\theta} > \bar{v}$, i.e. that uninformed investors have sufficient funds to buy the entire IPO at any valuation. All agents in the model are assumed to be risk neutral. The information structure of the model is as follows:

1) Probability distributions of v and θ, and the value of N are common knowledge. v and θ are independent.

2) The firm with the IPO does not know realizations of v and θ.

[2] All of the IPO shares must be sold once the offering price has been set.

3) The intermediary privately observes the realization of θ, but does not know the realization of v.

4) Each uninformed investor does not know realizations of v and θ.

5) Each informed investor privately observes the realization[3] of v, but does not know the realization of θ.

6) Identities of all informed and uninformed investors are private information.

I assume that N informed investors collude,[4] which precludes information extraction by informed investors' cross-reporting the realization of v.

I solve the problem of maximizing the expected proceeds from sale in the framework of optimal mechanism design under the restriction that the same price applies to both informed and uninformed investors.

4 Motivating Example

The following example is useful because it provides a benchmark and highlights difficulties in the underlying mechanism design problem.

4.1 Preliminary Observation

The expected revenue from the sale, $E(R)$, can not exceed $E(v)$, since this is the value of an informed investor's surplus. It is impossible to extract more than that without violating individual rationality or participation constraints.

4.2 Motivating Example

As an illustration suppose $v \sim U[0,1]$, there is only one informed investor, and the following mechanism: the intermediary first announces a share-price schedule $p(q)$, where q is the

[3]Notice that all informed investors have exactly the same valuation v in this model. This also could be interpreted as they all receive a perfectly precise signal about v.

[4]Here I assume a specific type of collusion in the spirit of an "exclusive club" - informed investors stick together as holders of exclusive information, and will receive equal allocations at the end. This implies that collusion in the distribution of shares is not allowed.

quantity (i.e. the number of shares) given to the informed investor, then the informed investor makes his choice of q, which determines the price at which the remaining $1-q$ shares are sold to uninformed investors. So, informed and uninformed investors pay the same share price. Assume for now common knowledge of the identity of the informed investor.[5]

As an example consider only schedules of the form

$$p(q) = q^a, \quad 0 < a < 1. \tag{1}$$

Then for any given v, the informed investor solves the problem

$$\max_q \{q(v - q^a)\}. \tag{P}$$

First order conditions give the solution since the objective function is concave:

$$q^*(v) = \left(\frac{v}{a+1}\right)^{\frac{1}{a}}, \tag{2}$$

$$p^*(v) = \frac{v}{a+1}. \tag{3}$$

Uninformed investors always participate in this mechanism, since they obtain positive profit at any value of v because they pay the same price p^* as the informed investor. This means that the issuer always sells all IPO shares at the price p^*, and the total expected revenue is

$$R = \int_0^1 \frac{v}{a+1} dv = \frac{1}{2(a+1)} \underset{a\to 0}{\longrightarrow} \frac{1}{2} = E(v). \tag{4}$$

Notice that the above mechanism is a particular case of a direct revelation mechanism where the informed investor announces v, and gets $q^*(v)$ while making the payment $q^*(v)p^*(v)$. Obviously it is incentive compatible, and it is ex post individually rational for everybody to participate in this mechanism.

The central idea of the above mechanism is that it is possible to force the informed investor to disclose his valuation using a very small allocation of shares, while leaving the informed investor with a positive profit. The high level of issuer's revenue is then achieved by selling the rest of the IPO issue to uninformed investors at the price chosen by the informed investor, which guarantees them a profit. Uninformed investors may be viewed as a powerful tool for the issuer to extract informational surplus from informed investors.

[5] This assumption will be relaxed later.

There are some implausible implications of the above mechanism. Let π_I be the profit of the informed investor, and π_U be the profit of an uninformed investor. Then

$$\pi_I = q^*(v)\,(v - p^*(v))\,, \tag{5}$$

$$\pi_U = \frac{1 - q^*(v)}{\theta}\,(v - p^*(v))\,. \tag{6}$$

Notice that $\pi_I < \pi_U$ for some values of v and θ as $a \to 0$. This may seem "unfair" to the informed investor, and thus the informed investor may choose to represent himself as an uninformed investor, if possible. Although the above example does not provide such an option to the informed investor, the general setup described in section 3 allows this option for informed investors.

4.3 Informed Investor's Outside Option in the General Model

The general model described in section 3 allows an informed investor an option of not revealing the information, and participating in the IPO process as an uninformed investor, since investors' identities are private information. This results in an endogenous incentive constraint that maintains that an informed investor's profit must be no less than an uninformed investor's profit, i.e.

$$\pi_I \geq \pi_U \tag{7}$$

Notice that in the context of a uniform price mechanism when informed and uninformed investors pay the same price, the above constraint is equivalent to the requirement that an informed investor receives no less of an allocation than an uninformed investor, i.e.

$$q_I \geq q_U \tag{8}$$

where q_I and q_U are informed and uninformed investors' allocations.

The effect of the above endogenous incentive constraint (8) in the uniform price optimal IPO mechanism is fully explored in the next section.

5 Uniform Price Optimal Mechanism

Consider the optimal mechanism design problem of an intermediary dealing with two groups of investors. The revelation principle allows me to restrict attention to a direct revelation mechanism (DRM) in the style of Myerson (1981). Informed investors report their valuation v to the intermediary, who then allocates $q(v)$ shares to all informed investors and gets a payment of $p(v)$. This is equivalent to allocating $\frac{q(v)}{N}$ shares to each informed investor and getting a payment of $\frac{p(v)}{N}$. The remaining shares are divided equally amongst the uninformed investors. No shares are allocated if informed investors do not disclose any valuation. Restricting attention to the class of mechanisms where informed and uninformed investors pay the same price, I conclude that the price per share, $p_s(v)$, for uninformed investors would be $\frac{p(v)}{q(v)}$ and they would receive a total allocation of $(1 - q(v))$. Since the total number of shares is normalized to 1, the revenue from the IPO under the above DRM would be

$$R = p_s(v) = \frac{p(v)}{q(v)}. \tag{9}$$

The DRM has to satisfy incentive compatibility and participation constraints for informed investors, i.e.

$$vq(v) - p(v) \geq vq(\hat{v}) - p(\hat{v}) \qquad \forall v, \hat{v}, \tag{IC-1$_I$}$$

$$vq(v) - p(v) \geq 0. \tag{IR$_I$}$$

Notice that any informed investor can misrepresent himself as an uninformed investor in this mechanism if it gives him a higher payoff. Hence it is necessary to introduce an additional incentive compatibility constraint,[6] so that informed investors would truthfully reveal that fact that they know the value of v, which means that each informed investor has to get at least as many shares as an uninformed investor:[7]

$$\frac{q(v)}{N} \geq \frac{1 - q(v)}{\theta}, \tag{IC-2$_I$}$$

which is equivalent to

$$q(v) \geq \frac{N}{N + \theta}. \tag{IC-2$'_I$}$$

[6] I.e. guarantee that informed investors receive higher payoff than uninformed investors for all values of v.

[7] Here the assumption that all uninformed investors have the same amount of funds has bite - it forces an informed investor to conform to the uninformed crowd, and submit the same quantity order. This assumption could be relaxed with the rationing rule when all uninformed investors are allocated the same amount no matter what their quantity orders were.

Here the marginal loss of value from participating as an uninformed investor is not accounted for, since it only changes N to $N + 1$, which hardly matters on a conceptual level.

Notice that there is no need for an uninformed investor's participation constraint, since (IR_I) already takes care of it.[8] Finally there is an obvious feasibility constraint

$$0 \leq q(v) \leq 1. \tag{FC}$$

Thus the intermediary's DRM design problem can be written as follows

$$\max_{p(v),q(v)} \left\{ E\left(\frac{p(v)}{q(v)}\right) \right\} \tag{P_{up}}$$

such that (IC-1_I), (IR_I), (IC-$2'_I$), and (FC) are satisfied.

Theorem 1 *The problem (P_{up}) with constraints (IC-1_I), (IR_I), (IC-$2'_I$), (FC) is equivalent to*

$$\max_{q(v)} \left\{ E(v) - E\left(\frac{\int_{\underline{v}}^{v} q(x)dx}{q(v)}\right) \right\} \tag{P'_{up}}$$

where $q(v)$ is a non-decreasing function subject to

$$q(\underline{v}) = \frac{N}{N+\theta}, \tag{IC-$2''_I$}$$

$$q(\bar{v}) \leq 1. \tag{FC'}$$

Proof. The proof follows the standard logic in Myerson (1981). Let $U(v) = vq(v) - p(v)$. Rewriting (IC-1_I) in terms of $\hat{v}$ I have

$$U(\hat{v}) = \hat{v}q(\hat{v}) - p(\hat{v}) \geq \hat{v}q(v) - p(v) \qquad \forall v, \hat{v}. \tag{10}$$

Combining (IC-1_I) and (10) gives

$$(v - \hat{v})q(\hat{v}) \leq U(v) - U(\hat{v}) \leq (v - \hat{v})q(v) \tag{11}$$

which implies that $q(v)$ and $U(v)$ are non-decreasing. The monotonicity of $q(v)$ implies that it is a.e. continuous. Thus rewriting (11) as

$$q(\hat{v}) \leq \frac{U(v) - U(\hat{v})}{v - \hat{v}} \leq q(v) \tag{12}$$

[8] Indeed, both informed and uninformed investors pay the same price, and informed investors always participate, hence uninformed investors cannot lose.

and taking limits as $\hat{v} \to v$ at points where $q(v)$ is continuous, I conclude that $U'(v) = q(v)$ a.e., which in turn yields absolute continuity of $U(v)$, and hence

$$U(v) = U(\underline{v}) + \int_{\underline{v}}^{v} q(x)dx \tag{13}$$

and

$$p(v) = vq(v) - \int_{\underline{v}}^{v} q(x)dx - U(\underline{v}). \tag{14}$$

Recalling that $U(v)$ is always non-negative and non-decreasing it is easy to see that in an optimal mechanism $U(\underline{v}) = 0$, hence $p(v) = vq(v) - \int_{\underline{v}}^{v} q(x)dx$ and

$$\frac{p(v)}{q(v)} = v - \frac{\int_{\underline{v}}^{v} q(x)dx}{q(v)}. \tag{15}$$

Finally, recalling that $q(v)$ is non-decreasing in conjunction with (IC-$2'_I$) yields

$$q(\underline{v}) = \frac{N}{N+\theta} \tag{16}$$

which along with (IC-$2'_I$) completes the proof. ■

Corollary 1

$$E(R) \leq E(v) - \frac{N}{N+\theta}E\left(v - \underline{v}\right) < E(v) \tag{17}$$

for any mechanism which satisfies the above restrictions.

Proof. From Theorem 1, $\frac{N}{N+\theta} \leq q(v) \leq 1$. So

$$\frac{\int_{\underline{v}}^{v} q(x)dx}{q(v)} \geq \frac{N}{N+\theta}\frac{v-\underline{v}}{q(v)} \geq \frac{N}{N+\theta}(v - \underline{v}). \tag{18}$$

This implies

$$E(v) - E\left(\frac{\int_{\underline{v}}^{v} q(x)dx}{q(v)}\right) \leq E(v) - \frac{N}{N+\theta}E\left(v - \underline{v}\right) < E(v). \quad ■ \tag{19}$$

Corollary 1 highlights the fact that the issuer's leverage to extract informational surplus from informed investors depends on participation of uninformed investors in the uniform price mechanism. It is possible to interpret $q(\underline{v}) = \frac{N}{N+\theta}$ as the value of the outside option to informed investors provided by the participation of uninformed investors in the IPO process.

The issuer can achieve higher revenues with larger numbers of uninformed investors participating in an IPO by lowering the value of the outside option for informed investors. The issuer can also achieve higher revenues with lower numbers of informed investors participating in an IPO, which lower the value of the informed investors' outside option. Notice that higher numbers of informed investors do not result in better information about the IPO value in this model, since each informed investor observes the exact IPO value v.

5.1 The Role of the Intermediary

Here I highlight the role of the intermediary in the IPO process by arguing that the intermediary serves as the only credible provider of information about uninformed investors' realized demand, θ, to informed investors. Credibly providing this information to informed investors results in a higher expected revenue for the issuer, as demonstrated below.

Consider the incentive constraint (IC-2_I) that states that that each informed investor is awarded at least as many shares as an uninformed investor, i.e.

$$\frac{q(v)}{N} \geq \frac{1-q(v)}{\theta}. \tag{20}$$

However, informed investors do not know the realized value of θ. An equilibrium strategy in a one-shot game is that informed investors make their decisions based upon the expected value of their outside option, as given by $\frac{1-q(v)}{\theta}$, with respect to θ. Technically, this means taking an expectation with respect to θ of the right hand side in (20), so, in fact, inequality (20) should read

$$\frac{1}{N}q(v) \geq E\left(\frac{1}{\theta}\right)(1-q(v)). \tag{21}$$

Since $\frac{1}{\theta}$ is a convex function, by Jensen's inequality $E\left(\frac{1}{\theta}\right) \geq \frac{1}{E(\theta)}$. This means that informed investors would overestimate their outside option of misrepresenting themselves as uninformed investors in the absence of credible information about θ. That would result in a lower payoff for the issuer. The issuer would benefit if informed investors were provided with the information about θ.

The intermediary is the only agent in the model who observes θ, and he can also signal the realized value of θ by announcing the starting point of the allocation schedule, $q(\underline{v})$.[9] The expected gains to the issuer are not easy to quantify, since the issuer's expected revenue

[9] Then the realized value of θ can be inferred from (IC-$2_I''$), which gives $\theta = \frac{N}{q(\underline{v})} - N$.

also includes θ.[10] A numerical solution for the case of $v \sim U[0,1]$, $N = 2$, and $\theta \sim U[1,100]$ yields $E(R) = .27$ with no signaling, and $E(R) = .29$ with costless signaling, demonstrating positive gains from signaling θ by the intermediary.

Unfortunately, it is impossible for the intermediary to truthfully and credibly signal its realization in an equilibrium of a one-shot game, even if he works in the best interest of the issuer. Indeed, the intermediary would be tempted to announce high values of θ to get a higher revenue, even if he actually observed low values of θ.[11]

In reality, it is more appropriate to consider IPO process in the context of a repeated game with the intermediary and informed investors being repeated players, as first argued in Benveniste and Spindt (1989). In a repeated game, the intermediary can credibly provide information about θ to informed investors with a "trigger" strategy that is contingent upon the fact that informed investors can ex-post observe the intermediary's actions and verify θ. Such a strategy involves informed investors playing the value of θ, as reported by the intermediary in each period, and reverting to the single-shot equilibrium strategy forever in the future, if the intermediary's report of θ turns out to be false upon the ex-post verification.

Notice that the effectiveness of this strategy in sustaining the intermediary's truth-telling relies on a threat of cutting off his future profits from signaling in the event of a single dishonest report. This implies that the intermediary must keep at least a part of the total revenue gain in order to sustain the above truth-telling strategy, which relies on the expected profit from truthful signaling the intermediary anticipates in the future. In reality, that means that substantial payments must be made from the issuer to the intermediary in order to guarantee his effectiveness in credibly disclosing θ to informed investors.

5.2 Numerical Solution

Solving (P'_{up}) for $q(v)$ in closed form is difficult. Here I demonstrate a numerical solution for the optimal allocation schedule for informed investors, $q(v)$, and the optimal underpricing schedule, $v - p_s(v)$, as well as issuer's expected revenue, $E(R)$, for different values of the

[10] The issuer's profit depends on the value of $q(\underline{v}) = \frac{N}{N+\theta}$.

[11] As mentioned before, equilibrium pure strategies for the intermediary and informed investors in a one-shot game would be to play $\left[E\left(\frac{1}{\theta}\right)\right]^{-1}$ instead of θ.

outside option $q(0) = \frac{N}{N+\theta}$ as given by uninformed investors' participation through the constraint (IC-$2''_I$) in the case of the uniform distribution on $[0, 1]$.

Figure 1 shows typical informed investors' allocation and underpricing schedules for low levels of uninformed investors' participation, which correspond to high values of the informed investors' outside option $q(0)$. Figure 2 shows typical allocation and underpricing schedules for high levels of interest on the part of uninformed investors, which correspond to low values of the informed investors' outside option $q(0)$.

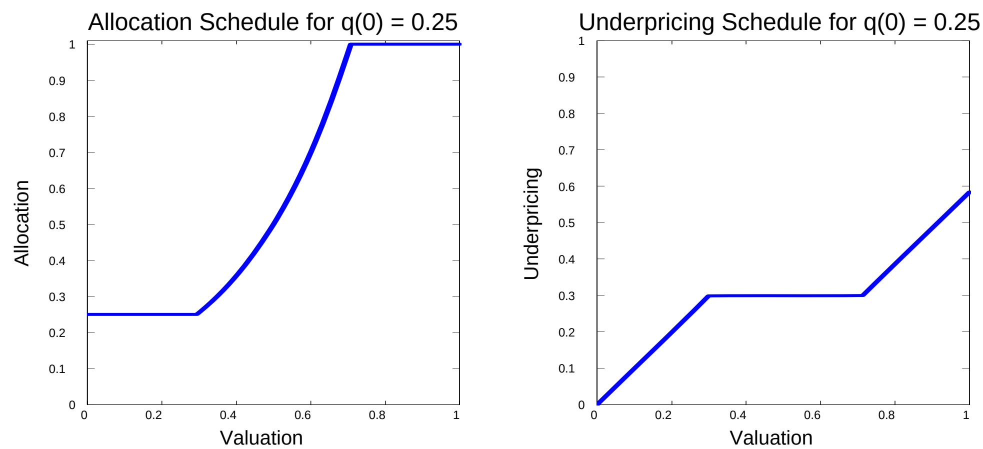

Figure 1: Low level of uninformed participation, $q(0) = .25$, $E(R) = .20$

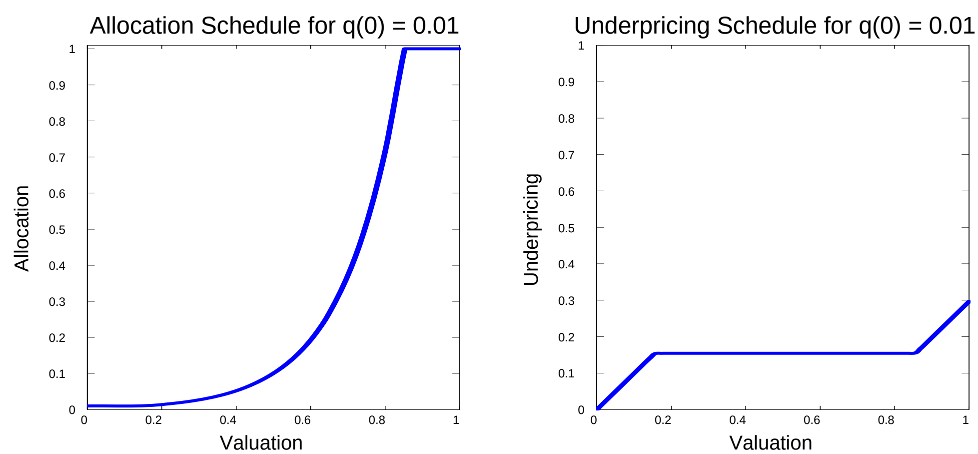

Figure 2: High level of uninformed participation, $q(0) = .01$, $E(R) = .35$

5.3 Empirical Implications

Corollary 1 along with the numerical solution illustrated in Figures 1 and 2 provide a set of empirical implications. Some of the implications are consistent with the existing empirical IPO literature, while the insight about the role of uniformed investors provides new testable empirical implications. These new implications are captured by the dynamics between Figures 1 and 2, and are summarized below.

First, the underpricing decreases with the increased level of participation of uninformed investors θ. This is demonstrated by the right panel dynamics between Figures 1 and 2.

Second, the total allocation to informed investors decreases with the increased level of participation by uninformed investors θ, as shown by the left panel dynamics between Figures 1 and 2. Notice that this effect is fundamentally different from a similar implication produced by a simple pro-rate allocation rule. The optimal IPO mechanism implies reduced allocations to informed investors as a result of the increased *absolute* level of the demand by uninformed investors, regardless of the size of the informed investors' demand. On the other hand, the pro-rate rule implies changes in allocations to informed investors only in response to changes in the *relative* demand by uninformed investors compared to the demand by informed investors.

Third, it is optimal to bunch allocations on both upper and lower ends of possible valuations, i.e. to allocate all of the most underpriced issues to informed investors and to allocate as much as possible without violating (IC-2_I) constraint of the least profitable issues to uninformed investors. However, the fraction of bunched allocations declines along with the value of informed investors' outside option $q(\underline{v}) = \frac{N}{N+\theta}$.

Other implications of this paper's model that are consistent with the existing empirical IPO literature are as follows.

First, both the IPO price and the level of underpricing increase with the IPO valuation, v, which is consistent with the partial adjustment phenomenon, first documented by Hanley (1993), and also confirmed by Ljungqvist and Wilhelm (2002).

Second, optimal IPO prices and informed investors' allocations are positively related, which is consistent with Ljungqvist and Wilhelm (2002) findings of positive relationship between institutional allocations and price revisions during the bookbuilding process.

Third, it is optimal to give larger allocations of the most underpriced issues to informed investors, and to give larger allocations of the least underpriced issues to uninformed investors. This is consistent with a pattern of biased allocations, when a few "privileged" informed investors receive a disproportionately large fraction of the most profitable high value issues. This was confirmed in Aggarwal, Prabhala, and Puri (2002) by findings of the positive relationship between institutional allocations and day one IPO returns.

6 Summary and Conclusions

In this paper I develop the optimal uniform price mechanism to sell initial public offerings to a mix of informed and uninformed investors under the assumption that informed investors are better informed than the issuer. I focus on the issuer's leverage provided by uninformed investors in both types of mechanisms. I consider uninformed investor's profit as a benchmark for informed investor's profit. This results in an endogenous incentive constraint for informed investors, that provides limitations on informational surplus extraction from informed investors in uniform price mechanisms.

I consider a uniform price mechanism, since IPO regulations in many countries require that a security should be offered to all investors at the same price. The main implications of the optimal IPO mechanism are as follows.

First, the degree of surplus extraction from informed investors critically depends on the number of uninformed investors participating in an IPO. Higher numbers of uninformed investors participating in an IPO allow the issuer to achieve higher revenues.

Second, the intermediary is essential in increasing the issuer's expected revenue by credibly providing information about uninformed investors' realized demand to informed investors. This provides a rationale for substantial payments from the issuer to the intermediary. The intermediary is also essential in providing the issuer with the access to a pool of uninformed investors.

Third, it is optimal to allocate 100% of the shares to informed investors over a substantial range of high-valued IPOs. This highlights the fact that excluding uninformed investors from the most underpriced IPOs is a robust outcome of the optimal IPO procedure.

The level of underpricing in the uniform price mechanism may be quite substantial, which contradicts an argument in Ritter and Welch (2002) claiming that underpricing should be no more than a few percentage points in models with asymmetric information. That argument relies on a low marginal value of each informed investor's information under assumptions of imperfect information held by informed investors, and the full revelation price being the aggregate of informed investors' signals. This implies a relatively low compensation by underpricing for informed investors to reveal their information. The model in this paper assumes collusion among informed investors, like an "exclusive club" of all information holders. This leads to a high marginal value of the cumulative information held by the informed investors' alliance, resulting in a high magnitude of underpricing required as a compensation for revealing that information. The role of uninformed investors in reducing the cost of information extraction is more critical when IPO demand by informed investors is relatively limited and the threat of collusion among informed investors is high.

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