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OVER-SIGNALING VS UNDERPRICING: THE ROLE OF FINANCIAL INTERMEDIARIES IN INITIAL PUBLIC OFFERINGS

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Over-signaling vs Underpricing: The Role of Financial Intermediaries in Initial Public Offerings*

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Abstract

We consider a model of Initial Public Offerings (IPOs) where issuing firms of better quality are more reluctant to go public. IPOs either generate or destroy value depending on the type of the issuing firm, which is only observed by the issuer. We show that, when the issuer directly offers the shares to the investors, market breakdown occurs. This is caused by the issuer's attempts to signal his type through the offering price. Things change if we introduce a financial intermediary which: 1) acts as an underwriter, 2) influences the offering price. Underwriting creates a wedge between the interests of the intermediary and those of the issuer. This allows trade with outside investors to be restored. A by-product of the conflict of interest between issuer and intermediary is that trade is characterized by underpricing. In the benchmark case where her profits are zero, the intermediary acts as a screening device: she underwrites the shares only upon receiving positive information about the issuer.

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KEYWORDS: IPO, Signaling, Financial Intermediary, Underwriting, Underpricing.

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1 Introduction

In most countries, initial public offerings (IPOs) are characterized by the presence of a financial intermediary.[1] Typically, the intermediary acts as the underwriter and plays an active role in setting the offering price at which the shares are to be issued to the public. If the issuing firm and the intermediary find an agreement so that the IPO takes place, the firm receives the proceeds of the issue net of the commission fee, or gross spread, to be paid to the intermediary. Researchers have paid little attention to the analysis of this intermediation process. In particular, the existing literature has largely ignored the question of why issuing firms do not seem able to do without intermediaries.

This paper aims at offering a theoretical justification of why IPOs are characterized by the presence of intermediaries. Since intermediaries are a pervasive feature of IPOs, a better understanding on their role and incentives is clearly important. We develop a model where, consistent with what happens in practice, the intermediary (1) underwrites shares and (2) sets the offering price in exchange for a fee conditional on the IPOs taking place. We show that, in the absence of an intermediary performing these functions, the market for IPOs may not be viable. By converse, the presence of an intermediary performing these two functions can ensure a positive amount of trade. This occurs because the intermediary's dual role as a buyer and a seller creates a wedge between her interests and those of the issuer. A by-product of this conflict of interest is that trade is characterized by underpricing.

More precisely, we consider a model of fixed price offers. There are two types of issuers: those who own good (high quality) firms and those who own bad (low quality) firms. The issuer knows his type, while investors observe a private noisy signal. Owners of good firms are more reluctant to go public than owners of bad firms since their outside option – namely, keeping full ownership of the firm – is more valuable. Moreover, going public generates gains from trade only if the firm is good. When firms are bad, trade is socially inefficient.

Under these assumptions, we compare IPOs in which the issuer directly offers shares to the investors with situations in which the offering is managed by a financial intermediary.

Since the issuer has more information than the investors, an adverse selection problem emerges. Bad firms may want to mimic good firms. We show that this adverse selection problem is exacerbated by the issuer's attempt to signal his type through the choice of the offering price. Signaling creates an upward pressure on the offering price that eventually causes market breakdown. The intuition is that good types of issuers tend to raise the offering price to differentiate themselves. Bad types raise the offering price to mimic. This signaling spiral only stops when the offering price is too high for trade to occur. The behavior of the issuer is thus characterized by what we call "over-signaling": the issuer would be better off by committing to offering prices that do not depend on his information. In this case, a positive amount of trade would be possible.

Since issuing securities directly to the investors is not a viable option for the issuer, we ask whether a financial intermediary (investment bank) can do better. The investment bank

[1] As Ritter 2003, page 255, puts it " When a firm decides to issue securities to the public, it almost always hires an intermediary, typically an investment banking firm."

underwrites the shares and is able to influence the offering price. We identify a key trade-off.

On the one hand, the use of an intermediary may ensure that a positive amount of trade is restored. Since the investment bank underwrites the shares, a conflict of interest emerges between the bank and the issuer. While all the benefits from a high offering price accrue to the issuer, the investment bank bears the cost of subscribing potentially overpriced shares. The presence of this conflict between the bank and the issuer reduces the upward pressure on the offering price, preventing it from spiralling as in the case of a direct issue. As a result, there is no over-signaling and trade is therefore possible. This happens even when the investment bank is privately informed.

On the other hand, we show that the intermediary always makes losses from her underwriting activities. Intuitively, the intermediary suffers from a "seller's curse". The shares that she manages to sell on behalf of the issuer are, on average, underpriced. In contrast, the shares that she doesn't manage to sell – and for which she has to pay herself – are, on average, overpriced. As a result, the intermediary is only viable if the underwriting fee she obtains from the issuer is sufficiently high. This implies that, although the presence of the investment bank may allow trade to occur, part of the gains from trade must be used to finance her loss-making underwriting activities.

The question then arises, whether it is possible to simultaneously restore trade, and keep the investment bank from making losses. We show that this is indeed the case, by fully characterizing the natural benchmark in which the investment bank makes exactly zero profits. In this equilibrium, trade between the issuer and the investor is possible. Moreover, underpricing is particularly severe since the offering price is the lowest compatible with participation by the issuer. Another characteristic of the equilibrium is that the underwriter acts as a screening device, weeding out those firms that are most likely to be of low quality. The bank only underwrites shares over which she receives favorable information. This function of the investment bank endogenously emerges in our model even in the absence of the reputation concerns or other motives that could apply in a multi-period setting.

The paper also discusses the implications of the presence of the intermediary for the abnormal first day returns documented by the literature (underpricing). We identify two channels through which our model generates systematic underpricing. First, the seller's curse suffered by the intermediary vis-à-vis the investor implies that, conditional on the investor purchasing the shares, these are on average priced below their value. Second, we show that shares that are traded are on average underpriced even when the intermediary's informational disadvantage with respect to the investor – and therefore the seller's curse – disappears. This is a direct result of the intermediary's dual role as a buyer and a seller. Independently of the information structure, the very presence of an underwriter has a negative impact upon the offering price. When the intermediary suffers from an informational disadvantage, this mitigates the effect of the seller's curse on the offering price. In standard models of adverse selection the seller's curse would make sellers more reluctant to trade, thus driving prices upwards. In our setting this logic applies only in part. On the one hand, a more pronounced seller's curse increases the underwriting fee that the intermediary requires to break even. This in turn exerts an upward pressure on the price at which the issuer, who pays the fee, is willing to participate. On the other hand, the intermediary is also a buyer and therefore suffers from paying an excessively high price to the issuer. This exerts a downward pressure on the offering price.

Finally, we show that the extent of underpricing is positively correlated with the investors' decision to subscribe the shares. This matches the evidence of Cornelli and Goldreich (2003) who document a positive correlation between first day return and oversubscription.

The paper is organized as follows. The next section briefly reviews the existing literature. Section three informally discusses the key features of the environment. Section four outlines the model. Section five presents the result that direct issues fail. Section six focuses on intermediated issues. Section seven discusses the model's implications. Section eight addresses possible extensions and robustness. A final section presents conclusions and discusses future research. All proofs can be found in the Appendix.

2 Related literature

The literature on IPOs consists of various strands, including the relationship between issuers and intermediaries, the reasons to go public and, of course, underpricing. The present paper puts forward a teory that justifies intermediation services in IPOs – namely underwriting and pricing. Baron (1982) analyses the optimal delegation contract between an issuer and an investment bank. The issuer faces problems of both adverse selection and moral hazard. The investment bank has private information about demand (and therefore potential proceeds from the issue), and her distribution effort is unobservable by the issuer.[2] Under the optimal contract, the intermediary operates both an advisory role (about the price) and a distribution role. Hölmstrom and Baron (1980) study the optimal contract in the context of negotiated sales where the asymmetry of information in favour of the banker emerges only after the contracting stage due to pre-selling activities. More recently, Biais, Bossaerts, and Rochet (2002) have analyzed the IPO mechanism that maximizes proceeds from sales in a setting where the issuer is again the less informed party.

In these contributions, the intermediary's superior information provides a natural justification for intermediation. By contrast, we focus on uncertainty about the quality of the prospects of issuing firms. This is known by the issuer but only imperfectly observed by the intermediary (and by investors). Hence, in our setting, the case for an intermediary is less obvious, since the intermediary does not possess superior information. Chemmanur and Fulghieri (1994) also focus on problems arising from uncertainty about the quality of the issuing firm. In their model, investment banks evaluate entrepreneurs' projects and report to investors in return for a fee. This costly activity is prone to moral hazard. Accordingly, investment banks' credibility depends on their history. Reputation concerns provide investment banks with the incentives to collect information and reveal it truthfully. A similar point is made by Sherman (1999) who allows for both reputation and litigation costs. Our

[2] Baron (1979) studies pricing and distribution of issuers when banks' distribution effort is unobservable and agents are risk averse. In that context, the optimal contract is such that issuer sacrifices some of the gains from risk sharing in order to provide the banker with the right incentives to distribute the issue.

results can be seen as complementary to theirs, since we show that underwriting can play a similar role to reputation or litigation costs in aligning the intermediary's incentives with those of the investors.

Our paper is also related to the underpricing literature. According to Ritter and Welch (2002, p.11), there are probably "[..] no exceptions to the rule that the IPOs of operating companies are underpriced, on average, in all countries [..]". The existing literature on underpricing in IPOs is extensive and has offered various explanations for such stylized fact. Under the optimal contract studied by Baron (1982), the issuer has to sacrifice part of the proceeds from the issue to provide the investment bank with the right incentives. However, this result is questioned by Muscarella and Vetsuypens (1989) on empirical grounds. They find that even in the case of investment banks going public – a situation in which asymmetric information about the demand for the issue should not be relevant – IPOs are still characterized by significant underpricing.[3] This suggests that asymmetry of information about demand does not play a central role in IPOs.

Several papers have tried to explain underpricing as the product of signaling – examples are Allen and Faulhaber (1989), Grinblatt and Hwang (1989), and Welch (1989).[4] In these models, issuing firms have private information about their value and try to signal the quality of their prospects to outside investors through the offering price. The rationale for underpricing is that good firms prefer to "leave money on the table" when going public. This should credibly signal the issuing firm's type and allow the issuer to profit from future equity issues. A problem with this literature is that it predicts a relationship between first day returns and subsequent seasoned equity issues that is not found in the data, as shown by Michaely and Shaw (1994). Furthermore, all these models assign a passive role to financial intermediaries. This seems at odds with the fact that hardly any issuing firm directly places its shares in the market.

Similarly to these contributions, our model explains underpricing as a result of asymmetric information. However, in our analysis underpricing emerges as the result of the conflict of interest between the privately informed issuer and the intermediary. As such, our explanation for underpricing does not rely on a "leaving money on the table" argument and is independent of seasoned equity offerings.

Finally, a further strand of literature on IPOs deals with the reasons to go public. Important contributions include Zingales (1995), Chemmanur and Fulghieri (1999), Mello and Parsons (2000), Brau et al. (2003), Faure-Grimaud and Gromb (2004). Although this is not the focus of our analysis, our modelling approach is consistent with several of the reasons

[3]These IPOs are characterized by the presence of underwriting syndicates. Consistent with our story, institutions whose incentives are not perfectly aligned with those of the issuer participate in the underwriting and distribution of shares. Muscarella and Vetsuypens (1989) also report that in these IPOs the maximum offering price is decided by an independent underwriter. This could be interpreted as a way to avoid over-signaling.

[4]Alternative or complementary explanations for underpricing are surveyed by Ritter (2003). Important contributions have focused on: information asymmetries among investors (Rock, 1986) information acquisition by the investment bank (Benveniste and Spindt, 1989), prospect theory (Loughran and Ritter, 2002), lawsuit avoidance (Hughes and Thakor, 1992), IPOs as marketing events (Chemmanur 1993, Aggarwal et al. 1992, Demers and Lewellen 2003, Habib and Ljungqvist, 2001).

highlighted by the literature.

3 Model Background

The model is introduced in section 4. Here, we discuss two main features of our modelling approach.

Recent empirical evidence (see Brau and Fawcett 2006) suggests that one of the main reasons why firm owners may be reluctant to go public is their desire to retain ownership and/or control. Intuitively, the benefits from retaining ownership/control should increase with the firm's quality. Consistent with this idea, a key feature of our analysis is that:

(a) Owners of high quality firms are more reluctant to go public than owners of low quality firms.

The point can be easily illustrated by analogy with a standard lemon setting. Consider a seller who wishes to sell a good, in exchange for a payment p from the buyer. The good may be either of type H (high quality) or of type L (low quality). The seller's valuation for a type $q = H, L$ good is v_q. Since type H goods have greater value, it is natural to assume that

$$v_H > v_L \tag{1}$$

Condition (1) implies that, when contemplating trade, the outside option of the owner of a high quality good – namely, keeping the good – is higher than that of the owner of a low quality good. In turn, this makes owners of high quality goods more reluctant to sell. Assumption (a) applies this notion to the case of firms undertaking an IPO. Owners of high quality firms are more reluctant to go public in the sense that any payment that would induce them to go public would also induce owners of low quality firms to do so – but not vice versa.

There is no general agreement on why firms go public.[5] However, there is some consensus (see Ritter and Welch 2002) that

(i) a firm's owner desire to finance further investments/growth opportunities within the firm and/or;

(ii) his desire to liquidate his position in the firm (cashing out) in order to finance new ventures

constitute important reasons. Brau and Fawcett (2006), in a survey of chief financial officers, find strong support for (i) and moderate support for (ii).[6] In section A.1 of the appendix,

[5] Alternative explanations for why firms go public comprise: i) to facilitate acquisitions (Brau et al. 2003), ii) to establish a market price for the firm (Zingales 1995, Mello and Parsons 2000, Faure-Grimaud and Gromb 2004), iii) to obtain ownership dispersion (Chemmanur and Fulghieri 1999).

[6] More precisely, they report that more than 30% of CFOs felt that the IPO provides a chance to cash out for the principal and/or for the venture capitalist.

we formally show that assumption (a) is compatible with both classes of situations, (i) and (ii).[7] In both cases, the issuer accepts to share (or forgo) the return of some assets he owns in order to raise cash. The issuer's outside option to going public is therefore determined by the quality of the assets already in place. Consistent with Tirole (2006, pp. 245-246), the higher the value of these assets, the more reluctant the issuer is to go public. The model we consider thus differs from existing signaling models of IPO underpricing, in that we assume that the outside option of the issuer depends on his type.[8] (In what follows, we will use the expressions "owner of a type q firm" and "type q issuer" interchangeably.)

Another feature of our setup is that

(b) Going public is socially efficient (inefficient) if the firm is of type H (type L).

Consider again a standard lemon setting. Suppose that there is a single buyer, and the maximum payment he is willing to make for a type q good is u_q. When a type q is sold, value is created so long as $u_q > v_q$, i.e. the maximum payment that the buyer is willing to make is above the minimum payment that the seller would accept. The requirement in (b) can be thus summarized by the following:

$$u_H > v_H, \quad u_L < v_L \tag{2}$$

In a frictionless world, going public never destroys value. In reality, however, there are compelling reasons why going public may entail costs that private companies do not face. A typical example is the cost of complying with a more stringent regulation. For instance, a survey by CRA international, a consultant, finds that the cost of complying with section 404 of the Sarbane Oxley act ranges between 1.5 billion dollars for small companies to 7.5 billions for large companies. Alternative examples include the costs resulting from executives having to spend time negotiating with shareholders and regulators, rather than "getting things done". For going public to be efficient, the potential gain from trade must be sufficiently high to outweigh such costs. In our model, this happens only for type H issuers.

In section A.1 of the appendix, we discuss how examples (i) and (ii) are compatible with assumption (b) when (a) is also satisfied. The key factor is that the value of the assets in place is positively correlated with the value of the investment opportunity to be financed. A natural explanation for this correlation is the persistency of issuer-specific factors such as

[7]It should however be stressed that other theories of going public are not necessarily in conflict with our assumption. For instance, in Chemmanur and Fulghieri (1999), the alternative to going public for a firm consists of raising finance privately with a venture capitalist. In equilibrium, high quality firms obtain better conditions from the venture capitalist. Hence, when considering whether to go public, high quality firms have a higher outside option.

[8]Typical models of IPO underpricing assume that the issuer seeks to raise cash to finance a project by offering a share of the future cash flows to investors. While projects differ in their expected value, issuers of both types *have identical outside options.* This implies that issuers of type L are more reluctant to go public than issuers of type H . Whatever share of future cash flows an issuer of type L would be willing to forgo, a type H issuer would also be willing to forgo. This in turn allows type H issuers to reveal their type by "leaving money on the table", i.e. by offering a relatively high share of future cash flows to investors. A stylized version of these types of models is discussed in Tirole 2006, pp. 262-264.

entrepreneurial ability, human capital, business or political connections. Issuers with more valuable investment opportunities are thus more reluctant to go public because they have more valuable assets in place.

It should be noted, however, that, while assumption (b) allows us to derive our results in a particularly striking form (especially in section 5, where the issuer tries to market the shares directly to the investors), it is not the driving force of our story. This point is discussed further in section 8.

4 The model

We consider issues in the primary market through fixed price offers. There is an issuer (S), an investor (I), and an investment bank (B). We compare two possible mechanisms for issuing stocks: 1) direct issues, 2) intermediated issues. In a direct issue, S chooses the offering price, I decides whether to buy, and B retains a passive role. In an intermediated issue, B acts as an underwriter. She is the only counterparty for both S and I, and can bargain with S over the offering price.

For simplicity, we concentrate on a model in which the offering price is the only choice variable. This naturally arises in IPOs where either the amount of cash that the issuer wishes to raise or the number of shares on offer are determined by exogenous forces.[9] As discussed in section 8, this assumption does not play a crucial role for our results.

4.1 Payoffs

In this section, we formally introduce and discuss payoffs of the issuer and of the investor. Section A.1 of the appendix illustrates how these payoffs may emerge within the context of the examples (i) and (ii) mentioned in section 3 – namely financing further growth and cashing out.

Issuer

The issuer S is risk neutral. S's firm can be of two types: $q \in \{H, L\}$ where H indicates a high quality firm, while L denotes a low quality one. We assume that S's type is private information to S.

The issuer's payoff from going public net of his outside option is $V(p, q)$, where p is the offering price and $q \in \{L, H\}$. $V(., q)$ is assumed to be continuous and differentiable, and to satisfy the following monotonicity conditions:

A 1.

[9] The first case emerges when for instance the investment opportunity to be financed through the IPO is characterized by indivisibilities. The second case applies for instance to privatization IPOs, where the share of the firm that remains in public hands is fixed by regulators. More generally, as argued by Biais, Bossaerts and Rochet (2002), in IPOs "[..] the number of shares is indeed most of the time set a priori".

(i) *For all* $p, p' \in \mathbb{R}^+$, $p > p'$ *and* $q \in \{L, H\}$

$$V(p,q) > V(p',q) \tag{3}$$

(ii) *For each* $q \in \{L, H\}$, *there exists* $v_q \in \mathbb{R}^+$ *such that*

$$V(v_q, q) = 0 \tag{4}$$

(iii) *For all* $p \in \mathbb{R}^+$

$$V(p,H) < V(p,L) \tag{5}$$

A 2. *For all* p *and* p' *such that* $p > p' \geq v_H$, $\frac{V(p,H)}{V(p,L)} > \frac{V(p',H)}{V(p',L)}$.

Assumption A1(i) states that the benefit from going public to the issuer increases in the price at which shares are sold to the investors. The intuition is straightforward if the issuer aims at cashing out by going public. However, the assumption stands even if the purpose of the IPO is to raise finance to be invested in the firm. Intuitively, keeping the amount of finance raised constant, a higher offering price implies that the issuer retains a larger stake in the firm. He will therefore be able to claim a larger share of the firm's future cash flows.

Assumption A1(ii) guarantees the existence of reservation prices (v_H and v_L for type H and L respectively). A type q issuer would never choose to go public if the offering price were below v_q. Assumption A1(iii) ensures that a type L issuer would profit more from going public than a type H issuer. Notice that assumptions A1(ii) and A1(iii) imply $v_H > v_L$, namely condition (a) described in section 3.

Assumption A2 provides a sorting condition. It implies that whenever type L weakly prefers the highest among two offering prices, type H strictly prefers the highest. Formally, let $p \geq v_H$ and $p' < p$ be two offering prices and let x and x' denote the probabilities that the IPO is successful at p and p' respectively. Then A2 implies that $xV(p,H) > x'V(p',H)$ whenever $xV(p,L) \geq x'V(p',L)$. Intuitively, type H benefits relatively more than type L from a higher price even when this reduces the chances of selling the shares.

Investor

The investor I is risk neutral. We denote I's net payoff from investing in the firm through the IPO with $U(p,q)$, where $U(.,q)$ is continuous and differentiable. The restrictions on $U(p,q)$ are symmetric to those in A1.

A 3.

(i) *For all* $p, p' \in \mathbb{R}^+$, $p > p'$ *and* $q \in \{L, H\}$

$$U(p,q) < U(p',q) \tag{6}$$

(ii) *For each* $q \in \{L, H\}$, *there exists* $u_q \in \mathbb{R}^+$ *such that*

$$U(u_q, q) = 0 \tag{7}$$

(iii) *For all* $p \in \mathbb{R}^+$

$$U(p, H) > U(p, L) \tag{8}$$

Assumption A3(i) ensures that I's net payoff is decreasing in the offering price. Assumption A3(ii) guarantees the existence of I's reservation prices for type H and L (u_H and u_L) respectively. With perfect information, I would accept to buy shares in a type q firm only if the offering price were less than u_q. Assumption A3(iii) ensures that I prefers type H to type L. Finally, as in the case of the issuer, assumption A3(ii) combined with assumption A3(iii) imply $u_H > u_L$.

A simple example of payoffs that satisfy assumptions A1-A3 is the linear case $V(p, q) = p - v_q$ and $U(p, q) = u_q - p$. This corresponds to a standard lemon model where the value of the firm is v_q for the issuer and u_q for the investor.

We concentrate on situations where the adverse selection problem is particularly severe, in that, on efficiency grounds, low quality firms should not go public at all. This is condition (b) discussed in the previous section. Accordingly, we make the following assumption:

A 4. *The surplus generated when a type* $q \in \{H, L\}$ *firm goes public*

$$V(p, q) + U(p, q) \tag{9}$$

is independent of p *and is positive for* $q = H$ *and negative for* $q = L$.

Note that assumption A4 implies that $u_H > v_H$ and $u_L < v_L$. The requirement that the surplus generated by trade be independent of the offering price is natural if we interpret p as a mere transfer of wealth from the investor to the issuer. This is for instance the case in the simple linear example sketched above. More generally, A4 allows us to establish a clear benchmark under which to evaluate direct and intermediated issues. This is because social welfare is only affected by trade and not by the prices at which trade occurs.

Investment Bank
The Investment Bank B performs an active role only in intermediated issues, which are discussed in section 6. We postpone the discussion of the presentation of B's payoff to that section.

4.2 Information structure

The issuer perfectly observes the firm's type. The information structure of other agents is as follows.

Investor. I's prior is that S is of type H with probability λ and of type L with probability $1 - \lambda$. Prior beliefs are common knowledge among all players. I observes two signals: the offering price, p, and an exogenous private noisy signal, $s \in [\underline{s}, \overline{s}]$, with conditional density $f(s|q)$ and cumulative distribution $F(s|q)$.

We assume that $f(s|q)$ satisfies the Monotone Likelihood Ratio Property (MLRP) so that $\frac{f(s|H)}{f(s|L)}$ is a strictly increasing function of s and has full support $(0, \infty)$.

Investment Bank. We assume that B receives a signal $\sigma \in \{h, l\}$ about S's type; σ is not observed by I and is distributed as follows

$$\Pr(\sigma = h|H) = \eta \tag{10}$$
$$\Pr(\sigma = h|L) = 1 - \eta \tag{11}$$

for $\eta \in (1/2, 1)$.[10] B's posteriors $\pi_h \equiv \Pr(H|h)$ and $\pi_l \equiv \Pr(H|l)$, with $\pi_h > \pi_l$, are thus

$$\pi_h = \frac{\eta\lambda}{\eta\lambda + (1-\eta)(1-\lambda)} \tag{12}$$

$$\pi_l = \frac{(1-\eta)\lambda}{(1-\eta)\lambda + \eta(1-\lambda)} \tag{13}$$

5 Direct Issues

The timing of a direct issue is as follows:

Stage 0 Nature draws $q \in \{H, L\}$ from a Bernoulli distribution with $\Pr(q = H) = \lambda$.

Stage 1 S observes q and selects an offering price $p \in \mathbb{R}^+$.

Stage 2 I observes p, his private signal $s \in [\underline{s}, \overline{s}]$ and chooses whether to buy or not.

Stage 3 payoffs are realized.

If no trade occurs at stage 2, then both S and I obtain their outside options.

The game just described is a signaling game between S and I and the appropriate equilibrium concept is Perfect Bayesian Equilibrium (PBE). Denote with $\mu(q|p, s)$ the belief function giving I's probability assessment that S is of type q given p and s. A PBE is a strategy profile for S and I and a belief function $\mu^*(q|p, s)$ which satisfy the usual conditions: 1) S's best reply, 2) I's best reply, 3) consistency of $\mu^*(q|p, s)$ with Bayes rule for all p that are selected with positive probability in equilibrium. In order to avoid the common "unsent message" problem, we refine the PBE concept with Cho and Kreps (1987) version of "Never a Weak Best Response" (NWBR). Intuitively, for any p that is selected with probability zero in equilibrium, if the set of I's best responses for which a type q issuer weakly benefits from selecting p (relative to his equilibrium payoff) is contained in the set for which a type q'

[10] The cases in which the intermediary is perfectly informed ($\eta = 1$) or uninformed ($\eta = 1/2$) are qualitatively equivalent. These are discussed in section 8.

issuer strictly benefits, then I, upon observing p, assigns probability zero to type q. This a standard refinement in the signaling literature.[11] Section 8 analyzes the robustness of our results to the use of this equilibrium concept.

We are now ready to state the main result of the section.

Proposition 1. *Under direct issue, there exists a unique NWBR-refined equilibrium outcome and is such that S charges some price $p \geq u_H$ and no trade occurs.*

The proof relies on two observations. The first is that there is no separating equilibrium in which trade occurs. Consider an equilibrium in which a type q issuer selects action p_q with $p_L \neq p_H$, and trade occurs with positive probability. In this equilibrium, type L would not be trading since, when $q = L$, trade would make either the issuer or the investor worse off. This follows from the assumption that it is socially inefficient to trade type L firms (S's reservation price v_L is greater than I's reservation price u_L). However, if type H were trading, this equilibrium would violate type L's incentive compatibility.

The second observation is that other types of equilibria in which trade may occur (pooling or hybrid) would violate NWBR. Whenever both types of issuer are pooled together at the same price, say p^*, a type L issuer would benefit from trading more than a type H issuer, since $v_H > v_L$. This implies that the set of I's best responses for which type L weakly benefits from a deviation, $p > p^*$, is contained in the set of best responses for which type H strictly benefits. According to NWBR, I's beliefs should then assign probability zero to the event that a type L issuer deviated to p. This gives the issuer a strong incentive to raise p in order to signal that he is of type H and hence increase the likelihood of trading.

A perhaps more intuitive way to explain the result of proposition 1 is the following. If offering prices were perfectly revealing, type L issuers would want to increase their price to mimic type H issuers. If offering prices were not perfectly revealing, type H issuers would want to raise their price to differentiate themselves from type L. This "upward race" would only stop when the offering price hit the investor's reservation utility for a type H firm. At that price, I never chooses to buy the shares as long as the price is selected by type L with positive probability. Hence, the market breaks down.

Although of similar flavor, the result of proposition 1 is thus different from the classic example of Akerlof (1970). In Akerlof's case the market breaks down because adverse selection exerts a downward pressure on the price. In our case, the reverse happens. The market breaks down because signaling concerns exert an upward pressure on the price. In a sense, there is "over-signaling". If S could ex-ante commit not to use the offering price as a signal for his type, he would always be able to trade with a positive probability. This is because, conditional on his private signal being sufficiently high, the investor would be willing to buy at any pooling price that does not exceed his reservation utility. Hence, rather than solving the adverse selection problem, signaling through prices exacerbates it.

[11] See for instance Fudenberg and Tirole (1991, pp. 454-56).

6 Intermediated Issues

In the previous section we have seen how trade collapses when S tries to market his shares directly to I. In this section, we show that this inefficiency can be mitigated by the presence of an investment bank acting as an underwriter. We identify conditions under which such an intermediary can restore trade between S and I and avoid losing money in the process.

As an underwriter, B buys all shares from the issuer and resells them to the investor. (In what follows, we use the expressions "the IPO takes place" and "B underwrites the shares" interchangeably, to signify that trade occurs between B and S.) For this service, B receives from S a fixed compensation, denoted with ϕ. The transfer ϕ is essentially an underwriting fee which is paid to B in exchange for her underwriting services. The payment of ϕ is therefore contingent on the IPO taking place. We do not explicitly model the market for underwriting services, but rather assume that B takes ϕ as given. The notion that underwriters do not condition their compensation on the characteristics of the IPO but instead stick to a given fee is backed by recent evidence by Chen and Ritter (2000). They show that, for the US, in more than 90% of IPOs raising between 20 and 80 million dollars, the underwriter compensation was exactly 7% of the value of the issue.

The offering price is determined after B observes her signal σ about S's type. An aspect in which this model differs from existing literature is that B is able to influence the offering price. In order to avoid the complications that naturally arise when considering bargaining under asymmetric information, we assume an extreme form of bargaining in which B makes a take it or leave it offer to S about the offering price. If S accepts the price offered by B, then the IPO takes place. In this case S makes the transfer ϕ to B and B announces the offering price to the investor. S's net payoff is thus $V(p,q) - \phi$. For future reference we denote with v_H^ϕ the offering price such that

$$V(v_H^\phi, q) - \phi = 0 \tag{14}$$

If S rejects B's offer, then no IPO takes place and all players obtain their outside option. For simplicity, we assume that in this case S cannot use a different underwriter.[12]

The timing of an intermediated issue is thus as follows.

Stage 0 the market for underwriting services determines ϕ.

Stage 1 Nature draws a type $q \in \{H, L\}$ for S which is observed by S only.

Stage 2 B observes σ and makes an offer p to S.

Stage 3 S chooses whether to accept of reject B's offer.

If the offer is rejected the game ends and players obtain their outside options. If it is accepted,

[12] Although not explicitly modelled here, one can suppose that the investor interprets using a different underwriter after the underwriter has acquired information as a signal that the information about the issuer is unfavorable.

Stage 4 B announces p to I.

Stage 5 I observes p and s and chooses whether to buy or not.

Stage 6 payoffs are realized.

A feature of our setup is that it rules out any form of contracting on the offering price prior to stage 2. As discussed by Ellis et al. (1999), this is consistent with typical IPO procedures. The firm and the underwriter generally meet to choose the offering price only on the day prior to the placement of the stocks. By that time, the process of information collection by the underwriter has already taken place.

Given B's role as underwriter, it is natural to assume that B acts as a self-interested agent with incentives that may be different from those of other players. We assume that when the IPO does not take place, B obtains a payoff equal to zero. When the IPO takes place and I chooses to buy, shares are transferred from S to I and B's payoff is equal to ϕ. If, by converse, I chooses not to buy, the shares remain in the hands of B. In this case, we need to determine the utility that B derives from holding a stake in the firm. A natural starting point is to assume that there are gains from trade between B and I – namely that holding shares is more valuable to I than to B. If this were not the case, then it would be unclear why B should act as an intermediary rather than being an investor. On the other hand, if both have access to the stock market, then the return that B and I can realize from owning shares in a type $q = H, L$ firm should be the same. For instance, I may want to buy shares in order to resell them on the stock market at a later date, when the firm's type has been observed. If this can be replicated by B, then their returns should coincide. If both have access to stock market, the gains from trade between B and I should then arise from different opportunity costs.[13] This is the route we take here. We assume that the net payoffs of B and I are identical up to a constant capturing the difference in opportunity costs. B's net payoff from a type q firm when I chooses not to buy is therefore $U(p, q) - K + \phi$, where the constant $K \geq 0$ represents the gains from trade between B and I.

A strategy for B is a map from the set of realizations of σ into the set of probability distributions over $\mathbb{R}^+$ (i.e. the set of admissible values for p). A strategy for S is a map from $\{H, L\} \times \mathbb{R}^+$ (i.e. the set of realizations of q and the set of possible p offered by B) into the set of probability distributions over {accept, reject}. Finally, a strategy for I is a map from $\mathbb{R}^+ \times [\underline{s}, \overline{s}]$ into the set {buy, not buy}. A PBE is a profile of strategies and belief functions for B, I, and S such that at any stage of the game: 1) strategies are optimal given beliefs, 2) beliefs are consistent with Bayes rule for all actions played with positive probability in equilibrium. An equilibrium for the intermediated case is then a PBE of the game just described and a level of ϕ such that B makes non-negative expected profits. Again, we focus on equilibria that pass NWBR.

From assumption A1(iii), $V(p, L) - \phi > V(p, H) - \phi$ for all ϕ and $p \in \mathbb{R}^+$. This implies that, whenever a type H is willing to accept B's offer, a type L issuer would also accept.

[13]Different opportunity costs may for instance arise if the investment bank has investment opportunities not available to the average investor, as in Sherman (1999).

An offering price is therefore either accepted by both types or only by type L. B is thus unable to weed type L out of the market by appropriately selecting the offering price. On the other hand, before choosing the price, B observes a signal that is not observed by I. Hence, although the choice of the offering price cannot perfectly reveal the issuer's type, it may nevertheless convey information about the realization of B's signal.

The remainder of this section is organized as follows. We first provide two results that illustrate the tension that emerges between the intermediary's ability to restore trade and her viability. We then turn to the full characterization of the benchmark case in which B's expected profits are exactly zero, showing that this is compatible with trade.

6.1 Trade vs Viability

In section 5, we saw how the issuer's signaling concern led to market breakdown. In this section we analyze the trade off between the requirements that trade should occur and that the intermediary should break even. We start off by considering the intermediary's pricing strategy.

If the offering price is too low to be accepted by type H, but is accepted by type L, then B would surely lose from underwriting the shares. Intuitively, this follows from the assumption that no gain from trade can be reaped from trading type L shares.[14] Hence, B may find it optimal to go ahead with the IPO only at a price p that is acceptable to a type H issuer, i.e. at a price greater than or equal to v_H^ϕ. Conditional on $p \geq v_H^\phi$, I believes that issuer's type is H with a positive probability. If the offering price is also lower than his valuation for type H shares, u_H, I is willing to buy the shares whenever his signal s is sufficiently high. Hence, trade between B and I occurs with positive probability. The next lemma shows that B would always find it optimal to select a price lower than u_H whenever this is compatible with type H's participation. Hence, once B has chosen to underwrite the shares, the "no trade" equilibrium identified in proposition 1 can no longer emerge.

Lemma 1. *Assume that there is trade between B and S (i.e. the IPO takes place). Then, $v_H^\phi < u_H$ is both necessary and sufficient to ensure that trade between B and I occurs with positive probability.*

The proof relies on the following argument. Suppose that B chooses a price $p \geq u_H$ so that I never buys. At this price, shares are on average overpriced. B would certainly gain by paying a lower price to the issuer. Hence, B has an incentive to decrease price below u_H. But then, trade with I occurs with positive probability.

Lemma 1 highlights how B's incentives on price setting differ from those of the issuer. Intuitively, although B is a seller when dealing with I, she is a buyer when dealing with S. As a buyer, B suffers from a higher price – since, given ϕ, her payoff from owning the shares, $U(p,q) - K$, is decreasing in p. In contrast, the issuer's payoff $V(p,q)$ is increasing in p. This difference in B and S's price-setting incentives implies that, when the intermediary

[14] This intuition is formally proved by lemma C.2 in the Appendix.

is present, the upward pressure on price that characterizes direct issues is mitigated. Trade may therefore occur at equilibrium.

This discussion stresses the desirability of a conflict of interest between the issuer and the intermediary. This is in contrast with the existing literature on intermediaries on IPOs, which has mainly focused on the design of mechanisms geared at aligning the two parties' incentives.[15]

The natural next question is whether B can gain from underwriting the shares. Since B has imperfect information, I's choice of buying or not conveys information about the value of the shares. Hence, whenever I chooses to buy at the offering price, B upwardly revises her valuation for the shares. Similarly, whenever I chooses not to buy at the offering price, B should revise her valuation downwards. Essentially, B faces an adverse selection problem, or "seller's curse". As a result, B on average makes losses from her underwriting activities. For B to break even, it is therefore necessary that ϕ, the underwriting fee, be strictly positive. This shares similarities with a well known result in the literature on market microstructure. Glosten and Milgrom (1985) show that, in the presence of informed traders, a risk neutral dealer would need a positive bid-ask spread in order to break even. The result is illustrated by the following lemma.

Lemma 2. *In any equilibrium in which the IPO takes place, B makes no expected losses only if $\phi > 0$. If the IPO takes place at price p, the following conditions are satisfied: $p \geq v_H^{\phi} > v_H > v_L > u_L$.*

As lemma 2 illustrates, the underwriting fee plays an essential role, which is that of compensating B of the expected losses from underwriting.

The requirement that $\phi > 0$ has implications for the price at which the IPO may occur. As seen above, a type H issuer is willing to accept B's offering price only if this is greater than v_H^{ϕ}, which is increasing in ϕ. Intuitively, the larger the fee the issuer must pay, the higher the offering price must be in order to induce him to sell the shares. Hence, the higher the expected losses from underwriting, the higher the offering price.

Lemma 1 and lemma 2 highlight a key tradeoff. On the one hand, the presence of an intermediary may allow trade by mitigating the upward pressure on price that is present with direct issues. On the other hand, the requirement that this intermediary should be viable introduces a different sort of upward pressure on the price. Formally, this tension is illustrated by the requirements imposed on ϕ by the two lemmata. From lemma 1, trade between B and I requires v_H^{ϕ}, and therefore ϕ, to be sufficiently small. However, lemma 2 suggests that the intermediary is viable only when ϕ is sufficiently large. These two requirements are in conflict with each other. The main question is therefore whether viability and trade may coexist. We show that this is indeed possible, by characterizing the benchmark case in which B makes exactly zero profit. Recent evidence suggests that this case is also empirically relevant. Indeed, as shown in Hansen (2001), the typical 7% spread earned by investment banks is too low to yield abnormal profits.

[15]See for instance Baron (1982), Hölmstrom and Baron (1980), and Biais, Bossaerts, and Rochet (2002).

6.2 Characterization and existence of the zero profit equilibrium

In this section we restrict attention to the case where B makes exactly zero profit. We divide the analysis in two parts. First, we characterize the zero-profit equilibrium. We then discuss the sufficient conditions for the equilibrium to exist, and for it to be unique.

Lemma 3. *(Characterization of the zero-profit equilibrium) Let Φ denote the set of values of ϕ for which trade between B and I occurs with positive probability and B makes zero profits. Whenever $\phi \in \Phi$, a NWBR-refined equilibrium with trade exhibits perfect separation. The IPO takes place only when B observes $\sigma = h$, in which case she offers the lowest price satisfying the participation constraint of type H (i.e. v_H^{ϕ}). When $\sigma = l$ is observed, B offers a price that violates the participation constraint of both types of issuers and no IPO takes place.*

Lemma 3 establishes several results. First, in a zero profit equilibrium the IPO takes place only when B receives favorable information about S's type ($\sigma = h$). By contrast, when information is unfavorable ($\sigma = l$), B proposes a price so low that the offer is always rejected by S, and no IPO takes place. Upon receiving unfavorable information, B therefore prefers to forgo the IPO altogether. Lemma 3 thus highlights how the presence of an intermediary may allow separating equilibria to emerge. As seen in section 5, when the issuer sells his shares directly to the investor, mimicking behavior by type L issuers would systematically destroy any separating equilibrium. By contrast, when B observes $\sigma = l$, her incentive to pretend otherwise is much weaker. So long as I trades on the basis of his private information, the likelihood of being unable to sell overpriced shares is relatively high if B underwrites them when $\sigma = l$.[16] This result suggests that the intermediary acts as a screening device, ensuring that firms that manage to go public have, on average, higher quality than those which fail to do so. This benefits I, since B's choice to underwrite or not credibly reveals her information. In a sense, through underwriting, B is forced to "put her money where her mouth is".

Second, when the IPO takes place, B selects the lowest price at which the high quality issuer is willing to sell the shares. A higher price would benefit the issuer, but would hurt the intermediary. By setting a higher price, B would sell the shares with a lower probability since I would only buy for higher realizations of his signal. As seen in the discussion of lemma 2, B revises her valuation for the shares downwards when I chooses not to buy them. Paying a higher price to the issuer and selling with a lower probability is thus unambiguously detrimental to B. Therefore, conditional on type H's participation, the intermediary's expected profits are strictly decreasing in p. Lemma 3 thus shows how B's pricing strategy in the zero-profit equilibrium totally diverges from S's pricing strategy under direct issues: B selects the lowest possible price that satisfies type H's participation constraint.

The next lemma provides sufficient conditions for existence and uniqueness of a zero profit equilibrium.

[16] On the other hand, mimicking would allow B to profit from the underwriting fee. However, it turns out that the value of ϕ ensuring that B makes zero profit when $\sigma = h$ is low enough to discourage mimicking when $\sigma = l$.

Lemma 4. *(Existence and uniqueness of a zero-profit equilibrium) If* $(1-\pi_h)U(u_H, L) + V(u_H, H) - K > 0$*, then* Φ *is non-empty. If* $U(p, H) - U(p, L)$ *is non-increasing in* p*,* Φ *is a singleton for* K *sufficiently small.*

The condition $(1-\pi_h)U(u_H, L) + V(u_H, H) - K > 0$ ensures the existence of a fee such that B makes zero profits and trade between B and I occurs with positive probability. The expression $(1-\pi_h)U(u_H, L) - K$ represents the maximum expected loss that the intermediary may suffer from underwriting.[17] The term $V(u_H, H)$ corresponds to the maximum fee that is compatible with participation by a high quality issuer. When this is greater than the maximum expected loss, a positive probability of trade is assured.

Note that, given $u_H > v_H > u_L$, $V(u_H, H) > 0$ and $U(u_H, L) < 0$. Hence, provided that K is not too large, existence is ensured for sufficiently high values of π_h. This makes clear that our results do not rely on B having inferior information to S. Indeed, trade is most likely to occur when B's information is almost perfect. Note that π_h is increasing both in η and in λ. This can be used to make predictions on the conditions that favor trade while ensuring the viability of the intermediary. If type L are frequently drawn (low λ), B's information should be very precise (high η). In other words, when bad firms are frequent, B must be an effective screening device. By converse, if B's information is not precise, type L firms must be infrequent. The requirement that K should not be too large has a natural interpretation. In equilibrium, I only buys when his signal s is sufficiently high. Hence, B stands to keep the shares with a positive probability. If K is too large, then the value of ϕ required to compensate B from losses incurred in that instance would be so large as to outweigh any gain from trade between I and S.

Finally, the requirements for uniqueness ensure that the marginal gain from quality to the buyer $(U(p, H) - U(p, L))$ does not increase with the price. This is however not necessary for the existence of the equilibrium.

The following proposition summarizes the results discussed in this section.

Proposition 2. *When* B *makes zero expected profits, trade from* S *to* I *may occur with positive probability provided that* B*'s information is not too imprecise and/or* K *is not too large. Under these conditions,* B *goes ahead with the IPO only when her signal is favorable, in which case she selects the lowest price at which the type* H *issuer is willing to trade.*

7 Implications

We now discuss the implications of the model for underpricing. The objective is to assess whether shares that change hands are on average under or overpriced. We define as underpricing (overpricing) a situation in which, at the offering price, the investor would make a profit (loss) if buying.[18] Average underpricing then occurs if, at the equilibrium price, the expected quality on offer is such that the investor would make expected profits.

[17]When the price is equal to u_H, I never buys. Hence, the expected loss from underwriting is $\pi_h U(u_H, H) + (1-\pi_h)U(u_H, L) - K = (1-\pi_h)U(u_H, L) - K$.

[18]Using B rather than I as a benchmark for defining under/overpricing would not change any of the results.

We show that the causes of underpricing are twofold. First, the intermediary suffers from an informational disadvantage vis-à-vis the investor. This implies that shares bought by I are on average underpriced while shares bought by B are on average overpriced. Second, the pricing behavior of the intermediary results in shares being on average underpriced (independently of who buys them) even when B's informational disadvantage becomes vanishingly small.

Proposition 3 summarizes the first point.

Proposition 3. *Assume that B's expected profits are zero and trade between B and I occurs with positive probability (i.e. $\phi \in \Phi$). Then, in equilibrium: i) shares in the hands of I are on average underpriced; ii) shares in the hands of B are on average overpriced.*

This result is a direct consequence of the adverse selection problem suffered by B when trading with I. In the zero profit equilibrium this problem is especially pronounced since B's pricing strategy perfectly reveals her information to I. By contrast, I's information remains private. Hence, I has an informational advantage vis-à-vis B. The seller's curse is therefore extreme. On average, when B manages to sell the shares, these are underpriced; when she is unable to sell them, they are overpriced.

The result has an implication for the relationship between underpricing and amount subscribed. In equilibrium, shares of both type L and type H issuers are underwritten by the investment bank with positive probability. Those of type H issuers are underpriced while those of type L issuers are overpriced. I is more likely to observe a high realization of his private signal s when the issuer is of type H than when the issuer is of type L. Hence, he is more likely to buy when the issuer is of type H. This implies that there is a positive correlation between I's decision to buy and the likelihood that shares are underpriced. This is line with the findings of Cornelli and Goldreich (2003) who find positive correlation between underpricing and oversubscription.

To fully appreciate the role of the intermediary, it is important to assess whether average underpricing emerges simply as a result of the intermediary's informational disadvantage or it is also driven by her pricing incentives. To this purpose, we consider what happens when B's informational disadvantage becomes vanishingly small. We thus analyze two limiting cases: i) B is almost perfectly informed, and ii) I is almost uninformed. Notice that B is almost perfectly informed when $\pi_h \to 1$. I is almost uninformed when the signal he receives converges to a random variable that is independent of q. Let then $\tilde{s} \in (\underline{s}, \overline{s})$ be a random variable with distribution $\tilde{F}$ independent of q.

Proposition 4. *Assume that ϕ is such that B's expected profits are zero. For $s \to^d \tilde{s}$, the probability of trade between B and I converges to a positive value if and only if, at the equilibrium price v_H^{ϕ}, shares are on average underpriced. For $\pi_h \to 1$, trade between B and I occurs with positive probability if and only if shares are on average underpriced.*

Proposition 4 shows that, in the limiting cases, trade occurs if and only if shares are on average underpriced. The intuition relies on the positive relationship between the equilibrium price and B's informational disadvantage vis-à-vis I. The greater this informational disadvantage, the more severe the seller's curse, and the greater the fee necessary to cover B's expected losses from her underwriting activities. In order to ensure S's participation, B then has to charge a higher price. Otherwise, S would not accept to trade, given that he has to pay a large fee to B. By converse, when B's signal is sufficiently precise, or I's signal is sufficiently imprecise, the fee necessary for B to break even is small. The price charged by B is accordingly low and underpricing occurs.

8 Robustness and Extensions

In this section, we informally discuss how our results may apply also when some of our assumptions do not hold. We concentrate on four issues. First, we consider a situation where the issuer may potentially signal his type through his choice of both a share price and the number of shares he puts up for sale on the market. Second, we discuss possible modifications of the information structure. As a third point, we address the implications of ignoring equilibrium refinements, and allowing multiple equilibria to emerge in the model. Finally, we consider a situation where, under perfect information, both high and low quality firms should be traded.

As will become clear below, all cases are characterized by a common theme. The key idea is that under direct issue, low quality firms have a strong incentive to mimic high quality firms. This reduces either the average quality or the amount of trade that can be achieved in equilibrium. By contrast, the intermediary's incentive to mimic when she has received unfavorable information are comparatively weak. As a result, distortions are reduced.

Most of the claims we make in this section are formally proved in section D of the appendix.

8.1 Allowing for two instruments

The model analyzed in previous sections assumes that the only instrument available to the issuer to signal his type is the share price. What would happen if the issuer could vary both the share price and the number of shares on sale? In that case, he would have two rather than one instrument at his disposal. It is therefore legitimate to wonder whether this greater scope for manoeuvre could allow the high quality issuer to credibly signal himself, eliminating the problems highlighted in Section 5. We argue that this conjecture is misguided. Under conditions (a) and (b) of Section 3, mimicking behavior by low quality firms may not be prevented, even if the issuer can use both price and number of shares as signals. Intuitively, any combination (price, number of shares) such that the high quality issuer wishes to undertake the IPO would also attract the low quality issuer. This point can be illustrated using the simple linear payoffs framework. Suppose that the value of S's firm is v_q. By going public, S sells a fraction $1-z$ of the firm for a payment p. The issuer's net payoff from going public is:

$$V(p,z,q) = p - (1-z)v_q \tag{15}$$

Since $v_H > v_L$, it follows that $V(p,z,H) < V(p,z,L)$ for all $z \in (0,1)$ and $p > 0$. In this case, any pair (p,z) that satisfies type H's participation constraint would also satisfy type L's.

Consider now type L's incentive compatibility. In a separating equilibrium, type L would be unable to trade (given $u_L < v_L$). It follows that he would always profit from mimicking type H. Separating equilibria are therefore not possible.

8.2 Information Structure

The information structure introduced in section 4 may raise a number of concerns: (1) Does it matter that the issuer has better information than the investment bank? (2) What would happen if the investment bank had no private information? We argue that our results are robust to these modifications of the information structure.

To address question (1) suppose that both the issuer and the intermediary perfectly observe the issuer's type. Since the intermediary is perfectly informed, she no longer suffers from an informational disadvantage vis-à-vis the investor. As a result, $\phi > 0$ is no longer required for her to break even. It can be shown that there exist a continuum of zero-profit equilibria such that ϕ is zero and the IPO takes place only when the issuer is of type H, in which case the investor buys with probability one. However, contrary to the result in lemma 3, the equilibrium price is no longer uniquely determined under NWBR, but can take any value in $[v_H, u_H]$. Underpricing still emerges in all but one of the possible equilibria.

Now consider question (2). If the intermediary possesses no private information, her pricing decisions do not convey any information. The intermediary's incentives, however, are unchanged. In the zero-profit equilibrium, her expected payoff is strictly decreasing in the offering price. Hence, she selects the lowest price acceptable to a type H issuer. However, here the informational disadvantage the intermediary suffers vis-à-vis the investor is maximal, and the value of ϕ required for her to break even is correspondingly large.

The argument sketched above makes clear that our results are qualitatively independent of the precision of the intermediary's information. Although having a well-informed intermediary may be desirable, this is not a necessary condition for intermediaries playing an important role in the market.

8.3 Direct Issues are Viable

As suggested by proposition 1, without intermediaries, the IPO market would collapse. Throughout the paper, we have relied on this result to justify the existence of intermediaries in IPOs. Here, we extend the analysis to cases in which proposition 1 may not fully apply so that direct issues could be viable. One may wonder whether there is any need for intermediaries in these cases. We argue that, in most circumstances, the presence of an intermediary increases either the amount or the average quality of trade (or both). This could provide a possible justification for the existence of intermediaries even when issuing shares directly would be possible.

8.3.1 Equilibria that fail NWBR

In the main body of the paper we use an equilibrium refinement (NWBR) that dramatically reduces indeterminacy. The refinement ensures that, when considering direct issues, the unique (refined) equilibrium involves no trade at all, and that, under intermediated issues, the offering price is unique when the intermediary's profits are zero. An alternative approach is that of ignoring the refinement and allowing for multiple equilibria. We argue that this would not invalidate our results. To see this, consider first the case of direct issues. There exist a continuum of perfect Bayesian equilibria such that both types are pooled at some offering price $p \in [v_H, u_H]$. In these equilibria, I uses a threshold strategy on his signal when observing p and chooses not to buy when observing any other price. This strategy is in turn sustained by (NWBR-failing) beliefs assigning probability one to type L when observing any price different from p. Efficiency would require that H firms be traded with probability one and L firms with probability zero. These equilibria are thus inefficient, since low quality firms may be traded with a positive probability and high quality firms are traded with probability less than one.

Consider now intermediated issues. As noted in 8.2, if the intermediary is perfectly informed, then a situation where the IPO takes place only when the issuer is of type H (in which case the investor buys with probability one) is an equilibrium. In this equilibrium, the intermediary achieves full efficiency, something that could not be reached through direct issues. Hence, the use of an intermediary is clearly beneficial. What if the intermediary is only imperfectly informed? Without refinement, the equilibrium price in the zero-profit equilibrium is not necessarily $p_h = v_H^{\phi}$. However, perfect Bayesian equilibria still involve full revelation of the intermediary's information through the price choice (the intermediary goes on with IPO only when she receives favorable information). This stands in contrast with the case of direct issues in which no information is revealed. However, it also introduces a different source of inefficiency. If the intermediary has received misleading information, she may prevent the investor from trading with a high quality issuer. A trade-off then arises. On the one hand, in the separating equilibrium, the intermediary reveals her information to the investor. Keeping everything else equal, this improves efficiency. On the other hand, the intermediary may also mistakenly prevent good firms from going public. As her information becomes more precise, the second effect weakens, while the first becomes stronger. When the intermediary is perfectly informed, the second effect disappears altogether.

8.3.2 Low quality firms should also be traded

A running hypothesis of our model is that low quality firms would not be traded under perfect information. This assumption plays an important role in ensuring that, under direct issues, no separating equilibrium is possible, and trade may collapse altogether. A natural question is therefore whether the case for intermediaries would collapse if all firms generated gains from trade when going public independently of their quality. We argue that this is not the case. As discussed in Ellingsen (1997), in this case the only refined equilibrium that may emerge with direct issues is a separating equilibrium where trade is rationed for high quality firms – i.e., high quality firms sell their shares with probability less than one. By contrast efficiency would require that all types of firms be traded with probability one.

Consider now intermediated issues. First, suppose that the intermediary is perfectly informed. In this case, there exists a continuum of equilibria in which trade occurs for sure.

We refer to these equilibria as "efficient equilibria" since they maximize social welfare. In an efficient equilibrium, the intermediary selects

$$p = \begin{cases} p_H \in [v_H, u_H] \text{ when } q = H \\ p_L \in [v_L, u_L] \text{ when } q = L \end{cases} \tag{16}$$

the issuer always chooses to sell at p_q, $q = H, L$, and the investor buys. Efficient equilibria are typically separating (i.e. $p_H \neq p_L$) – although a pooling can also be efficient when $u_L > v_H$. These equilibria are sustained, for instance, by beliefs assigning probability one to type H when observing any out of equilibrium price in the interval $[v_H, u_H]$ and probability one to type L for prices lower than v_H. It is easy to check that these beliefs pass NWBR. Given the other party's strategy, both the investor and the intermediary have no incentive to deviate. It is then immediate to check that selling at p_q is a best reply for S. When one of these equilibria is selected, the presence of an intermediary unambiguously improves welfare, since it ensures full efficiency.

Now suppose that the intermediary is not perfectly informed. As seen in lemma 3, the intermediary then selects the price to maximize the probability of selling the shares she has underwritten. Suppose that $u_L > v_H$. Then, if $v_H^{\phi} < u_L$, by selecting a price $p \in \left[v_H^{\phi}, u_L\right]$ the intermediary would be able to sell the shares with probability one. This is clearly her favorite course of action. Intuitively, therefore, the zero-profit equilibrium outcome would have: $\phi = 0$, $p \in [v_H, u_L]$. This outcome would again generate full efficiency, since trade between the issuer and the investor would occur with certainty. Overall, therefore, the case where the intermediary is fully informed and the case where $u_L > v_H$ provide examples of how the use of an intermediary may be desirable, even when both high and low quality firms should be traded.

9 Concluding Remarks

This paper provides a possible rationale for the presence of financial intermediaries in IPOs, an issue that has been largely ignored by previous theoretical literature. We have shown how, in certain circumstances, signaling concerns by issuers may cause the market to break down when intermediaries are absent. The presence of a price-setting intermediary acting as an underwriter restores trade. However, the intermediary is not financially viable unless the underwriting fee she receives from the issuer is sufficiently high. This is potentially problematic, since hefty fees may dissuade issuers from going public, even when this would be efficient. Nonetheless, we show that a zero-profit equilibrium – where the intermediary just breaks even on average – can exist. In this equilibrium, the intermediary acts as a screening device, by agreeing to underwrite only the shares of firms over which she has favorable information. Consistent with empirical evidence, our model predicts that whenever the IPO takes place, shares subscribed by investors are underpriced.

Our model opens up several avenues for future research. For instance, it would be interesting to provide an explicit analysis of the market for intermediary services. In principle, competition in this market may take two different forms. On the one hand, we may have intermediaries competing to attract firms wishing to go public. On the other hand, we may have different firm-intermediary pairs competing to attract investors. Whether fully unregulated competition would deliver trade is not entirely clear. Our paper has shown that, for trade to occur, a conflict of interests must exist between the issuer and the intermediary. However – at least in the first case described above – in order to become more attractive to potential clients, intermediaries may have an incentive to find devices that align their interests with those of the issuers. So, in the absence of any form of regulation, market forces could potentially act against efficiency. Interventions that limit the firms' scope for manoeuvre in aligning their interests with the issuers' could then enhance efficiency.

A Appendix

A.1 Model Background

In this section we provide a rationale for the assumptions on the payoffs. We sketch two stories. In the first the issuer seeks cash to finance an expansion of the firm's activities. In the second a venture capitalist wants to cash out part of the value of his current venture in order to invest in a new venture. Several elements are common to both examples:

- All players can invest at the market rate $r \geq 1$.
- The issuer cannot borrow.
- There is a small cost in going public: a small amount $c > 0$ of resources is wasted in order to complain with regulatory requirements (transparency etc.).
- The issuer has already invested an amount $a > 0$ in the firm.
- Only type H firms yield above market returns. The per unit of finance return of the initial investment a is $R_H > r$ for firms of type H and is $R_L = r$ for firms of type L.

For both stories, we discuss the assumptions that ensure that conditions (a) and (b) discussed in section 2 are met. We also provide simple numerical examples that illustrate how, under (a) and (b), all the other assumptions we make are met rather naturally.

(i) Financing Further Growth. Consider the case of an entrepreneur who relies on the stock market to finance a possible expansion of his firm. There are two types of entrepreneurs: high ability (type H) and low ability (type L). Firms of type H entrepreneurs are high quality firms, in that they have growth opportunities (positive NPV projects), while firms of type L entrepreneurs do not. More precisely, entrepreneurs of type H can make further investments with positive NPV. We assume for simplicity that these further investment opportunities consist of one project to be conducted within the firm, which requires one unit of finance. If less than one unit of finance is invested, the project is unsuccessful, and yields a zero return. Provided that the unit of finance is invested, the project is successful and yields an above market return. We let this return be denoted as $R_H^{IPO} > r$. Following Tirole (2006, p. 244), we assume that it is not possible to contract on the cash flow generated by this additional project separately from that of the projects already in place within the firm. Moreover, since the entrepreneur is credit-constrained, we restrict attention to situations where the IPO allows him to raise the whole unit of finance he requires.

Type L firms have no positive NPV projects, but only carry projects that yield the market rate r. Hence, they have the same unit return whether they go public and raise finance or stay private: $R_L^{IPO} = R_L = r$.

Given R_H the return of assets in place for $q = H$, the present value of the firm to the entrepreneur in the absence of IPO is

$$\begin{cases} \frac{R_H a}{r} & if \;\; q = H. \\ a & if \;\; q = L. \end{cases} \tag{A.1}$$

This represents the opportunity cost incurred by the entrepreneur when going public. Note that, since $R_H > r$, this opportunity cost is always greater when $q = H$ than when $q = L$. This reflects the persistence of entrepreneurial ability: not only do type H entrepreneurs have better investment opportunities, they also have more valuable firms.

The value of the firm after the IPO has taken place (and one extra unit is injected in the firm) is

$$\begin{cases} \frac{R_H^{IPO} + R_H a}{r} - c & if \;\; q = H. \\ 1 + a - c & if \;\; q = L. \end{cases} \tag{A.2}$$

The investor's alternative to purchasing the shares is that of investing his unit of capital at the market rate. The net surplus generated when the firm goes public is thus equal to

$$\begin{cases} \frac{R_H^{IPO} - r}{r} - c & if \;\; q = H. \\ -c & if \;\; q = L. \end{cases} \tag{A.3}$$

Given $c > 0$, it is clear that, from an efficiency standpoint, low quality firms should not go public (condition (b)). This is because, when quality is low, going public entails no benefit (since the cash raised is used to finance a project that yields the same return as the market), but only costs. In contrast, provided that c is not too large – so that $\left(R_H^{IPO} - r\right)/r - c > 0$ – high quality firms should indeed go public. By going public, the entrepreneur is able to finance a project that yields returns exceeding those provided by the market.

We now turn to condition (a). This is satisfied if a type L entrepreneur would be willing to go public for all offering prices such that a type H entrepreneur would be willing to do so, but not vice versa. Suppose that the entrepreneur offers a fraction $1 - z$ of the company's profits in exchange for one unit of finance to be injected into the company. Let the total number of shares be normalized to one. The price of a share is thus $p = \frac{1}{1-z}$ so that $z = 1 - \frac{1}{p}$ (henceforth denoted as $z(p)$). The net payoff of a type $q = H, L$ entrepreneur is:

$$V(p,q) = \begin{cases} z(p)\left(\frac{R_H^{IPO} + R_H a}{r} - c\right) - \frac{R_H a}{r} & if \;\; q = H. \\ z(p)\left(1 + a - c\right) - a & if \;\; q = L. \end{cases} \tag{A.4}$$

while the net payoff for the investor is:

$$U(p,q) = \begin{cases} (1 - z(p))\left(\frac{R_H^{IPO} + R_H a}{r} - c\right) - 1 & if \;\; q = H. \\ (1 - z(p))\left(1 + a - c\right) - 1 & if \;\; q = L. \end{cases} \tag{A.5}$$

The conditions that need to be satisfied to induce the entrepreneur to go public are

$$z(p) \geq \begin{cases} \frac{R_H a}{R_H^{IPO} + R_H a - cr} & if \quad q = H. \\ \\ \frac{a}{1+a-c} & if \quad q = L. \end{cases} \tag{A.6}$$

Condition (a) is satisfied whenever

$$c < \frac{R_H - R_H^{IPO}}{R_H - r} \tag{A.7}$$

Condition (A.7) ensures that the minimum share price at which type H issuers are willing to go public is higher than for type L. This is always the case whenever c is not too large and

$$R_H > R_H^{IPO} \tag{A.8}$$

Inequality (A.8) states that there are decreasing returns to investment. For instance, the (financially constrained) issuer may have allocated the initial a to the project with the highest NPV. Further projects, while still ensuring a positive NPV, will yield a lower return.[19]

It is straightforward to verify that all our restrictions are satisfied for reasonable parameter values. Consider for instance $a = r = 1$, $R_H^{IPO} = 1.25$, $R_H = 1.5$. In this case, we have

$$V(p,q) = \begin{cases} z(p)\,(2.75 - c) - 1.5 & \text{if} \quad q = H. \\ z(p)(2-c) - 1 & \text{if} \quad q = L. \end{cases}$$

$$U(p,q) = \begin{cases} (1 - z(p))\,(2.75 - c) - 1 & \text{if} \quad q = H. \\ (1 - z(p))\,(2 - c) - 1 & \text{if} \quad q = L. \end{cases} \tag{A.9}$$

$$\text{so that } v_H = \tfrac{2.75-c}{1.25-c},\ v_L = \tfrac{2-c}{1-c},\ u_H = 2.75 - c \text{ and } u_L = 2 - c$$

The requirement for condition (b) to be met – namely, that $\left(R_H^{IPO} - r\right)/r - c > 0$ – becomes: $c < \frac{1}{4}$. Whenever this is the case, $u_H > v_H > v_L > u_L$ and assumptions A2-A4 are satisfied.[20] As for A1, the requirement that $V(p,H) < V(p,L)\ \forall p \in \mathbb{R}^+$ is unnecessarily restrictive, and was imposed in section 4 only for notational convenience. Even if $V(p,H) \geq V(p,L)$ for some $p > u_H$, this is irrelevant since these prices violate I's participation constraint. The relevant requirement is therefore that $V(p,H) < V(p,L)\ \forall p \in [0, u_H]$. It is straightforward to verify that, in the numerical example, $V(p,H) < V(p,L)$ for all p such that $z(p) < 2/3$. This is always met for all values of $p \in [0, u_H]$.

[19] This is in line with the findings of Pagano, Panetta, and Zingales (1998) who document that profitability decreases after the IPO.

[20] For instance, $\frac{d(V(p,H)/V(p,L))}{dp} = \frac{1}{4}\frac{1-2c}{(z(p)(c-2)+1)^2}\frac{dz}{dp} > 0$ given $c < 1/4$.

(ii) Cashing out. Consider now the case of a venture capitalist (VC) who wants to raise one unit of finance to be invested in a new venture. The setup is very similar to that of case (i). The only difference here is that the new investment is not carried out within the existing firm but within a new venture whose cash flows are entirely appropriated by the VC. As discussed above and in section 3, the types H and L can be interpreted as capturing the VC's ability (or experience). A more skilled VC has greater ability to identify profitable projects. The profitability of both his current and new ventures is therefore higher.

The notation is the same as in case (i) with the exception of R_q^{IPO} which now indicates the return that the VC obtains from investing the unit of capital in the new venture. As before, we set $R_L^{IPO} = R_L = r$.

The outside option for the VC when going public is given by (A.1). Expression (A.2) now represents the present value of combined assets from the existing firm *and* the new project when the IPO takes place. The net surplus generated by the IPO is given by (A.3). Therefore, as in the previous case, type L firms should never go public whereas type H firms should go public if $c < (R_H^{IPO} - r)/r$. When this holds, condition (b) is satisfied.

We now turn to condition (a). For simplicity we impose $a = 1$. The VC's net payoff is:

$$V(p,q) = \begin{cases} \frac{R_H^{IPO}}{r} + z(p)\left(\frac{R_H}{r} - c\right) - \frac{R_H}{r} & if \quad q = H. \\ z(p)\left(1 - c\right) & if \quad q = L. \end{cases} \tag{A.10}$$

while the net payoff for the investor is:

$$U(p,q) = \begin{cases} (1 - z(p))\left(\frac{R_H}{r} - c\right) - 1 & if \quad q = H. \\ (1 - z(p))\left(1 - c\right) - 1 & if \quad q = L. \end{cases} \tag{A.11}$$

The conditions that need to be satisfied to induce the VC to go public are

$$\begin{cases} z(p)(R_H - cr) \geq R_H - R_H^{IPO} & if \quad q = H. \\ z(p)(1 - c) \geq 0 & if \quad q = L. \end{cases} \tag{A.12}$$

If $c < 1$, type L goes public for all $z(p) \geq 0$. In that case, condition (a) is satisfied if $R_H > R_H^{IPO}$. If $c \geq 1$, type L never goes public. Condition (a) is thus never satisfied – since, at best, both types are equally reluctant to undertake the IPO. Overall, therefore, the necessary and sufficient conditions for (a) are:

$$c < 1 \tag{A.13}$$

and

$$R_H > R_H^{IPO} \tag{A.14}$$

The first requirement is straightforward. The second is equivalent to condition (A.8). Again, this is consistent with the idea of a VC selecting first the projects with higher NPV.

It is straightforward to verify that all our restrictions are satisfied using the same parameter values as in example (i): $r = 1$, $R_H^{IPO} = 1.25$, $R_H = 1.5$. We have

$$V(p,q) = \begin{cases} z(p)\,(1.5-c) - 0.25 & \text{if } q = H. \\ z(p)(1-c) & \text{if } q = L. \end{cases}$$

$$U(p,q) = \begin{cases} (1 - z(p))\,(1.5-c) - 1 & \text{if } q = H. \\ (1 - z(p))\,(1-c) - 1 & \text{if } q = L. \end{cases} \tag{A.15}$$

so that $v_H = \frac{1.5-c}{1.25-c}$, $v_L = 0$ (for $c < 1$), $u_H = 1.5 - c$ and $u_L = 1 - c$

The requirement for condition (b) to be met – namely, that $\left(R_H^{IPO} - r\right)/r - c > 0$ – becomes: $c < \frac{1}{4}$. Whenever this is the case, $u_H > v_H > v_L > u_L$ and assumptions A2-A4 are satisfied.[21] As for A1, the discussion at the end of example (i) applies. It is straightforward to verify that $V(p,H) < V(p,L)$ for all p such that $z(p) < 1/2$. This is always met for all values of $p \in [0, u_H]$.

B Proof of Proposition 1

We start by showing that there exists no separating equilibrium in which trade occurs. Then we show that no pooling or hybrid equilibrium in which trade occurs passes NWBR. Finally, we show that there exists a NWBR-refined equilibrium in which no trade occurs.

Lemma B.1. *There is no separating equilibrium in which trade occurs.*

Proof. In a separating equilibrium, I always discards her private signal as equilibrium prices are fully informative. Let $\mathcal{P}_q$ be the set of p selected in equilibrium by type q. If $\mathcal{P}_L \cap \mathcal{P}_H = \oslash$, type L is never able to trade since $u_L > v_L$. However, type L would benefit from trading at any $p \in \mathcal{P}_H$ given that p is optimal for type H and $v_L < v_H$. Hence, type L would always try to mimic type H. □

Lemma B.2. *No pooling-hybrid equilibrium in which trade occurs survives NWBR.*

Proof. Assume that trade occurs in a pooling or hybrid equilibrium. Suppose that pooling occurs at $\hat{p}$, with $v_H \leq \hat{p} < u_H$. A type H issuer selects $\hat{p}$ with probability $\beta_H \in (0,1]$ and a type L Issuer announces $\hat{p}$ with probability $\beta_L \in (0,1]$. I observes $\hat{p}$ and receives a signal s. I's expected net payoff from buying at $\hat{p}$ is:

$$\frac{\lambda\beta_H f_H(s)}{\lambda\beta_H f_H(s) + (1-\lambda)\beta_L f_L(s)} U(\hat{p}, H) + \frac{(1-\lambda)\beta_L f_L(s)}{\lambda\beta_H f_H(s) + (1-\lambda)\beta_L f_L(s)} U(\hat{p}, L) \tag{B.1}$$

[21] For instance, $\frac{d(V(p,H)/V(p,L))}{dp} = \frac{0.25(1-c)}{(z(p)(1-c))^2}\frac{dz}{dp} > 0$ given $c < 1/4$.

Expected utility is nonnegative if:

$$\frac{f_H(s)}{f_L(s)} \geq -\frac{(1-\lambda)\beta_L}{\lambda\beta_H}\frac{U(\hat{p},L)}{U(\hat{p},H)} \tag{B.2}$$

Notice that the LHS is an increasing function of s and the RHS is positive for $\hat{p} \in (u_L, u_H)$. Given the full support assumption, there always exists a threshold $s^* \in [\underline{s}, \overline{s}]$ such that (B.2) holds if $s \geq s^*$ and does not hold if $s < s^*$. Hence, I's threshold strategy is to buy if $s \geq s^*$ and not to buy for $s < s^*$. S's payoff is:

$$[1 - F_q(s^*)]V(\hat{p}, q) \tag{B.3}$$

where $q \in \{H, L\}$. Suppose now that I observes a deviation $p > \hat{p}$. Upon observing p, I uses a threshold s^D (see Bénabou and Tirole 2003 on this way to use NWBR). According to NWBR, type L can be eliminated from the deviation if the set of values for s^D that make him weakly benefit from the deviation is contained in the set of values that make type H strictly benefit. Type L would (weakly) benefit whenever:

$$[1 - F_L(s^D)]V(p, L) \geq [1 - F_L(s^*)]V(\hat{p}, L) \tag{B.4}$$

Type L is eliminated if, whenever (B.4) holds, the following also holds:

$$[1 - F_H(s^D)]V(p, H) > [1 - F_H(s^*)]V(\hat{p}, H) \tag{B.5}$$

Note that (B.5) is always verified whenever $s^D \leq s^*$ since the issuer would get a higher price and a *lower* threshold (which implies a higher probability to sell). Consider then $s^D > s^*$. For a deviation $p > \hat{p}$, assumption A2 implies that (B.5) is always satisfied when (B.4) holds so long as:

$$\frac{1 - F_H(s^D)}{1 - F_H(s^*)} \geq \frac{1 - F_L(s^D)}{1 - F_L(s^*)} \tag{B.6}$$

Rewrite the above as:

$$(1 - F_H(s^D))(1 - F_L(s^*)) - (1 - F_H(s^*))(1 - F_L(s^D)) \geq 0 \tag{B.7}$$

The derivative of the above expression with respect to s^D is

$$-f_H(s^D)(1 - F_L(s^*)) + f_L(s^D)(1 - F_H(s^*)) \tag{B.8}$$

so that the LHS of equation (B.7) is increasing whenever:

$$\frac{f_H(s^D)}{f_L(s^D)} < \frac{1 - F_L(s^*)}{1 - F_H(s^*)} \tag{B.9}$$

and is decreasing whenever the reverse inequality holds. Given the MLRP (which implies that $\frac{f_H(s^D)}{f_L(s^D)}$ is an increasing function), the LHS of inequality (B.7) must be an increasing-decreasing function (i.e. increasing for small values of s^D and decreasing beyond a threshold).

We note that the limits of (B.7) for $s^D \to s^*$ and $s^D \to \overline{s}$ are both zero. Since the LHS of inequality (B.7) is an increasing-decreasing function which converges to zero as s^D moves toward the bounds of $(s^*, \overline{s})$, it follows that it cannot be negative in $(s^*, \overline{s})$. Hence, (B.6) holds and type L can be always eliminated. Since type L can be eliminated, for deviations to $p < u_H$, I would always buy with probability one. But then, it is always optimal for S to deviate to $p \in (\hat{p}, u_H)$, which implies that there cannot be any pooling or hybrid equilibrium with trade. □

Lemma B.3. *There always exists a NWBR-refined equilibrium in which trade does not occur.*

Proof. Consider a situation in which S always announces $p = u_H$ and I selects a threshold equal to $\overline{s}$ for all p. This is clearly an equilibrium if I believes any deviation to emanate from type L. It is also robust to NWBR since, for any deviation $p \geq v_H$, the set of I's best responses that make type L willing to deviate coincides with the set of best responses that make type H willing to deviate. Therefore, type L cannot be eliminated. □

C Intermediated Issues

We start by establishing a number of intermediate results that will be extensively used to prove the results in sections 6 and 7. Lemmata C.1-C.2 provide some characterization of the prices that may emerge in any equilibrium with trade. Lemma C.3 focuses on I's best reply in stage 5, taking ϕ and p as given. Lemma C.4 focuses on B's interim payoff given ϕ. We then turn to the proofs of the results stated in sections 6 and 7.

Lemma C.1. *Trade between B and I occurs only if $p < u_H$.*

Proof. For any $p \geq u_H$, I would always lose from trading unless p were exactly equal to u_H and I knew the issuer to be of type H for sure. This however cannot happen since: i) given assumption A1, type L would be willing to trade at $p = u_H$ whenever type H would be willing to trade, ii) neither B nor I are able to perfectly discriminate between L and H, given the information at their disposal. □

Lemma C.2. *If B cannot make losses, the IPO takes place only if $V(p, H) - \phi \geq 0$.*

Proof. The IPO can take place only if type H is willing to sell his shares. This follows from the assumption that gains from trade are positive only when the firm's quality is high. Suppose that the IPO takes place and only type L is willing to sell. Then, if trade between B and I occurs, I's payoff is $U(p, L)$, type L's payoff is $V(p, L) - \phi$, and B's payoff is equal to ϕ. Given assumption A4, the sum of all payoffs is negative for all p. Hence, someone would be better off by not participating. Suppose now that there is no trade between B and I. Then, B's payoff is $U(p, L) - K + \phi$ and I's payoff is zero. Again, the sum of B and S's payoffs is negative, implying that either B or S would be better off by not participating. □

As mentioned in section 6, for a given ϕ, v_H^ϕ is the price level solving:

$$V(v_H^\phi, H) - \phi = 0 \tag{C.1}$$

so that lemma C.2 can be equivalently expressed as $p \geq v_H^{\phi}$.

We now turn to I's optimal strategy at stage 5. The next lemma shows that, abstracting from B's incentive to participate, the necessary conditions in lemmata C.1 and C.2, are sufficient for trade between S and I.

Lemma C.3. *Assume that $v_H^{\phi} < u_H$ and that B offers a price $p \geq v_H^{\phi}$. Then, I follows a threshold strategy $s^*(p)$ on his signal s. $s^*(p)$ satisfies:*

$$\begin{cases} s^* = \overline{s} & p \geq u_H \\ \lambda f_H(s^*) \Pr(p|H) U(p,H) + (1-\lambda) f_L(s^*) \Pr(p|L) U(p,L) = 0 & u_L < p < u_H \\ s^* = \underline{s} & p \leq u_L \end{cases} \tag{C.2}$$

where $\Pr(p|q)$, $q \in \{H, L\}$ denotes the probability that I ascribes to observing p given type q.

Corollary C.1. *Trade between B and I occurs with positive probability at any p such that $v_H^{\phi} \leq p < u_H$.*

Proof. Recall that B's strategy is a map from the set $\{h, l\}$ of realizations of her signal σ to the set of probability distributions over p. Since σ is, conditionally on q, independent of s, p is also independent of s conditionally on q. Hence, it is easy to show that:

$$\Pr(q|s,p) = \frac{f_q(s) \Pr(p|q) \Pr(q)}{\sum_{q \in \{H,L\}} f_q(s) \Pr(p|q) \Pr(q)} \tag{C.3}$$

I's expected payoff from buying at p is therefore:

$$\frac{\lambda f_H(s) \Pr(p|H) U(p,H) + (1-\lambda) f_L(s) \Pr(p|L) U(p,L)}{\lambda f_H(s) \Pr(p|H) + (1-\lambda) f_L(s) \Pr(p|L)} \tag{C.4}$$

This can also be written as

$$\frac{\lambda \left(\frac{f_H(s)}{f_L(s)}\right) \Pr(p|H)}{\lambda \left(\frac{f_H(s)}{f_L(s)}\right) \Pr(p|H) + (1-\lambda) \Pr(p|L)} U(p,H) + \frac{(1-\lambda) \Pr(p|L)}{\lambda \left(\frac{f_H(s)}{f_L(s)}\right) \Pr(p|H) + (1-\lambda) \Pr(p|L)} U(p,L) \tag{C.5}$$

Given $p \geq v_H^{\phi}$, $\Pr(p|H) > 0$ and $\Pr(p|L) > 0$ (We assume that S accepts to trade when indifferent). The derivative of (C.5) with respect to s is

$$\frac{d\left(\frac{f_H(s)}{f_L(s)}\right)}{ds} \frac{\lambda (1-\lambda) \Pr(p|H) \Pr(p|L)}{\left(\lambda \left(\frac{f_H(s)}{f_L(s)}\right) \Pr(p|H) + (1-\lambda) \Pr(p|L)\right)^2} [U(p,H) - U(p,L)] \tag{C.6}$$

From the MLRP, $\frac{f_H(s)}{f_L(s)}$ is a strictly increasing function of s. From assumption A3, $U(p,H) - U(p,L) > 0$. Hence, (C.6) is positive, implying that (C.5) is strictly increasing in s. Therefore, I follows a threshold strategy. Namely, there exists a value $s^*(p)$ such that, for $s \leq s^*(p)$, I does not purchase the shares, while, for $s > s^*(p)$, I purchases the shares.

For $p \geq u_H$, $U(p,L) < U(p,H) \leq 0$. Hence, (C.5) is negative for all s and, therefore, $s^*(p) = \overline{s}$ (no trade between B and I). For $p \leq u_L$, $U(p,H) > U(p,L) \geq 0$. Hence, (C.5) is positive for all s and, therefore, $s^*(p) = \underline{s}$ (trade between B and I occurs with probability one).

Given $u_L < p < u_H$, $U(p,H) > 0$ and $U(p,L) < 0$. For $s \to \overline{s}$, $f_H(s)/f_L(s) \to +\infty$. $U(p,H) > 0$ then implies that (C.5) is positive. For $s \to \underline{s}$, $f_H(s)/f_L(s) \to 0$. Given $U(p,L) < 0$, (C.5) is negative. By monotonicity and continuity, there exists a unique value s^* such that (C.5) is equal to zero. Finally, setting (C.5) equal to zero and rearranging yields the expression in (C.2). □

We can now derive B's expected payoff in the subgame starting in stage 2 from announcing a price at which S is willing to trade.

Lemma C.4. *Denote as p_σ the price set by B upon observing $\sigma \in \{h,l\}$, and as $s^*(p_\sigma)$ I's threshold when observing p_σ. B's interim expected payoff when the IPO takes place is:*

$$\pi_\sigma F_H(s^*(p_\sigma))\,(U(p_\sigma,H) - K) + (1-\pi_\sigma)F_L(s^*(p_\sigma))\,(U(p_\sigma,L) - K) + \phi \qquad \text{(C.7)}$$

Proof. Given σ and I's threshold strategy s^*, the conditional probability that I does not buy and S is of type H is:

$$\Pr(H, s < s^*|\sigma) = \frac{\Pr(s < s^*, \sigma|H)\Pr(H)}{\Pr(\sigma|H)\Pr(H) + \Pr(\sigma|L)\Pr(L)} =$$
$$= \frac{\Pr(\sigma|H)\Pr(H)}{\Pr(\sigma|H)\Pr(H) + \Pr(\sigma|L)\Pr(L)}\Pr(s < s^*|H) = \pi_\sigma F_H(s^*) \qquad \text{(C.8)}$$

for $\sigma \in \{h,l\}$. By the same token, $\Pr(L, s < s^*|\sigma) = (1-\pi_\sigma)F_L(s^*)$. Expression (C.7) follows. □

C.1 Proof of Lemma 1

According to lemmata C.1, C.2, and C.3, $v_H^\phi \leq p < u_H$ is necessary and sufficient for trade between B and I to occur with positive probability. We now show that B has incentive to charge such a price when $v_H^\phi < u_H$. If the IPO takes place, then lemma C.2 implies that B must be charging $p \geq v_H^\phi$. Hence, all we need to show is that B has incentive to charge $p < u_H$. Suppose then that B has received a signal $\sigma \in \{h,l\}$ and that, at equilibrium, she charges $p_\sigma \geq u_H$ so that no trade occurs between her and I. Given that $U(.,L)$ is decreasing in p and $U(p,H) \leq 0$ for $p \geq u_H$, B's expected payoff is at most

$$(1-\pi_\sigma)U(u_H,L) - K + \phi \qquad \text{(C.9)}$$

By deviating, and charging a lower price $v_H^\phi \leq p' < u_H$, B could sell with a positive probability. Denoting as s' I's threshold in that case, B's expected payoff would be

$$\pi_\sigma F_H(s')\left(U(p',H) - K\right) + (1-\pi_\sigma)\,F_L(s')\left(U(p',L) - K\right) + \phi \qquad \text{(C.10)}$$

Now,

$$\pi_\sigma F_H(s')\left(U(p',H)-K\right)+(1-\pi_\sigma)\,F_L(s')\left(U(p',L)-K\right)+\phi>$$
$$>(1-\pi_\sigma)U(u_H,L)-K+\phi \tag{C.11}$$

if

$$\pi_\sigma F_H(s')U(p',H)+(1-\pi_\sigma)\left[F_L(s')U(p',L)-U(u_H,L)\right]+$$
$$+K\left[1-\pi_\sigma F_H(s')-(1-\pi_\sigma)\,F_L(s')\right]>0 \tag{C.12}$$

Notice that, since $p'<u_H$, $U(p',H)>0$. Moreover, since $U(.,L)$ is strictly decreasing and $U(u_H,L)<0$, $F(s'\mid L)U(p',L)-U(u_H,L)>0$. Finally, $1-\pi_\sigma F_H(s')-(1-\pi_\sigma)\,F_L(s')\geq 0$. Hence, the inequality is always satisfied. By charging $v_H^\phi\leq p'<u_H$, B is strictly better off than by charging $p_\sigma\geq u_H$.□

C.2 Proof of Lemma 2

Assume $\phi\leq 0$. Two cases may arise: a) $p\leq u_L$ and b) $p>u_L$. Consider case a). For $p\leq u_L$, I is willing to buy for all realizations of s. Hence, trade between B and I occurs with probability one, so that B's net payoff is equal to ϕ. If $\phi<0$, B makes expected losses. If $\phi=0$, lemma C.2 shows that the IPO takes place only if $p\geq v_H^\phi=v_H>u_L$, which contradicts $p\leq u_L$. Consider now case b). Assume first $p\geq u_H$ so that no trade occurs between B and I. In this case, B's profits are at most:

$$(1-\pi_\sigma)U(u_H,L)-K+\phi \tag{C.13}$$

Given $U(u_H,L)<0$ and $K\geq 0$, B's profits are negative for all $\phi\leq 0$. Assume now $p<u_H$ so that trade between B and I occurs with positive probability.

Given lemma C.3, I follows a threshold strategy $s^*(p)$ such that:

$$\lambda\Pr(p|H)f_H(s)U(p,H)+(1-\lambda)\Pr(p|L)f_L(s)U(p,L)<0 \tag{C.14}$$

for all $s<s^*(p)$. Notice that:

$$\Pr(p|q)=\begin{cases}\eta\beta_h+(1-\eta)\beta_l & q=H\\ (1-\eta)\beta_h+\eta\beta_l & q=L\end{cases} \tag{C.15}$$

where $\beta_\sigma\equiv\Pr(p|\sigma)$ is derived from B's equilibrium strategy (we omit the argument p, but it should be clear that $\beta_\sigma$is a function of p). Inequality (C.14) can be thus rewritten as:

$$\lambda[\eta\beta_h+(1-\eta)\beta_l]f_H(s)U(p,H)+(1-\lambda)[(1-\eta)\beta_h+\eta\beta_l]f_L(s)U(p,L)<0 \tag{C.16}$$

Since the inequality holds for all $s\leq s^*(p)$, one can integrate between $\underline{s}$ and $s^*(p)$ to obtain

$$\lambda[\beta_h\eta+\beta_l(1-\eta)]F_H(s^*(p))U(p,H)+$$
$$+(1-\lambda)[\beta_h(1-\eta)+\beta_l\eta]F_L(s^*(p))U(p,L)<0 \tag{C.17}$$

When B follows a strategy that consists of announcing p with probability β_σ upon observing σ, B's ex-ante payoff is:

$$\sum_{p\in\mathcal{P}}\{\lambda[\beta_h\eta+\beta_l(1-\eta)]F_H(s^*(p))[U(p,H)-K]+$$
$$+(1-\lambda)[\beta_h(1-\eta)+\beta_l\eta]F_L(s^*(p))[U(p,L)-K]+\Gamma\phi\} \tag{C.18}$$

where $\Gamma\equiv\lambda[\beta_h\eta+\beta_l(1-\eta)]+(1-\lambda)[\beta_h(1-\eta)+\beta_l\eta]>0$ and $\mathcal{P}$ denotes the set of prices announced with positive probability. Given $K\geq 0$ and (C.17), B's expected profits for any $p\in(u_L,u_H)$ can be non-negative only if $\phi>0$. This proves the first statement of lemma 2. The second statement follows from the first statement ($v_H^\phi>v_H$) and lemma C.2 ($p\geq v_H^\phi$). □

C.3 Proof of Lemma 3

In order to prove lemma 3, we need to characterize the equilibrium in the subgame starting in stage 2. We first discuss B's interim participation constraint. This is used to show that the IPO takes place if and only if B observes $\sigma=h$, so that no trade between B and S occurs when B observes $\sigma=l$. We then show that there is only one equilibrium with trade that passes NWBR, and this is such that $p_h=v_H^\phi$.

Once σ is observed, the price p_σ must satisfy B's interim participation constraint. Otherwise, B could offer a price p_σ so low that S would always reject it and make zero profits – a situation *de facto* equivalent to no IPO occurring at all. Moreover, in the candidate equilibrium, B's expected profits prior to observing σ must be zero. This can only happen if the interim participation constraint is satisfied with equality.

B's interim payoff is derived in lemma C.4. If the IPO takes place for $\sigma=h$, the price p_h must then satisfy:

$$\pi_hF_H(s^*(p_h))\,(U(p_h,H)-K)+(1-\pi_h)F_L(s^*(p_h))\,(U(p_h,L)-K)+\phi=0 \tag{C.19}$$

Similarly, if the IPO takes place when $\sigma=l$, p_l satisfies:

$$\pi_lF_H(s^*(p_l))\,(U(p_l,H)-K)+(1-\pi_l)F_L(s^*(p_l))\,(U(p_l,L)-K)+\phi=0 \tag{C.20}$$

Lemma C.5. *The IPO takes place only when $\sigma=h$.*

Proof. We proceed by contradiction. Consider an equilibrium in which the IPO takes place when B observes $\sigma=l$. In equilibrium, the incentive compatibility of B when observing $\sigma=h$ must be satisfied:

$$\Delta\left[\pi_hF_H(s^*(p_h))\,(U(p_h,H)-K)+(1-\pi_h)F_L(s^*(p_h))\,(U(p_h,L)-K)+\phi\right]\geq$$
$$\pi_hF_H(s^*(p_l))\,(U(p_l,H)-K)+(1-\pi_h)F_L(s^*(p_l))\,(U(p_l,L)-K)+\phi \tag{C.21}$$

where $\Delta = 1$ if the IPO takes place also when B observes $\sigma = h$ and $\Delta = 0$ otherwise. Notice that the price p_h, in principle, need not be different from p_l if pooling or hybrid equilibria are possible. Consider first $\Delta = 1$. In this case both (C.19) and (C.20) must hold. This implies:

$$\pi_h F_H(s^*(p_h))\,(U(p_h, H) - K) + (1 - \pi_h) F_L(s^*(p_h))\,(U(p_h, L) - K) = \\ \pi_l F_H(s^*(p_l))\,(U(p_l, H) - K) + (1 - \pi_l) F_L(s^*(p_l))\,(U(p_l, L) - K) \qquad \text{(C.22)}$$

Putting together (C.21) and (C.22), we obtain:

$$F_H(s^*(p_l))U(p_l, H) - F_L(s^*(p_l))U(p_l, L) \leq -K\,[F_L(s^*(p_l)) - F_H(s^*(p_l))] \qquad \text{(C.23)}$$

Note that, since trade occurs between B and I, lemma C.1 requires $p_l < u_H$. Lemmata C.2 and 2 then ensure that $p_l \geq v_H^{\phi} > u_L$. Given $u_L < p_l < u_H$, the LHS of (C.23) is strictly positive for all $s^* \in (\underline{s}, \overline{s})$. However, since $f_q(.)$ satisfies the monotone likelihood property, $[F_L(s^*) - F_H(s^*)] > 0$ for all $s^* \in (\underline{s}, \overline{s})$. This implies that the RHS of (C.23) is strictly negative. Hence, (C.23) is never satisfied. There is no equilibrium in which the IPO takes place for both $\sigma = l$ and $\sigma = h$.

Assume now $\Delta = 0$. Since trade occurs when $\sigma = l$, the interim participation constraint (C.20) must be satisfied. One can then verify that (C.21) and (C.20) imply that (C.23) should hold also in this case, so that the same argument used for $\Delta = 1$ applies.

To summarize, given that trade never occurs when B observes $\sigma = l$, any equilibrium with trade must be separating: when $\sigma = h$, B goes ahead with the IPO, and offers a price p_h at which trade occurs with positive probability. When $\sigma = l$, B does not go ahead with the IPO. (Equivalently, B goes ahead but offers a price $p_l \leq v_L$, i.e. a price that is never accepted by S). We now show that this is indeed the case by verifying that, when $\sigma = l$, B has no incentive to mimic and set p_h. Forgoing the IPO is incentive compatible if:

$$\pi_l F_H(s^*(p_h))\,(U(p_h, H) - K) + (1 - \pi_l) F_L(s^*(p_h))\,(U(p_h, L) - K) + \phi \leq 0 \qquad \text{(C.24)}$$

Substituting ϕ from C.19 and rearranging yields:

$$F_H(s^*(p_h))U(p_l, H) - F_L(s^*(p_h))U(p_l, L) \geq -K\,[F_L(s^*(p_h)) - F_H(s^*(p_h))] \qquad \text{(C.25)}$$

Applying a similar logic to that for (C.23), this is always satisfied for $u_L < p_h < u_H$. We now show that p_h must be in this range. Since trade occurs between B and I, lemma C.1 ensures that $p_h < u_H$. Lemma C.2 ensures $p_h \geq v_H^{\phi}$. Given lemma 2, this implies $p_h > u_L$. □

The next lemma characterizes I's best reply given the separating equilibrium considered.

Lemma C.6. *Given the equilibrium price p_h, I's equilibrium threshold $s^*(.)$ solves*

$$\pi_h f_H(s^*(p_h))U(p_h, H) + (1 - \pi_h) f_L(s^*(p_h))U(p_h, L) = 0 \qquad \text{(C.26)}$$

Proof. This follows from lemma C.3, given $u_L < p_h < u_H$ and $p_h \geq v_H^\phi$. The threshold $s^*(p_h)$ solves

$$\lambda f_H(s^*(p_h)) \Pr(p_h|H) U(p_h, H) + (1-\lambda) f_L(s^*(p_h)) \Pr(p_h|L) U(p_h, L) = 0 \qquad \text{(C.27)}$$

In the separating equilibrium considered, $\Pr(p_h|H) = \eta$ and $\Pr(p_h|L) = 1 - \eta$. Dividing by $\eta\lambda + (1-\lambda)(1-\eta)$ and rearranging, one obtains (C.26). □

From lemma 2, $v_H^\phi > u_L$. As a result, candidate equilibria are characterized by p_h belonging to the continuum $[v_H^\phi, u_H)$. We now show that only $p = v_H^\phi$ survives NWBR.

Lemma C.7. *The unique offering price that survives NWBR is* $p_h = v_H^\phi$.

Proof. To prove that the unique offering price passing NWBR is $p_h = v_H^\phi$, we show that any situation where $p_h > v_H^\phi$ would be dominated. If I has refined beliefs, B could be better off by decreasing p_h.

To see this, suppose that the equilibrium is such that $p_h > v_H^\phi$. Recall that, since $\phi > 0$, $v_H^\phi > u_L$. Consider then a deviation $\tilde{p}$ such that $v_H^\phi < \tilde{p} < p_h$. I replies by using threshold $\tilde{s}$. When observing h, B benefits from the deviation if:

$$\begin{aligned} &\pi_h F_H(\tilde{s}) U(\tilde{p}, H) + (1-\pi_h) F_L(\tilde{s}) U(\tilde{p}, L) - K\left[\pi_h F_H(\tilde{s}) + (1-\pi_h) F_L(\tilde{s})\right] > \\ &\pi_h F_H(s^*) U(p_h, H) + (1-\pi_h) F_L(s^*) U(p_h, L) - K\left[\pi_h F_H(s^*) + (1-\pi_h) F_L(s^*)\right] \qquad \text{(C.28)} \end{aligned}$$

When observing l, B (weakly) benefits if:

$$\pi_l F_H(\tilde{s}) U(\tilde{p}, H) + (1-\pi_l) F_L(\tilde{s}) U(\tilde{p}, L) - K\left[\pi_l F_H(s^*) + (1-\pi_l) F_L(s^*)\right] + \phi \geq 0 \qquad \text{(C.29)}$$

Substituting ϕ from condition (C.19) – the interim participation constraint for B when $\sigma = h$ – one obtains:

$$\begin{aligned} \pi_l F_H(\tilde{s}) U(\tilde{p}, H) + (1-\pi_l) F_L(\tilde{s}) U(\tilde{p}, L) - K\left[\pi_l F_H(\tilde{s}) + (1-\pi_l) F_L(\tilde{s})\right] \geq \\ \geq \pi_h F_H(s^*) U(p_h, H) + (1-\pi_h) F_L(s^*) U(p_h, L) - \\ -K\left[\pi_h F_H(s^*) + (1-\pi_h) F_L(s^*)\right] \qquad \text{(C.30)} \end{aligned}$$

Given $\tilde{p} > v_H^\phi > u_L$, then $U(\tilde{p}, L) < 0$. From $\tilde{p} < p_h < u_H$, it follows that $U(\tilde{p}, H) > 0$. Since $\pi_h > \pi_l$, the LHS of (C.28) is greater than the LHS of (C.30). Hence, if B weakly benefits from the deviation upon observing l, then she *strictly* benefits from the deviation upon observing h. Following a deviation to a lower price, the investor should then infer that it comes from B having received signal h. Upon observing such a deviation, I's threshold $\tilde{s}(\tilde{p})$ is therefore equal to $s^*(\tilde{p})$.

We now show that, given that I's threshold function stays the same for all $\tilde{p} \in [v_H^\phi, p_h]$, B has an incentive to deviate to a lower price whenever the participation constraint of the type H issuer is not binding. To see this, note that differentiating B's payoff with respect to $\tilde{p}$ yields:

$$\{\pi_h f_H(s^*) \left(U(\tilde{p}, H) - K\right) + (1-\pi_h) f_L(s^*) \left(U(\tilde{p}, L) - K\right)\} \frac{ds^*(\tilde{p})}{d\tilde{p}} + \\ + \pi_h F_H(s^*) \frac{dU(\tilde{p}, H)}{d\tilde{p}} + (1-\pi_h) F_L(s^*) \frac{dU(\tilde{p}, L)}{d\tilde{p}} \tag{C.31}$$

The last two terms are strictly negative. What about the first term?

From lemma C.6, s^* solves (C.26). Hence, the first term in (C.31) can be rewritten as:

$$-K \left(\pi_h f_H(s^*) + (1-\pi_h) f_L(s^*)\right) \frac{ds^*(\tilde{p})}{d\tilde{p}} \tag{C.32}$$

which is negative whenever $s^*(\tilde{p})$ is increasing in $\tilde{p}$. Rearranging (C.26), we see that s^* solves

$$\frac{f_H(s^*)}{f_L(s^*)} = -\frac{1-\pi_h}{\pi_h} \frac{U(\tilde{p}, L)}{U(\tilde{p}, H)} \tag{C.33}$$

so that

$$\frac{ds^*(\tilde{p})}{d\tilde{p}} = -\frac{1-\pi_h}{\pi_h} \frac{d\left(\frac{U(\tilde{p},L)}{U(\tilde{p},H)}\right)/d\tilde{p}}{d\left(\frac{f_H(s^*)}{f_L(s^*)}\right)/ds^*} > 0 \tag{C.34}$$

Hence, B's expected payoff is decreasing in the offering price.

This proves that, in a NWBR-refined equilibrium with trade, the price p_h must be equal to the minimum price that satisfies the participation constraint of the high quality issuer: $p_h = v_H^{\phi}$. $\square$

C.4 Proof of lemma 4

The set Φ is the set of values of ϕ such that: i) trade between B and I occurs with positive probability; ii) B makes zero profits in expectation.

Let Φ_T denote the set of values for ϕ such that trade between B and I occurs with positive probability. Given that in equilibrium $p_h = v_H^{\phi}$, any $\phi \in \Phi_T$ must satisfy $s^*(v_H^{\phi}) < \overline{s}$. This occurs if and only if $v_H^{\phi} < u_H$. Hence,

$$\Phi_T \equiv \{\phi : v_H^{\phi} < u_H\} \tag{C.35}$$

Let

$$\Phi_Z \equiv \{\phi : \pi_h F_H(s^*(v_H^{\phi})) U(v_H^{\phi}, H) + (1-\pi_h) F_L(s^*(v_H^{\phi})) U(v_H^{\phi}, L) - \\ - K \left[\pi_h F_H(s^*(p_l)) + (1-\pi_h) F_L(s^*(p_l))\right] + \phi = 0\} \tag{C.36}$$

denote the set of values of ϕ such that B makes zero profits. Clearly, $\Phi = \Phi_T \cap \Phi_Z$. We start by determining conditions under which the intersection of Φ_T and Φ_Z is non-empty. Then we turn to uniqueness. Φ is non-empty if there exists $\phi \in \Phi_Z$ such that $v_H^\phi < u_H$. Using the identity $\phi = V(v_H^\phi, H)$, the equation in definition (C.36) can be rewritten as:

$$\pi_h F_H(s^*(v_H^\phi))U(v_H^\phi, H) + (1-\pi_h)F_L(s^*(v_H^\phi))U(v_H^\phi, L) - \\ -K\left[\pi_h F_H(s^*(p_l)) + (1-\pi_h)F_L(s^*(p_l))\right] + V(v_H^\phi, H) = 0 \tag{C.37}$$

Since v_H^ϕ is an increasing function of ϕ, finding values of v_H^ϕ for which (C.37) is satisfied is equivalent to finding values of ϕ for which it is satisfied.

The upper limit for v_H^ϕ is u_H. For $v_H^\phi \leq v_H$, the LHS of (C.37) is negative. This is because: (1) the first line of (C.37) is negative (this can be shown by using the optimal condition for I's threshold – lemma C.6), (2) $K \geq 0$, and (3) for all $\phi \leq 0$ (equivalently, $v_H^\phi \leq v_H$), $V(v_H^\phi, H) \leq 0$. By continuity, therefore, if the LHS of (C.37) is positive when $v_H^\phi \to u_H$, then there exists a value $\phi \in \Phi_Z$ such that $v_H^\phi < u_H$. Consider then $v_H^\phi \to u_H$. The LHS of (C.37) converges to:

$$(1-\pi_h)U(u_H, L) + V(u_H, H) - K \tag{C.38}$$

This proves the first statement of lemma 4.

We now prove the second part of the lemma. To do this is sufficient to show that the LHS of (C.37) is increasing in v_H^ϕ. Differentiating the LHS of (C.37):

$$\pi_h[f_H(s^*(v_H^\phi))U(v_H^\phi, H) + (1-\pi_h)f_L(s^*(v_H^\phi))U(v_H^\phi, L)]\frac{ds^*(v_H^\phi)}{dv_H^\phi} + \\ \pi_h F_H(s^*(v_H^\phi))\frac{dU(v_H^\phi, H)}{dv_H^\phi} + (1-\pi_h)F_L(s^*(v_H^\phi))\frac{dU(v_H^\phi, L)}{dv_H^\phi} \\ + \frac{dV(v_H^\phi, H)}{dv_H^\phi} - K\left[\pi_h f_H(s^*(v_H^\phi)) + (1-\pi_h)f_L(s^*(v_H^\phi))\right]\frac{ds^*(v_H^\phi)}{dv_H^\phi} \tag{C.39}$$

From the characterization of the optimal threshold for I in lemma C.6, $s^*(v_H^\phi)$ is such that the first term is zero. Given A4, $V(p, H) + U(p, H)$ is independent of p and therefore:

$$\frac{dV(v_H^\phi, H)}{dv_H^\phi} = -\frac{dU(v_H^\phi, H)}{dv_H^\phi} \tag{C.40}$$

It follows that:

$$\pi_h \frac{dU(v_H^\phi, H)}{dv_H^\phi} + (1-\pi_h)\frac{dU(v_H^\phi, L)}{dv_H^\phi} + \frac{dV(v_H^\phi, H)}{dv_H^\phi} = \\ = (1-\pi_h)\left[\frac{dU(v_H^\phi, L)}{dv_H^\phi} - \frac{dU(v_H^\phi, H)}{dv_H^\phi}\right] \tag{C.41}$$

Given that the RHS of (C.41) is non-negative by assumption, the LHS must also be non-negative. Since $U(p,q)$ is decreasing in p and $F_q(s^*(v_H^\phi)) < 1$ for $q = H, L$, the sum of the second, third, and fourth term in (C.39) is positive. The last term is is negative, but becomes small as $K \to 0$. By continuity, for K sufficiently small, B's expected payoff is strictly increasing in v_H^ϕ. Hence, for K sufficiently small, we know that if a ϕ exists that satisfies (C.37), then it is unique. □

C.5 Proof of Proposition 3

Consider the equilibrium described in lemma 3. We want to show that, evaluated from I's perspective, shares in the hands of I are underpriced and shares in the hands of B are overpriced. The expected net gain from the shares conditional on I choosing to buy them is:

$$\frac{\pi_h[1 - F_H(s^*(v_H^\phi)]U(v_H^\phi, H) + (1-\pi_h)[1 - F_L(s^*(v_H^\phi)]U(v_H^\phi, L)}{\pi_h[1 - F_H(s^*(v_H^\phi)] + (1-\pi_h)[1 - F_L(s^*(v_H^\phi)]} \tag{C.42}$$

From lemma C.6, I follows a threshold strategy that depends on v_H^ϕ. The threshold $s^*(v_H^\phi)$ must be such that:

$$\pi_h f_H(s)U(p_h, H) + (1-\pi_h) f_L(s)U(p_h, L) > 0 \tag{C.43}$$

for all $s > s^*(v_H^\phi)$. Integrating (C.43) between $s^*(v_H^\phi)$ and $\overline{s}$ shows that shares bought by I are on average underpriced.

We now turn attention to the case in which I does not buy and B holds the shares. The expected net gain from the shares conditional on I choosing not to buy them is:

$$\frac{\pi_h F_H(s^*)U(p_h, H) + (1-\pi_h)F_L(s^*)U(p_h, L)}{\pi_h F_H(s^*) + (1-\pi_h)F_L(s^*)} \tag{C.44}$$

The threshold $s^*(v_H^\phi)$ must be such that:

$$\pi_h f_H(s)U(p_h, H) + (1-\pi_h) f_L(s)U(p_h, L) < 0 \tag{C.45}$$

for all $s < s^*(v_H^\phi)$. Integrating (C.45) between $\underline{s}$ and $s^*(v_H^\phi)$ shows that (C.44) is negative. □

C.6 Proof of Proposition 4

Consider the equilibrium discussed in lemma 3. Total expected net gains from the shares (whether bought by I or not) are:

$$\pi_h U(v_H^\phi, H) + (1-\pi_h)U(v_H^\phi, L) \tag{C.46}$$

We first show that (C.46) is positive when the precision of B's information is extremely high and then we turn to the case in which I's signal s is almost independent of q. Given the equilibrium in lemma 3, trade between I and B occurs if and only if the price v_H^ϕ does not exceed I's reservation price for a type H issuer: $v_H^\phi < u_H$. This is necessary and sufficient for $U(v_H^\phi, H) > 0$. It is then clear that, for π_h close enough to unity, (C.46) is positive if and only if $v_H^\phi < u_H$. This establishes the first claim in the proposition. We now turn to the second.

From lemma C.6, I follows a threshold strategy that depends on v_H^ϕ. The threshold $s^*(v_H^\phi)$ must be such that:

$$\pi_h f_H(s) U(v_H^\phi, H) + (1 - \pi_h) f_L(s) U(v_H^\phi, L) > 0 \tag{C.47}$$

for all $s > s^*(v_H^\phi)$. Integrating (C.47) between $s^*(v_H^\phi)$ and $\overline{s}$ shows that:

$$\pi_h [1 - F_H(s^*(v_H^\phi))] U(v_H^\phi, H) + (1 - \pi_h)[1 - F_L(s^*(v_H^\phi))] U(v_H^\phi, L) > 0 \tag{C.48}$$

If $s \to^d \tilde{s}$, then $F_H(.)$ and $F_L(.)$ converge to the same distribution $\tilde{F}(.)$. For trade to occur with positive probability, $\tilde{F}$ evaluated at the threshold must be less than one. But then the LHS of expression (C.48) reduces to (C.46) whenever the probability of trade is positive implying that, if trade occurs with positive probability, shares are underpriced. We now show that if shares are underpriced then trade occurs. Expression (C.47) evaluated at $s = s^*(v_H^\phi)$ is equal to zero. Solving it for the likelihood ratio $f_H(s^*)/f_L(s^*)$ shows that $f_H(s^*)/f_L(s^*) < 1$ whenever (C.46) is positive. The threshold s^* is thus bounded above by some $\hat{s}$ defined as the value of s such that $f_H(\hat{s})/f_L(\hat{s}) = 1$. Since $\hat{s} < \overline{s}$, it follows that $s^* < \overline{s}$. Hence, given underpricing, trade occurs with positive probability. □

D Proofs of Claims Made in Section 8 (Material not meant for publication)

Information Structure

Claim 1. *When B is perfectly informed, there is a continuum of zero-profit equilibria where: (i) the IPO takes place only when $q = H$, (ii) $\phi = 0$, (iii) the offering price is in the interval $[v_H, u_H]$, and (iv) I buys with probability one.*

Proof. Suppose that $\phi = 0$. When $q = L$, B has no incentive to undertake the IPO: if she sells the shares with probability one, she earns zero profits, while if she doesn't sell the shares with probability one, she makes losses. Therefore, when $q = L$, not undertaking the IPO is a best reply for B. Now consider $q = H$. Let the equilibrium price selected when $q = H$ be $p^* \in [v_H, u_H]$. It is clear that, given p^*, purchasing the shares with probability one is optimal for I. Since at $p = p^*$ B sells the shares with probability one, she makes neither losses nor gains from underwriting. Hence, $\phi = 0$ guarantees zero profits. What about B's pricing incentives? Suppose that, when he observes an out of equilibrium price $p \in [v_H, u_H]$, I purchases the shares with probability one. Then it is clear that setting $p = p^*$ when $q = H$ is optimal for B. Setting $p > u_H$ would result in B keeping the high-quality shares for sure, but would also entail losses. Setting $p < v_H$ would not satisfy the H-type issuer's participation constraint. Finally, we need to verify that the proposed out of equilibrium strategy for I – namely, that when he observes an out of equilibrium price $p \in [v_H, u_H]$,

I purchases the shares with probability one – does not violate NWBR. To see that this is indeed the case, consider an out of equilibrium price $p \in [v_H, u_H]$. Suppose that B selects p and that, upon observing p, I uses a threshold s^D. B's payoff from deviating to p having observed $q = L$ is:

$$(1 - F_L(s^D))(U(p, L) - K) \leq 0 \tag{D.1}$$

Hence, for $q = L$, B can only (weakly) lose from deviating to p. Two cases may then arise: (1) B loses from deviating to p both when $q = L$ and when $q = H$, or (2) B only loses from deviating to p when $q = L$. In both cases, beliefs such that the deviation emanates from B having observed $q = H$ are not ruled out by NWBR. □

Claim 2. *When B is entirely uninformed, her expected payoff is decreasing in p.*

Proof. Upon selecting a price $p \in [v_H, u_H]$, B's expected payoff is

$$\lambda F_H(s^*(p))\,(U(p, H) - K) + (1 - \lambda)F_L(s^*(p))\,(U(p, L) - K) + \phi \tag{D.2}$$

The derivative of (D.2) with respect to p is

$$\begin{aligned} &[\lambda f_H(s^*(p))U(p, H) + (1 - \lambda) f_L(s^*(p))U(p, L)]\, \tfrac{ds^*(p)}{dp} \\ &-K \tfrac{ds^*(p)}{dp}\, [\lambda f_H(s^*(p)) + (1 - \lambda) f_L(s^*(p))] \\ &+ \left[\lambda F_H(s^*(p)) \tfrac{dU(p,H)}{dp} + (1 - \lambda) F_L(s^*(p)) \tfrac{dU(p,L)}{dp}\right] \end{aligned} \tag{D.3}$$

From the definition of $s^*(p)$, the first term in (D.3) is equal to zero. Since $\frac{ds^*(p)}{dp} > 0$, the second term in (D.3) is negative. Finally, from A3(i), $\frac{dU(p,q)}{dp} < 0$ for both $q = H, L$. Hence, the third expression in (D.3) is negative, which proves our claim. □

Equilibria that fail NWBR

Claim 3. *When B is perfectly informed, then a situation where the IPO takes place only when the issuer is of type H (in which case the investor buys with probability one) is an equilibrium.*

Proof. This trivially follows from claim 1. □

Claim 4. *When the intermediary is imperfectly informed, perfect Bayesian equilibria with zero profits involve full revelation of the intermediary's information through the price choice (the intermediary goes on with IPO only when she receives favorable information).*

Proof. Consider the proof of lemma 3. Lemma C.5 implies the result. Notice that lemma C.5 does not require NWBR. Hence, in all perfect Bayesian equilibria with zero profits, the intermediary goes on with the IPO only when she observes $\sigma = h$. □

Low quality should be traded

Claim 5. *Existence of "efficient equilibria" when the intermediary is perfectly informed.*

Proof. Consider a situation in which a type q issuer sells whenever $p \geq v_q$, the intermediary announces some $p_q \in [v_q, u_q]$, and the investor buys with probability one at p_q. Clearly enough, S and I are playing best replies. Assume that I's beliefs assign probability one to type H for all out of equilibrium prices in the interval $[v_H, u_H]$ and probability one to type L for all prices lower than v_H. These ensure that setting p_q is a best reply for the intermediary. When $u_L \geq v_H$, the intermediary would sell with probability one at all prices in the interval $[v_L, u_H]$. When $v_H > u_L$ she would sell with probability one at all prices in the intervals $[v_L, u_L]$ and $[v_H, u_H]$. At these prices, her payoff would be equal to ϕ independently of the price she announces. When $v_H > u_L$, B would sell with probability zero at all prices in the interval (u_L, v_H). Given S's strategy, $q = L$ at all prices (u_L, v_H) so that B has no incentive to deviate to these prices. Hence, given I's beliefs, announcing $p_q \in [v_q, u_q]$ is a best reply for B. Zero profits then requires $\phi = 0$. We now show that I's beliefs are compatible with NWBR. B's payoff from deviating to any $p \in [v_H, u_H]$ having observed q is:

$$(1 - F_q(s^D))[U(p, q) - K] \tag{D.4}$$

where s^D is I's threshold upon observing p. Since $U(p, H) > U(p, L)$, if (D.4) is weakly positive for $q = L$, then it is strictly positive for $q = H$. Hence, beliefs such that the deviation emanates from B having observed $q = H$ are compatible with NWBR. Finally, if all qualities generate gains from trade, welfare is maximized when the amount of trade is maximized. Hence, these equilibria are efficient. □

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