IPO Pricing and Informational Efficiency: The Role of Aftermarket Short Covering

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Abstract

Investment banks legally pursue supposedly price stabilizing activities in the aftermarket of IPOs. We model the offering procedure as a signaling game and analyze how the possibility of potentially profitable trading in the aftermarket influences pricing decisions by investment banks. When maximizing the sum of both the gross spread of the offer revenue and profits from aftermarket trading, investment banks have an incentive to distort the offer price by employing aftermarket short covering and exercise of the overallotment option strategically. This results either in informational inefficiencies or, on average, exacerbated underpricing. Wealth is redistributed in favor of investment banks.

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1 Introduction

The Committee of European Securities Regulators (CESR (2002), FESCO (2001)) recently proposed rules allowing offering syndicates to stabilize market prices of public offerings. From their documents it transpires in their opinion that all sides of the market benefit – issuers, investors and underwriters.[1] On the other side of the Atlantic, stabilization has also been legal practice since the United States' Securities Act of 1934. In their latest release of Regulation M the U.S. Securities and Exchange Commission (SEC) opines: "Although stabilization is a price influencing activity intended to induce others to purchase the offered security, when appropriately regulated it is an effective mechanism for fostering the orderly distribution of securities and promotes the interests of shareholders, underwriters, and issuers."[2] With this paper we challenge the assertion that current regulation always serves the interests of all involved parties. We argue that issuing investment banks *can* combine two regulated stabilization tools to generate risk-free profits. Employing a model that captures the impact of this arbitrage opportunity on the offer price, we find that (a) either market transparency is lower or, on average, underpricing is exacerbated, and (b) the issuing investment bank's profits are boosted at the expense of issuer and investors.

Current regulation allows investment banks to pursue the following three types of aftermarket activities. First, *stabilizing bids* can be posted at or below the offer price during the distribution period of the securities. Second, banks can establish a short position by selling securities in excess of the pre-announced amount. *Aftermarket short covering* refers to the practice of filling these positions in the aftermarket, which is done if the market price falls below the offer price. If the price instead rises, the bank is hedged by an *overallotment option* which grants the right to obtain typically up to 15% additional securities from the issuer at the offer price. Third, *penalty bids* are used to penalize customers who immediately resell their securities in the aftermarket.

Although on average IPOs have high first-day returns, there is a significant number of IPOs with negative returns. In these 'cold' IPOs, stabilizing bids and short covering should ensure liquidity for the security to offset potential selling pressure (in the first days after the float), and thus prevent sharp drops in prices. Penalty bids are meant to reduce selling pressure. In this paper we focus exclusively on the impact of short covering. An investment bank intending to support the security price adheres to the following procedure. It enters the aftermarket short. This position must be filled eventually. Suppose that the market

[1] The main argument put forward for allowing such market manipulation is that stabilization will ensure an "orderly market" so that sudden selling pressure can be countered (see also FSA (2000)).

[2] SEC (1997), Regulation M, Release No. 34-38067, p. 81.

price exceeds the offer price. Then there is supposedly no selling pressure and no need to provide extra liquidity. Covering the short position in the market, however, would be expensive. This is why almost all IPO contracts include a so-called 'Greenshoe' or overallotment option. It allows the bank to buy extra securities from the issuer at the offer price. In the bulk of offerings, the initial short position is perfectly hedged by this option. Increasing prices are therefore no risk for the bank. Suppose now that the price drops. The bank does provide liquidity, however, by doing so it also covers the short position in the market – at a price below the offer price. The difference between the market price and the offer price (minus the gross spread) is pure profit. In other words, the opportunity to enter the market short, paired with the overallotment option, provides investment banks with a second, risk-free potential source of income.

Only recently, new data became available that allowed to analyze investment banks' activities in the aftermarket directly. Aggarwal (2000) reports that underwriters utilize a combination of aftermarket short covering, penalty bids, and exercise of the overallotment option. Stabilizing bids are never observed. Ellis, Michaely and O'Hara (2000) report that the lead underwriter always becomes the dominant market maker. They also find that market makers take large inventory positions, but reduce their risk by exercising the overallotment option.

There are two cases studies which support the casual observation that aftermarket trading can be very profitable. Jenkinson and Ljungqvist (2001) provide a study of the 1995 GenCo2 IPO (U.K.) during which the price fell in the aftermarket. The assigned investment banks Barclays de Zoete Wedd and Kleinwort Benson repurchased 45.7 million securities at the low market price to cover their short positions that were established at the offer price. Jenkinson and Ljungqvist (2001) conclude: "It demonstrates how valuable the over-allotment option potentially is to the syndicate of investment banks selling the issue. Since they will buy back the shares in the market only if the price is below the issue price, in closing (partially or in full) their short position they make profits. These profits accrue to the syndicate itself, as the holder of the option, rather than to the [...] vendors" (p. 180). Boehmer and Fishe (2001) analyze a case-study of an IPO in which the lead underwriter took a nearly perfectly hedged short position which was then covered in the aftermarket. The profits from trading amounted to 52% of the syndicate's overall profit from the offering. In their words: "[...][short covering activities] represent an economically significant profit opportunity for the Lead" (p. 4).[3]

[3] Aggarwal (2000) finds that "short covering is not expensive for underwriters" (p. 1077). In more detail, she finds that for weak offerings investment banks make profits, for strong offerings however they may lose money. This stems from the fact that either the overallotment option is not fully exercised or investment banks had established a "naked short" prior to the offering such that short positions had to

The existing literature on the impact of price support on offer prices models stabilization to be costly. The two seminal theoretical papers on stabilization, Benveniste, Busaba and Wilhelm Jr. (1996) and Chowdhry and Nanda (1996), assume that banks post stabilizing bids to keep prices up. However, such stabilizing bids are never observed. Both models imply that stabilizing activities decrease underpricing – our model predicts the opposite. This paper thus contrasts the existing literature as we model explicitly that investment banks can earn money in the aftermarket, and to the best of our knowledge we are the first to do so in a theoretical framework.

We propose a stylized model of an offering procedure that is in accordance with empirical findings and perceived industry practice. We assume that both the investment bank and investors hold private information about the intrinsic value of the offered security. We assume this information asymmetry to arise at a point in time when all official, mandatory information has been released. Thus, any further public statement by bank or issuer will be perceived as cheap talk, and it is only actions, i.e. price-setting, that can convey additional information. We model the procedure as a signaling game in which the investment bank moves first and sets the offer price. It chooses the offer price strategically to maximize its profits form both the gross spread of the offer revenue and trading profits in the aftermarket. The bank anticipates investors' best replies to the offer price.

As a benchmark, we first analyze a setting without aftermarket activities and identify the conditions for the equilibrium to be both unique and separating (that is, a bank with different information sets different prices). We call a separating equilibrium *informationally efficient* since the bank's information is fully revealed by the offer price. After the offer is floated, prices adjust according to market demand. In equilibrium, the security can turn out to be either under- or overpriced, but investors account for this when ordering the security. We show that on average there is underpricing.

When introducing aftermarket short covering, relative to the benchmark one of two outcomes transpires: either the offer price falls on average, or separation breaks down and the offer-price equilibrium morphs into a pooling equilibrium. In the first case, an investment bank with favorable information distorts the price downwards and thereby,

be covered at prices above the offer price. Our model cannot explain why investment banks sometimes establish "naked shorts" or do not fully exercise the overallotment option. We merely analyze the effects aftermarket short covering can have when investment banks utilize the possibility to make risk-free profits, i.e. when they do not establish "naked shorts" and fully exercise the overallotment option when prices rise. Ellis et al. (2000) find that aftermarket activities of the lead underwriter are profitable and account for about 23% of the overall profit of underwriting. Reported profits stem from both market making and stabilizing activities (that is accumulating inventory positions). From the presentation in the paper it does not seem possible to disentangle whether stabilization contributed to or reduced trading profits. The claim that stabilization can be a profitable activity is thus not rejected by the data.

on average, *exacerbates underpricing*. In the second case investors are unable to infer the investment bank's signal from the offer price. This equilibrium is *informationally inefficient* since investors' decisions are based on private signals only and not also on the signal of the bank. A major objective of financial market regulation is market transparency. Without modelling an explicit payoff from higher transparency we simply assume that it is desirable if prices contain more rather than less information. Consequently, pooling equilibria are undesirable.

Furthermore, the price distortion leads to redistribution of wealth in favor of the investment bank. Looking at per-share profits, the issuer loses if separation prevails; in a pooling equilibrium he is better off. The issuer's losses are the investors' gains and vice versa. On the comparative statics side, an increase of the gross spread or the amount of overalloted securities reduces the parameter-set with informational efficiency.

The remainder of the paper is organized as follows. In Section 2 we introduce our model of the offering procedure absent aftermarket short covering and identify necessary and sufficient conditions under which the investment bank reveals its private signals through separating offer prices. In Section 3 we introduce aftermarket short covering, identify the conditions under which the investment bank pools in the offer price and thus holds back its private information and show that, if separation is upheld, prices fall on average. We also provide results on comparative statics. In Section 4 we discuss the redistribution of profits. Section 5 concludes. Proofs and specifications of tools used in the equilibrium analysis are in the Appendix.

2 The Benchmark: Offer Prices in a Model without Aftermarket Short Covering

2.1 The Model Ingredients and Agents' Best Replies

Consider the following stylized model of the IPO process.

The Security. The security on offer can take values $V \in \mathbb{V} = \{0, 1\}$, both equally likely. The number of securities is denoted by S.

The Investors. There are N identical, risk neutral investors. N is assumed to be strictly larger than S. They can either order one unit of the security or none. Each investor receives a costless, private, conditionally i.i.d. signal $s_i \in \mathbb{V}$ about the value of the security. This information is noisy, i.e. $\mathsf{Pr}(s_i = v|V = v) = q_i$ with $q_i \in (\frac{1}{2}, 1)$. If an investor orders, he may or may not obtain the security during the offering procedure; if the issue is oversubscribed shares are distributed with uniform probability. If he does, his payoff is the market price minus the offer price. If the offer is not floated, his payoff is zero even if he ordered the security. An investor's type is his signal. We refer to the investor as a 'high-signal investor' if $s_i = 1$. For $s_i = 0$, it is a 'low-signal investor'.

The Issuer. We assume that the issuer has no strategic impact. He holds no private information about the value of the security. The issuer signs a contract with an investment bank that delegates the pricing decision and constitutes the amount of securities S to be sold.[4] It also specifies the gross spread β of the offer revenue that remains as remuneration at the bank. The issuer's payoff is thus fraction $(1 - \beta)$ of the offer revenue if the offer is floated, otherwise it is zero.

The Investment Bank. The risk neutral investment bank who signed the contract with the issuer receives a private signal $s_b \in \mathbb{V}$ about the value of the security. This signal is noisy and conditionally independent from investors' signals. Yet it is more informative, i.e. $q_b > q_i$, where $\mathsf{Pr}(s_b = v|V = v) = q_b$. Signals characterize a bank's type. If $s_b = 1$ we refer to the investment bank as a 'high-signal bank'. For $s_b = 0$, it is a 'low-signal bank'. The bank receives the signal after the contract has been signed and then announces the offer price p.[5] If demand is too weak to match supply, i.e. if the number of investors willing to buy is less than the number of securities to be sold, we assume that the offer is called off.[6] In case of excess demand securities are allocated at random. We assume that failure of the offering inflicts fixed costs C on the investment bank.[7] These costs are external to our formulation and can be thought of as deterioration of reputational capital. They may also capture the opportunity costs resulting from lost market share when being

[4] The two most widely used contracts between issuers and investment banks are firm commitment and best efforts contracts. These contracts differ with respect to risk allocation and incentive provision that may be necessary due to imperfectly observable distribution effort and asymmetric information about the value of the securities. However, in this stylized model we abstract form these complications.

[5] We discuss fixed-price offerings vs. bookbuilding at the end of this subsection.

[6] Busaba, Benveniste and Guo (2001) report for a sample of 2,510 IPOs filed with the SEC from 1984 to 1994 that 14.3% of the offerings got called off. Issuers have the option to withdraw an offer if the investment bank proposes a price that is perceived as too low. During the road show the bank learns about investors' valuations. In a firm commitment contract the bank uses this information to propose an offer price such that it can find enough investors to sell the entire offer; in a best efforts contract, such that selling all securities will not be too difficult. This model abstracts from the issuer's option to withdraw, and it leaves no room to the bank to adjust the offer price to investors' valuations.

[7] The model could be extended to allow the bank to buy up unsold securities. Costs then result from expensively bought inventory positions and not from failure. C would thus be 'smoothed'. This would, however, not alter our qualitative results but complicate the analysis considerably.

associated with an unsuccessful IPO.[8] Without loss of generality, we do not specify any costs the offering procedure itself may cause for the investment bank. Thus, if the offer is successful, the bank's payoff is $\beta \mathsf{p}\mathsf{S}$; if it fails, its payoff is $-C$.

Signaling Value of the Offer Price. An investor bases his decision on his private information and on the information that the investment bank reveals about its own signal through the offer price. We denote this information by $\mu(\mathsf{p})$ and write $\mu(\mathsf{p}) = 1$ if the price reflects that the bank's signal is $s_b = 1$, $\mu(\mathsf{p}) = 0$ if the price reflects that $s_b = 0$, and $\mu(\mathsf{p}) = \frac{1}{2}$ to indicate that the price is uninformative. These three are the only relevant cases in equilibrium. We refer to μ as the *price-information* about the bank's signal.

The Aftermarket Price. The equilibrium market price is determined by the aggregate number of investors' favorable signals. In our model this number is always revealed, either directly through investor demand or immediately after the float through trading activities. Thus write $\mathsf{p}^m(d)$ for the market price as a function of $d \in \{0, \ldots, N\}$, the number of high-signal investors. Appendix A fleshes out this argument and provides an extensive treatment of price formation.

Investors' Decisions and Expected Payoffs. We admit only symmetric, pure strategies; thus all investors with the same signal take identical decisions. These can then be aggregated so that only three cases need to be considered. First, all investors buy, denoted $B_{0,1}$, second, only high-signal investors subscribe, denoted B_1, and third, no investor buys, denoted $B_\emptyset$. Thus, the set of potential collective best replies is $\mathbb{B} := \{B_{0,1}, B_1, B_\emptyset\}$.

To compute his expected payoff, an investors has to account for the probability of actually getting the security. There are two cases to consider. In the first, all investors buy. Thus, market demand is N and all investors receive the security with equal probability S/N. In the second case, only high-signal investors buy. If $d-1$ others buy, then an investor receives the security with probability $\mathsf{S}/(d)$. If overall demand d is smaller than the number of shares on offer, $d < \mathsf{S}$ the IPO fails and the investor who ordered gets it with probability 0.

Investors order the security whenever their expected payoff from doing so is non-negative. Suppose only high-signal investors buy, B_1. After observing the offer price, an investor's information set contains both his signal s_i and the information inferred from the offer price, $\mu(\mathsf{p})$. Since signals are conditionally i.i.d., for every $V \in \mathbb{V}$ there is a different

[8] Dunbar (2000), for instance, provides evidence that established investment banks lose market share when being associated with withdrawn offerings.

distribution over the number of favorable signals ($s_i = 1$), which we denote $f(d|V)$. The investors' posterior distribution over demands is given by

$$g(d-1|s_i, \mu(\mathsf{p})) := \mathsf{Pr}(V = s_i|s_i, \mu(\mathsf{p}))\cdot f(d-1|V = s_i)+\mathsf{Pr}(V \neq s_i|s_i, \mu(\mathsf{p}))\cdot f(d-1|V \neq s_i). \tag{1}$$

Then for a high-signal investor, at price p his rational-expectation payoff from buying has to be non-negative,

$$\sum_{d=\mathsf{S}}^{N} \frac{\mathsf{S}}{d} \cdot (\mathsf{p}^m(d) - \mathsf{p}) \cdot g(d-1|s_i = 1, \mu(\mathsf{p})) \geq 0. \tag{2}$$

Likewise for $B_{0,1}$, in which case the summation runs from 1 to N, S/d is substituted with S/N, and $s_i = 1$ is replaced by $s_i = 0$.

Threshold Prices. Denote by $p_{s_i,\mu}$ the highest price that an investor is willing to pay in equilibrium if all investors with signal $\tilde{s}_i \geq s_i$ order, given signal s_i and price-information μ. Thus $p_{1,1}$ is the highest (separating) price with B_1, $p_{1,\frac{1}{2}}$ the highest (pooling) price with B_1, $p_{0,\frac{1}{2}}$ the highest (pooling) price with $B_{0,1}$, and $p_{0,0}$ the highest (separating) price with $B_{0,1}$. Note that at all these prices investors are aware that the security price may drop in the aftermarket and that they may not get the security. The threshold prices are formally derived in Appendix B.

The Investment Bank's Expected Payoff. First consider case B_1. Variable d denotes the number of buys, i.e. the number of high-signal investors. If the true value is $V = 1$, we have

$$\mathsf{Pr}(d \geq \mathsf{S}|B_1) = \sum_{d=\mathsf{S}}^{N} \binom{N}{d} q_i^d (1 - q_i)^{N-d}, \tag{3}$$

analogously for $V = 0$. A bank with signal s_b assigns probability $\alpha_{s_b}(\mathsf{S})$ to the event that at least S investors have the favorable signal. Since the investment bank receives its signal with quality q_b, for $s_b = 1$,

$$\alpha_1(\mathsf{S}) = q_b \cdot \sum_{d=\mathsf{S}}^{N} \binom{N}{d} q_i^d (1 - q_i)^{N-d} + (1 - q_b) \cdot \sum_{d=\mathsf{S}}^{N} \binom{N}{d} (1 - q_i)^d q_i^{N-d}. \tag{4}$$

$\alpha_0(\mathsf{S})$ is defined analogously. If the bank charges a price at which only high-signal investors buy, its expected profit is

$$\Pi(\mathsf{p}|s_b, B_1) = \alpha_{s_b}(\mathsf{S}) \cdot \beta \mathsf{p}\mathsf{S} - (1 - \alpha_{s_b}(\mathsf{S})) \cdot C. \tag{5}$$

Consider now $B_{0,1}$, the case where the offer price is low enough so that all investors are willing to buy, irrespective of their signals. The offer never fails, thus payoffs are given by $\Pi(\mathsf{p}|B_{0,1}) = \beta \mathsf{p}\mathsf{S}$. If the price is set so high that no investor buys, as in case $B_\emptyset$, a loss of C results with certainty.

Simplifying Assumptions. The unconditional distribution over favorable signals is a composite of the two conditional distribution and thus bimodal To obtain closed form solutions (or rather approximations) for success-probabilities and prices, we make two simplifying assumptions: the first simplifies computations, since the two modes of the distribution over favorable signals are centered around $N(1-q_i)$ and Nq_i. The results of the paper will also hold if it was not satisfied, as long as $\mathsf{S} < N/2$, but the assumption allows us to get closed form solutions for success-probabilities. The second assumption ensures that we can analyse the two underlying conditional distributions separately.

Assumption 1 $\mathsf{S} = (1-q_i)N$.

For every signal quality q_i, there exists an $\bar{N}(q_i)$ so that for all $N > \bar{N}(q_i)$ the two conditional distributions over favorable signals generated by $V = 0$ and $V = 1$ do not 'overlap.'[9] By standard results from statistics, sufficient for $\bar{N}(q_i)$ is $\bar{N}(q_i) > 64q_i(1-q_i)/(2q_i-1)^2$.

Assumption 2 *The number of investors N is larger than $\bar{N}(q_i)$.*

As a consequence of the second assumption we can apply the Law of Large Numbers and DeMoivre-Laplace's Theorem.[10] Since we assume that the IPO fails whenever $d < \mathsf{S}$, Assumption 1 implies $\alpha_0(\mathsf{S}) = (2-q_b)/2$ and $\alpha_1 = (1+q_b)/2$; in what follows we thus omit S. A consequence of the Law of Large Numbers is that $\mathsf{p}^m(d) \in \{0, 1\}$ for almost all values of d.[11]

[9]To be more precise: We need to ensure that if $V = 1$, the probability of demand $d < \mathsf{S}$ is zero.

[10]For instance, the mode of a binomial distribution is generally not exactly symmetric. However, if N is large enough, we can apply DeMoivre-LaPlace ($0 < q_i \pm 2\sqrt{q_i(1-q_i)/N} < 1$) and employ the normal distribution instead. Thus we can treat each mode to be symmetric. The number traders has to large enough so that for $V = 0$, there are almost never more than $N/2$ traders with a favourable signal and vice versa for $V = 1$.

[11]To be more precise, for $d \gg N/2$, $\mathsf{p}^m(d) = 1$, and for $d \ll N/2$, $\mathsf{p}^m(d) = 0$. Thus to get interesting equilibria, it is necessary that S is strictly smaller than $N/2$. If it was not, an IPO where only $s_i = 1$ investors buy, would never be at risk of being overpriced as it fails in all overpriced cases.

Fixed Price Offerings vs. Bookbuilding. On most stock exchanges in the world IPOs are sold through bookbuilding (for instance in the US, the UK, Germany, but not in France), whereas our model is a fixed-price offering. Current regulation allows risk-free aftermarket short covering profits and this paper tries to capture their strategic impact. These potential profits depend primarily on price movements and thus one should study the the offer price as the strategic decision variable. In any imaginable framework the investment bank faces a trade-off between higher revenue and likelihood of failure. Thus it is reasonable to assert that the offer price or, depending on the formulation, the bookbuilding span has signalling value. A fixed-price mechanism is, arguably, the simplest possible way to capture the price's strategic dimension.

A hypothetical bookbuilding model will capture the strategic dimension in a similar fashion, yet the analysis would become less tractable without adding insight: In bookbuilding, the investment bank must set a bookbuilding span. This span can certainly have signaling value because it is, arguably, similar to setting a single price (a degenerate span). Suppose bookbuilding spans have to be sufficiently tight so that they are strictly in the $[0, 1]$-interval's interior. During the bookbuilding period, investors submit their orders which (potentially) reveal their private information – just as with our fixed price mechanism. At the end of the bookbuilding period the investment bank will set the final selling price somewhere in the span, distribute the shares, and reveal overall demand. As long as the span and thus the issue price in the span is strictly in the interior of the $[0, 1]$-interval, secondary market prices will adjust to a price outside the span. Our stylized, parsimonious model is rich enough to capture the same result that a more complicated bookbuilding model would yield.

2.2 Derivation of the Separating Equilibrium

The focus of this paper is the pricing decision of the investment bank given its signal. In the following we identify the conditions under which a profit maximizing investment bank will reveal its information through the offer price. A separating equilibrium is defined as *informationally efficient* since investors can derive the bank's signal from the offer price. In a pooling equilibrium information is shaded and thus it is *informationally inefficient*. In this case, investors decide only on the basis of their private signals.

The Equilibrium Concept and Selection Criteria. The equilibrium concept for this signalling game is, naturally, the Perfect Bayesian Equilibrium (PBE). A common problem with PBEs, however, is their multiplicity, stemming equilibria being supported by "unreasonable" out-of-equilibrium beliefs. The common way to overcome this problem is to apply an equilibrium selection rule such as the *Intuitive Criterion* (IC), introduced by Cho and Kreps (1987). We follow this line of research and consider only equilibria that do not fail the IC. All of these PBE selection devices favour separating over pooling equilibria. It will turn out, however, that in our framework under certain conditions the IC cannot rule out pooling price equilibria. Moreover, from the perspective of the investment bank the pooling equilibrium then Pareto dominates any separating equilibrium. It would thus be unreasonable not to assume that these equilibria will be picked. Thus in what follows, we will only consider equilibria that *satisfy the IC* and among these, we consider those that are *Pareto efficient* for the bank

A *pooling equilibrium* is specified through (i) an equilibrium offer price p^* from which investors infer (ii) price-information $\mu = \frac{1}{2}$, and (iii) investors' best replies given their private signals, μ, and p^*. A *separating equilibrium* is (i) a system of prices $\{\underline{\mathsf{p}}^*, \bar{\mathsf{p}}^*\}$ and price-information such that (ii) at $\mathsf{p}^* = \bar{\mathsf{p}}^*$, the *high separation price*, the price-information is that the bank has the favorable signal, $\mu = 1$, at $\mathsf{p}^* = \underline{\mathsf{p}}^*$, the *low separation price*, the price-information is that the bank has the low signal, $\mu = 0$, and (iii) investors' best replies given their private signals, μ, and p^*. In both separating and pooling equilibria, for $\mathsf{p} \notin \{\bar{\mathsf{p}}^*, \underline{\mathsf{p}}^*\}$ out-of-equilibrium public beliefs are chosen 'appropriately.' The following result is a straightforward consequence of signaling, the proof of which is in Appendix E.

Lemma 1 [The Highest Possible Low Separating Price] *There exists no separating offer price* $\underline{\mathsf{p}}^* > p_{0,0}$.

In any separating equilibrium, therefore, the low price must be such that all investors buy, and the highest such separating price, given price-information $\mu = 0$, is $\underline{\mathsf{p}}^* = p_{0,0}$. In what follows we refer to $p_{0,0}$ as *the* low separation price.

Signaling equilibria in our setting come in one of three guises: The already mentioned separating equilibrium, a pooling equilibrium in which only high-signal investors buy, and a pooling equilibrium in which all investors buy. In the following, we characterize the conditions guaranteeing that only separating equilibria survive our selection criterion.

Fix a potential price $\mathsf{p} \in [p_{0,0}, p_{0,\frac{1}{2}}]$, the interval of potential pooling prices at which all investors would buy. Define $\phi_1(\mathsf{p})$ as the price at which the high-signal bank would be indifferent between charging a *risky* price $\phi_1(\mathsf{p})$ at which only high-signal investors buy, B_1, and a *safe* pooling price p with $B_{0,1}$ (all investors buy). Formally,

$$\alpha_1 \beta \phi_1(\mathsf{p})\mathsf{S} - (1 - \alpha_1)C = \beta \mathsf{p}\mathsf{S} \quad \Leftrightarrow \quad \phi_1(\mathsf{p}) = \frac{\mathsf{p}}{\alpha_1} + \frac{1 - \alpha_1}{\alpha_1} \frac{C}{\beta \mathsf{S}}. \tag{6}$$

Price $\phi_0(\mathsf{p})$ is defined analogously for the low-signal bank. Thus price $\phi_{s_b}(\mathsf{p})$ is the lowest risky price that a bank with signal s_b is willing to deviate to from safe price p.[12] In what follows we refer to $\phi_1(\mathsf{p})$ as the *high-signal bank's deviation price*, and to $\phi_0(\mathsf{p})$ as the *low-signal bank's deviation price.* It is straightforward to see that $\phi_0(\mathsf{p}) > \phi_1(\mathsf{p})$ for all $\mathsf{p} \in [p_{0,0}, p_{0,\frac{1}{2}}]$, that is, the low-signal bank requires a higher price as compensation for risk taking. In addition, $\partial\phi_j(\mathsf{p})/\partial\mathsf{p} > 0$, $j \in \{0,1\}$, so the higher the pooling price, the higher the lowest profitable deviation price. We can now establish our first major result.

Proposition 1 (Conditions for Informationally Efficient Prices)
If (i) the high-signal bank's deviation price from the highest safe pooling price is not higher than the highest separating price, $\phi_1(p_{0,\frac{1}{2}}) \leq p_{1,1}$, and if (ii) the low-signal bank's deviation price from the low separating price is not smaller than the highest risky pooling price, $\phi_0(p_{0,0}) \geq p_{1,\frac{1}{2}}$ then there exists a unique PBE that satisfies the Intuitive Criterion and it is the separating equilibrium $\{(\underline{\mathsf{p}}^* = p_{0,0}, \mu = 0, B_{0,1}); (\bar{\mathsf{p}}^* = \min\{p_{1,1}, \phi_0(p_{0,0})\}, \mu = 1, B_1); (\mathsf{p} \neq \{\underline{p}^*, \bar{p}^*\}, \mu = 0, B_{0,1}$ if $\mathsf{p} \leq p_{0,0}, B_1$ if $p_{0,0} < \mathsf{p} \leq p_{1,0}, B_\emptyset$ else$)\}$.

Interpretation of the Proposition. The first condition, $\phi_1(p_{0,\frac{1}{2}}) \leq p_{1,1}$, together with the IC is necessary and sufficient to rule out pooling equilibria in which all investors buy, irrespective of their signals. The second condition, $\phi_0(p_{0,0}) \geq p_{1,\frac{1}{2}}$, ensures that there is no pooling where only high-signal investors buy, B_1. The IC itself ensures that the bank with $s_b = 1$ always charges the highest sustainable separating price. The high separation price $\bar{\mathsf{p}}^*$ is the minimum of $p_{1,1}$ and $\phi_0(p_{0,0})$. The bank cannot charge more than $p_{1,1}$, and it cannot credibly charge more than $\phi_0(p_{0,0})$ as otherwise the bank with $s_b = 0$ would deviate. Finally, since $\phi_1(p_{0,0}) < \phi_1(p_{0,\frac{1}{2}}) \leq p_{1,1}$, the bank with $s_b = 1$ is willing to separate. The proof's details are in Appendix E. A definition of the IC can be found, for instance, in Fudenberg and Tirole (1991)[p.448].

Underpricing. In the context of this model the first-day return is the difference between market price and offer price. We can establish the following proposition. The proof is in Appendix E.

Proposition 2 (Underpricing)
In a separating equilibrium, on average, securities are underpriced.

[12]Deviation to a high, risky price can lead to increased overpricing, which is commonly perceived to be bad for a bank's reputation. Nanda and Yun (1997) analyze the impact of IPO mispricing on the market value of investment banks. They find that overpriced offerings result in decreased lead-underwriter market value. In our model, however, investors fully take into account that the offer price may drop in the aftermarket. Modelling such reputation effects would thus be contradictory in our setting.

Interpretation of the Result. The intuition behind the result is clear: Both types of investors only buy if their expected payoff is non-negative. At $p_{0,0}$ the low-signal investor just breaks even in expectation but the high-signal investor expects a strictly positive payoff. At $p_{1,1}$ the high-signal investor just breaks even and the low-signal investor abstains. Thus, ex-ante, expected payoff is positive, i.e. there is underpricing.

2.3 An Intuitive Characterization of the Equilibrium

The concept of deviation prices ϕ_{s_b} is a convenient tool to describe restrictions. We will now reformulate the conditions from Proposition 1 in terms of exogenous costs C. This allows us to derive a simple linear descriptive characterization of the equilibrium. Consider first condition (i), $\phi_1(p_{0,\frac{1}{2}}) \leq p_{1,1}$. If C is so high that

$$\phi_1(p_{0,\frac{1}{2}}) = \frac{p_{0,\frac{1}{2}}}{\alpha_1} + \frac{1-\alpha_1}{\alpha_1}\frac{C}{\beta \mathsf{S}} \;\; > p_{1,1} \tag{7}$$

then a separating equilibrium cannot be sustained. Even a high-signal bank then prefers to sell the security at a price where all investors buy. Consider now condition (ii), $\phi_0(p_{0,0}) \geq p_{1,\frac{1}{2}}$. If C is so low that

$$\phi_0(p_{0,0}) = \frac{p_{0,0}}{\alpha_0} + \frac{1-\alpha_0}{\alpha_0}\frac{C}{\beta \mathsf{S}} \;\; < p_{1,\frac{1}{2}} \tag{8}$$

then a separating equilibrium, again, cannot be sustained (by the SIC). In this case, even a low-signal bank is willing to choose a high, risky pooling price and the high-signal bank can thus not credibly signal its information. If C is so high that $\phi_0(p_{0,0}) > p_{1,1}$ then for the low-signal bank it does not even pay to deviate to the highest separating price, $p_{1,1}$. This bound on C is given by

$$\hat{C} := \frac{\alpha_0 p_{1,1} - p_{0,0}}{1-\alpha_0}\, \beta \mathsf{S}. \tag{9}$$

Define, analogously, $\bar{C}$ and $\underline{C}$ such that (7) and (8) hold with equality. We get $\underline{C} < \hat{C} < \bar{C}$. The following Corollary to Proposition 1 summarizes the above characterization.

Corollary 1 (Proposition 1 in Terms of Costs)
If $C \in (\underline{C}, \bar{C})$ then the unique equilibrium is the separating equilibrium stated in Proposition 1. If $C \in (\underline{C}, \hat{C})$ then $\bar{\mathsf{p}}^* = \phi_0(p_{0,0})$, and if $C \in [\hat{C}, \bar{C})$ then $\bar{\mathsf{p}}^* = p_{1,1}$.

It has often been argued that certifying agents, here the investment bank, must have 'enough' reputational capital at stake to make certification credible. In this context, also

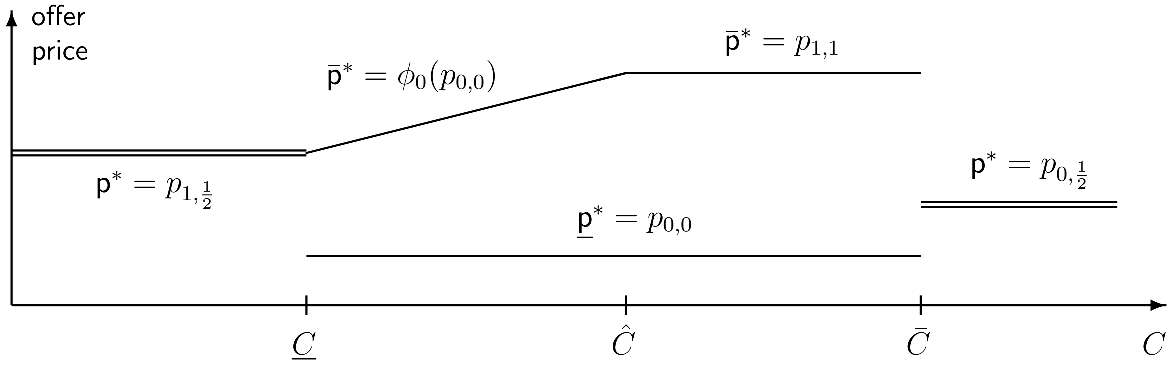

Figure 1: **Threshold Costs and Equilibrium Prices.** For costs smaller than $\underline{C}$, it holds that $\phi_0(p_{0,0}) < p_{1,1/2}$ so that the low-signal bank chooses a risky price. A pooling equilibrium in $p_{1,1/2}$ results. If $C \in (\underline{C}, \bar{C})$ a separating equilibrium results. For $C \in (\underline{C}, \hat{C})$ the high-signal bank cannot charge the highest separation price $p_{1,1}$ but must set a lower price $\phi_0(p_{0,0})$ to prevent the low-signal bank from mimicking. For $C \in [\hat{C}, \bar{C})$ the high signal bank can charge $\bar{p}^* = p_{1,1}$. Finally, if $C > \bar{C}$ it holds that $\phi_1(p_{0,1/2}) > p_{1,1}$ so that even the high-type bank prefers a safe price and pooling in $p_{0,\frac{1}{2}}$ results.

'too much' reputation can inhibit certification (separation from a low-signal bank) if it becomes to expensive to jeopardize one's reputation at a high, risky offer price. Figure 1 plots threshold costs and corresponding equilibrium prices.

3 The Impact of Aftermarket Short Covering

In this section we extend the model and allow the investment bank to pursue aftermarket short covering. We analyze its effect on the investment bank's pricing decision and investigate under which conditions informational efficiency will be undermined. We find that, in general, the conditions for a separating equilibrium become more restrictive. Upholding separation may come at a cost – thus on average the investment bank has to distort prices down, which causes more underpricing.

3.1 Overview of Short Covering and a Bank's Strategy

With aftermarket short covering the investment bank has the opportunity to allot a predetermined amount of up to O securities on top of the principal volume of securities S. This amount O is referred to as the overallotment facility. It typically constitutes 15% of the number of initial securities S. The investment bank goes short in a position of this size. If the market price falls below the offer price, the bank fills its short positions in the aftermarket. This practise is referred to as aftermarket short covering. If the price is below the offer price, the bank makes a profit. If the market price rises above the offer price, the bank exercises a so-called overallotment option, the right to obtain up to O securities from the the issuer at the offer price. The option is only valid if the bank had indeed established a short position. Consequently, the bank is perfectly hedged against rising prices. We restrict attention to the case where either the entire amount of $\mathsf{S}+\mathsf{O}$ securities is sold or, if only fewer securities can be sold, the IPO fails; the restriction merely simplifies the analysis and does not affect the qualitative results. The bank receives the gross spread only on the securities that actually remain floated.

Intuitively, the size of a potential price drop and thus of profits from aftermarket short covering is larger the higher the offer price. In the benchmark case's separating equilibrium, a low-signal bank would not mimic a high-signal bank because it fears costs from a potential IPO failure. With short covering expected aftermarket profits are higher the larger the potential price drop. Moreover, a bank with a low signal considers such a drop more likely. It is then possible, that potential losses from a failed offering are offset by higher expected aftermarket gains. Two scenarios are possible: In equilibrium, the high-signal bank sets a *lower* price to separate from a low-signal bank. The high-signal bank, however, is only willing to do so as long as separation pays. Thus there is a point where defending separation becomes too costly so that the high-signal bank *pools* with the low-signal bank and an informationally inefficient outcome results.

3.2 Equilibrium Analysis

We write $\Pi^1(\mathsf{p}^*, B, s_b)$ for the investment bank's expected profits from their share of the offer revenue. Let $\Pi^2(\mathsf{p}^*, B, s_b)$ denote the expected second period profit from filling the short position at lower prices. In case of a separating equilibrium these are

$$\Pi^2(\bar{p}^*, B_1, s_b = 1) = \sum_{d=\mathsf{S}+\mathsf{O}}^{N} \mathsf{O} \cdot \max\{\bar{p}^*(1-\beta) - \mathsf{p}^m(d), 0\} \cdot \mathsf{Pr}(d|s_b = 1) \qquad (10)$$

if the price is risky and $s_b = 1$. For safe prices, the summation in $\Pi^2(\underline{p}^*, B_{0,1}, s_b = 0)$ is from 0 to N, as the IPO never fails. The conditional distribution $\mathsf{Pr}(d|s_b)$ of demand d is the distribution derived for $\alpha_{s_b}(\mathsf{S})$. Note that a high-signal bank sums from $\mathsf{S}+\mathsf{O}$, since lower demand leads to a failure of the IPO. An investment bank with $s_b = 0$, on the other hand, sums from 0 since the IPO is always successful. The bank also accounts for the foregone gross spread β when buying back in the market.

The market price after the offering $\mathsf{p}^m(d)$ adjusts according to investors' signals and with respect to these signals it is informationally efficient. The bank cannot stabilize 'against' this efficient price, but, of course, if the price is efficient, it need not and must not be 'stabilized'. In our model it is, therefore, not possible to study potentially beneficial effects of price stabilization. More generally, however, if one believes in efficient markets, stabilization is undesirable and, if at all, it can have no more than a short-term impact.

With short covering, a high separation price, $\bar{\mathsf{p}}^*$ has to be *small* enough so a low-signal bank cannot profitably deviate from the low, riskless price, $p_{0,0}$. Thus the investment bank with $s_b = 1$ has to determine $\phi_0'(p_{0,0})$ so that

$$\Pi^1(\phi_0'(p_{0,0})|s_b = 0, B_1) + \Pi^2(\phi_0'(p_{0,0})|s_b = 0) = \Pi^1(p_{0,0}|s_b = 0, B_{0,1}) + \Pi^2(p_{0,0}|s_b = 0). \quad (11)$$

In what follows, we make two further assumptions. The first states that the overall amount of shares that can be issued remains constant relative to the scenario without aftermarket short-covering. This simplifies computations and later allows us to compare the relative payoffs in both scenarios. The second requires that together signals of investors and bank are sufficiently informative. Figure 2 has an illustration of Assumption 4.

Assumption 3 $\mathsf{S} + \mathsf{O} = (1 - q_i)N$.

Assumption 4 *q_i and q_b are large enough so that $p_{1,\frac{1}{2}} > 2p_{0,0}$.*

Using Assumptions 3 and 4, we can prove the following lemma.

Lemma 2 (The Low-Signal Bank's Deviation Price Drops)
The low-signal bank's deviation price with short covering is smaller than without short covering, $\phi_0(\mathsf{p}) \geq \phi_0'(\mathsf{p}) \quad \forall\ \mathsf{p} \in [p_{0,0}, p_{0,\frac{1}{2}}]$.

In the proof we show that for any low-signal bank's deviation price $\phi_0(\mathsf{p})$, second period profits from aftermarket short covering for the low-signal bank are higher at the high, risky price $\bar{\mathsf{p}}^*$. Consequently, this bank has an additional incentive to deviate. The low-signal bank considers it more likely that the price drops, hence its potential gain from short covering is large, in particular, relative to what it can gain by setting the low separation price. To prevent a low-signal bank from mimicking, the high-signal bank has to reduce its offer price. The proof is in Appendix E. In what follows, if there is a switch from separating to pooling, we restrict attention to those switches that are to the risky pooling price $p_{1,\frac{1}{2}}$.[13] We can now establish the main result. Analogously to Corollary 1 we spell it out in terms of separation costs as this allows for a more straightforward interpretation. The proof can be found in Appendix E.

[13]Our results on informational efficiency are not affected by this restriction. On the contrary, taking pooling in a risk-free price also into account would strengthen our findings. In addition, if there is a choice between the high, risky pooling price, $p_{1,\frac{1}{2}}$, and the low, safe pooling price, $p_{0,\frac{1}{2}}$, the former will always generate more ex-ante revenue. We thus focus on high pooling prices to keep the analysis simple.

Proposition 3 (Equilibrium with Short Covering Relative to the Benchmark)

1. *There exists a lower bound threshold cost* $\underline{C}' > \underline{C}$ *such that for all costs* $C \in [\underline{C}, \underline{C}')$*, the only equilibrium that satisfies the Intuitive Criterion and Pareto efficiency is a pooling equilibrium at the highest risky pooling price* $p_{1,\frac{1}{2}}$*. This price is informationally inefficient.*

2. *There exists an upper bound threshold cost* $\bar{C}'$ *such that for all costs* $C \in [\underline{C}', \bar{C}']$ *the unique equilibrium that satisfies the Intuitive Criterion and Pareto efficiency is a separating equilibrium. For the high separating price* $\bar{\mathsf{p}}^*$ *there exists a threshold cost level* $\hat{C}' \in [\hat{C}, \bar{C}')$ *so that*

   (a) *for costs* $C \in [\underline{C}', \hat{C}')$ *the high separation price is the low-signal bank's deviation price from the low separating price,* $\bar{\mathsf{p}}^* = \phi_0'(p_{0,0})$*,* $p_{1,\frac{1}{2}} < \phi_0'(p_{0,0}) < p_{1,1}$*, and*

   (b) *for costs* $C \in [\hat{C}', \bar{C}']$ *the high separation price is the highest possible risky price* $\bar{\mathsf{p}}^* = p_{1,1}$.

On average, underpricing in the separating equilibrium is exacerbated.

Interpretation of the Result. The first part of the proposition states that for all costs smaller than $\underline{C}'$, both types of the bank prefer to pool and hence prices are informationally inefficient. Since $\underline{C}' > \underline{C}$ pooling occurs for a region of parameters where without aftermarket short covering there was separation. That is, the cost region for which we get informational efficiency becomes more restrictive. The second part of the proposition outlines the region in which separation is sustained. For all costs smaller than threshold $\hat{C}'$, the investment bank with the good signal charges $\phi_0'(p_{0,0})$, which, by Lemma 2, is smaller than the price charged in that corresponding parameter region without short covering. In other words, for costs between $\underline{C}'$ and $\hat{C}'$ offer prices drop. By Proposition 2, there is underpricing in a separating equilibrium. Thus, on average, underpricing is exacerbated when separation is sustained. At first glance this result is surprising since second period expected gains are larger the higher the offer price. One might expect that agents are then more inclined to set higher prices. In our model, this casual intuition fails.

The Impact on the Upper Threshold Level for Costs. So far we have focussed on the relation of lower bound threshold costs $\underline{C}$ and $\underline{C}'$ and 'middle' bound threshold costs $\hat{C}$ and $\hat{C}'$. Surely, if $\hat{C}'$ increases relative to $\hat{C}$ (by Lemma 2) and $\underline{C}'$ increases relative to $\underline{C}$, then also $\bar{C}'$ should increase relative to $\bar{C}$. But this is not necessarily true – it may actually decrease. Furthermore, if it does increase, it is irrelevant. This is why: Keeping

N, β, and O fixed, $\bar{C}$ and $\bar{C}'$ are functions of the signal qualities q_b and q_i. For low signal qualities, $\bar{C}'$ actually decreases. For such values the high separation price $p_{1,1}$ and the low, risk-free pooling price $p_{0,\frac{1}{2}}$ are close. Expected aftermarket profits are higher for the risk-free price and this outweighs the lower expected pooling revenue. For high values of q_b and q_i, both $\bar{C}$ and $\bar{C}'$ exceed the 'natural' upper bound for costs: The worst that can happen, is that a bank loses all (discounted) future business. This upper bound on C can be estimated. In Appendix D we go into the details of this argument, but in what follows we restrict attention to $\underline{C}$, $\underline{C}'$, $\hat{C}$, and $\hat{C}'$. To summarize: The first case of a decreasing upper bound strengthens our result, the second case does not weaken our argument.

Comparative Statics. We can express the overallotment option O as share r of S, that is $\mathsf{S} + \mathsf{O} = (1 + r)\mathsf{S}$. Thus, $r = 0$ is the benchmark case without short covering. Potential policy variables in this setup are the bank's share of the revenue, β, and the size of the overallotment option, r. The proof of the following Proposition is in Appendix E.

Proposition 4 (Comparative Statics)
The conditions for informational efficiency become more restrictive for the gross spread, β, or the amount of the overallotment facility, r, increasing.

Interpretation of the Proposition. A higher level of β or an increased amount of r strengthen an investment bank's incentive to set higher prices. For a high-signal bank it is thus more difficult to defend a high separation price, consequently, more pooling results.

3.3 How would the result change if there was no signalling?

In order to understand the impact of signaling, consider the case where the investment bank gets no signal at all. This is equivalent to the case of a neutral signal $q_b = 1/2$. The conditional probability of there being at least S high-signal investors is

$$\alpha(\mathsf{S}) = \sum_{d=\mathsf{S}}^{N} \binom{N}{d} \frac{1}{2} \left(q_i^d (1 - q_i)^{N-d} + (1 - q_i)^d q_i^{N-d} \right). \tag{12}$$

Here an offer price has no signaling value, investors learn nothing from it. If an investor has favorable signal $s_i = 1$, he buys the security if $\mathsf{p} \leq p_{1,\frac{1}{2}}$, if he has $s_i = 0$ he buys if $\mathsf{p} \leq p_{0,\frac{1}{2}}$. Thus price $p_{0,\frac{1}{2}}$ is risk-free. The investment bank then sets risky price $p_{1,\frac{1}{2}}$, if its expected payoffs are higher than those for the risk-free price,

$$\alpha(\mathsf{S})\beta p_{1,\frac{1}{2}}\mathsf{S} - (1 - \alpha(\mathsf{S}))C \geq \beta p_{0,\frac{1}{2}}\mathsf{S}, \tag{13}$$

and it sets $p_{0,\frac{1}{2}}$ otherwise. Thus there exists a threshold $\tilde{C}$, such that for all costs $C \leq \tilde{C}$, the investment bank would charge the high price $p_{1,\frac{1}{2}}$, and for all $C > \tilde{C}$, it would play safe and charge $p_{0,\frac{1}{2}}$. However, once short covering is introduced, this second profit opportunity may enable the investment bank to charge a higher price. Simulation of prices show that, $\Pi^2(p_{1,\frac{1}{2}}) > \Pi^2(p_{0,\frac{1}{2}})$. Thus there exists a threshold cost $\tilde{C}'$ larger than $\tilde{C}$ such that the investment bank charges the higher, riskier price where it used to charge the low price. In this case, there would be more *overpricing*, for $C \in [\tilde{C}, \tilde{C}')$. This contrasts our signaling model, which produces the opposite effect: For a non trivial region of parameters we expect to observe, on average, more *underpricing*.

4 Payoff Analysis

Although the investment bank has a second source of profits, it is not immediately obvious that it will indeed be better off – if it has the high signal, it may have to distort prices downwards. The bank will thus receive lower expected revenues that may not be outweighed by short covering profits.

Measuring Payoffs. The investment bank's expected payoffs can be measured at two points in time: *Ex-ante*, that is before the bank receives its private information, and *interim*, that is after the signals are realized but before investors take decisions. Issuers have no private information, so their information is exclusively determined ex-ante. As a convention, we compare per-share profits and costs.

Table 1 summarizes a bank's conditional signal probabilities, the prices that are charged for each signal, the conditional probabilities of a successful IPO and, given it is indeed successful, the probability of short covering and its profitability. For instance, take $V = 0$ and $s_b = 1$, which occurs with probability $1 - q_b$. In a separating equilibrium the high-signal bank charges $\bar{\mathsf{p}}$ without and $\bar{\mathsf{p}}'$ with short covering. The IPO is successful with probability 1/2 and, given this, there is short covering with probability 1. With probability 1/2 the IPO fails and the bank incurs cost C. Note that if $V = 1$, by the Law of Large Numbers, the IPO almost never fails.

4.1 Payoff Comparison for the Investment Bank

We will trickle down from the the strongest to the weakest case: First we analyze the interim type-specific payoffs. This is the strongest case, because we determine when types gain individually. We then proceed with the ex-ante payoff gains. We specify under which

Without Aftermarket Short Covering						
	$s_b = 1$			$s_b = 0$		
	$\mathsf{Pr}(s_b \| V)$	Price	Pr(success)	$\mathsf{Pr}(s_b \| V)$	Price	Pr(success)
$V = 1$	q_b	$\bar{\mathsf{p}} = \min\{p_{1,1}, \phi_0(p_{0,0})\}$	1	$1 - q_b$	$p_{0,0}$	1
$V = 0$	$1 - q_b$	$\bar{\mathsf{p}} = \min\{p_{1,1}, \phi_0(p_{0,0})\}$	$\frac{1}{2}$	q_b	$p_{0,0}$	1

With Aftermarket Short Covering					
	$s_b = 1$				
	$\mathsf{Pr}(s_b \| V)$	Price	Pr(success)	Pr(short cov.)	Profit $\mathsf{p} - p^m$
$V = 1$	q_b	$\bar{\mathsf{p}}' = \min\{p_{1,1}, \phi_0'(p_{0,0})\}$	1	0	0
$V = 0$	$1 - q_b$	$\bar{\mathsf{p}}' = \min\{p_{1,1}, \phi_0'(p_{0,0})\}$	$\frac{1}{2}$	1	$\kappa\bar{\mathsf{p}}'$
	$s_b = 0$				
	$\mathsf{Pr}(s_b \| V)$	Price	Pr(success)	Pr(short cov.)	Profit $\mathsf{p} - p^m$
$V = 1$	$1 - q_b$	$p_{0,0}$	1	0	0
$V = 0$	q_b	$p_{0,0}$	1	1	$\kappa p_{0,0}$

Table 1: **Summary of State-Profits.** The table summarizes the probabilities of signals given values, the separating prices that are charged in each case, the probabilities of a successful IPO and, given that, the probability of short covering, and its profitability. κ is defined as $(1-\beta)r/\beta(1+r)$.

conditions the bank would prefer a setting with short covering. Payoffs are then averaged over signal-types because ex-ante, the signal is unknown. This is the weaker case. We focus on the extreme scenarios, that is (a) on the costs with the largest price drops after regime shifts and (b) on costs for which ex-ante payoff *with* short covering is lowest.

To derive the results, we construct the payoff differences from both settings at a given threshold cost and then substitute in closed form approximations of the threshold prices. Details of the formulae can be derived straightforwardly from Table 1. Appendix C outlines how the risky threshold prices can be approximated. The resulting risky threshold prices that we find can be interpreted as

$$p_{s,\mu} = \frac{\text{expected liquidation value given the price's information content}}{\text{fraction of cases where this information can be used}} .$$

So for instance, if $\mu(\mathsf{p}) = 1$, the unconditional value of this information piece is the q_b, the quality of the bank's signal. The fraction of cases where this information can be used is the probability of a successful IPO, given $\mu(\mathsf{p}) = 1$: Here it is α_1. Thus $p_{1,1} = q_b/\alpha_1$. By the same token $p_{1,\frac{1}{2}} = .5/(3/4)$. For the statements below we computed payoff differences for $\beta = 7\%$ and $\mathsf{O} = .15\ \mathsf{S}$, which are the empirically most commonly observed parameters.[14]

[14] Chen and Ritter (2000) report that β is almost always 7 percent. Naturally, when both O is small

In summary:

Interim Payoffs for the Low-Signal Bank. Suppose that separation is maintained. Without short covering, per-share profits are $p_{0,0}$. With short covering there are additional expected aftermarket profits of $q_b \kappa p_{0,0}$, as can be seen from Table 1. Suppose now that a pooling equilibrium results. Then, by definition of the pooling equilibrium, the low-signal bank benefits. In both cases the low-signal bank is better off with short covering.

Interim Payoffs for the High-Signal Bank. If costs are lower than $\underline{C}$ or if costs are higher than $\hat{C}'$, the bank always wins: In both cases expected revenue remains constant and the bank also gets short covering profits. Suppose now that costs are in $(\underline{C}, \hat{C}')$ and that the price decrease is strongest, from from $p_{1,1}$ to $p_{1,\frac{1}{2}}$. Then for signal qualities in areas A and B in the Left Panel of Figure 2, the bank is always better off, despite the maximal price decrease; in areas C and D the bank loses. It may not be better off in all cases, but the smaller the price decrease, the smaller areas C and D become.

Ex-ante Payoffs. There are two subcases to consider: (i) The threshold costs for which the highest price decrease occurs, which is $\hat{C}$. (ii) The threshold cost for which the ex-ante payoff *with* short covering is lowest, which is $\underline{C}'$.

(i) Suppose at $\hat{C}$, prices drop from separation in $p_{1,1}$ and $p_{0,0}$ to pooling in $p_{1,\frac{1}{2}}$. At $\hat{C}$, without short covering the low type is indifferent between riskless $p_{0,0}$ and risky $p_{1,1}$. Using the risky payoffs, without short covering payoffs are $(\alpha_1 - \alpha_0)p_{1,1} - costs$. With short covering payoffs are $(\alpha_1 - \alpha_0)p_{1,\frac{1}{2}} - cost + short$ *covering profits*. So costs cancel, revenues are lower, but, as it turns out, the short-covering profits *always* overcompensate for the loss in revenue. Thus despite the maximum price decrease at $\hat{C}$, ex-ante the investment bank is always better off with short-covering.

(ii) The bank has lowest ex-ante payoffs *with* short covering at $\underline{C}'$, the costs where the low bank is indifferent between choosing risky separation price $p_{1,\frac{1}{2}} = \phi_0'(p_{0,0})$ and riskless price $p_{0,0}$. The most extreme drop in revenue happens when $\hat{C} < \underline{C}'$, so that without short covering, the bank plays a separation

and β is large, some of the statements below may change. Clearly, if these contract variables are such that there is very little to be won in the aftermarket (low O) but a lot to be lost in revenue (high β), then matters may change. However, the essence of the arguments below is that even at the most extreme price drops there is a non-trivial parameter space where the bank is always better off. Taking also parameters sets for β and O into the description of the analysis would merely complicate the exposition.

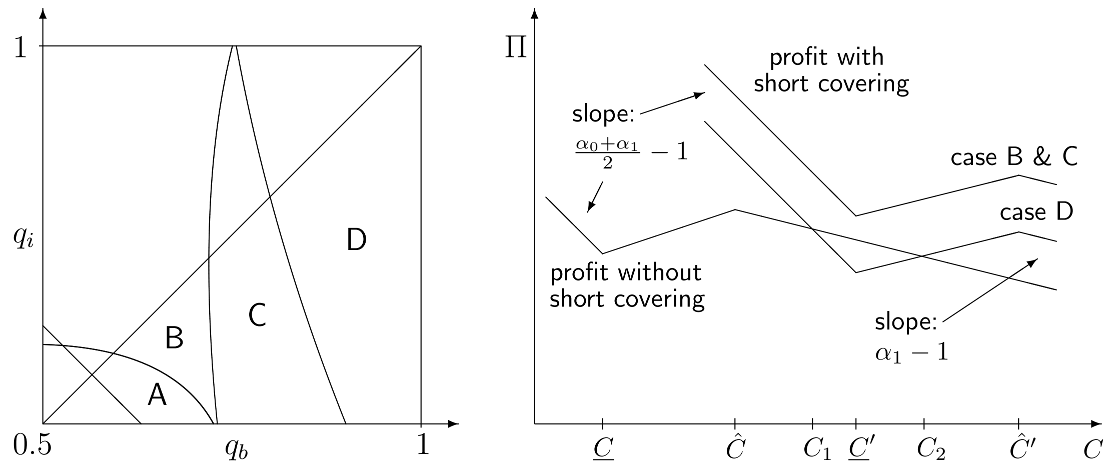

Figure 2: **Informational Efficiency and Sign of Bank's Profit Change.**
Left Panel: Areas A, B, C, and D indicate permitted values of q_i and q_b, i.e. $q_b > q_i > .5$ and $p_{1,\frac{1}{2}} > 2p_{0,0}$. For $C = \hat{C}$, A indicates where an informational efficient separating equilibrium is uphold with short covering; in B, C, and D a pooling equilibrium results. The high-signal bank is better off in A and B, and worse off in C and D at $C = \hat{C}$. Ex-ante, the bank is better off in A, B, and C, for all C; in D there exist $C_1 \in [\hat{C}, \underline{C}']$ and $C_2 \in [\underline{C}', \hat{C}']$ such that for $C \in [C_1, C_2]$ it may lose. The figure is based on simulated values for $\beta = .07$, $r = .15$, and $N = 1000$.
Right Panel: The lower line indicates *ex-ante* profits of the bank as a function of C without short covering. The higher lines indicate profits with aftermarket short covering. For the values of q_i and q_b in areas B and C these profits are always higher; in area D it may be the case that for $C \in [C_1, C_2]$ these profits are lower.

equilibrium. Note that at this cost $\underline{C}'$, without short covering the low type is *not* indifferent between a risky and a riskless price as $\phi_0(p_{0,0}) > p_{1,1}$. Payoffs without short covering are of the order $\alpha_1 p_{1,1} + p_{0,0} - costs$, with short covering they are $\alpha_1 p_{1,\frac{1}{2}} + p_{0,0} - costs + short\ covering\ profits$. The investment bank is better off for parameters q_b, q_i in areas A, B, and C, but not D (Left Panel, Figure 2). With respect to signal qualities, this area appears to be large. However, taking (i) into account, this is only relevant for a strict subinterval of $[\hat{C}, \hat{C}']$ and if also $\underline{C}' > \hat{C}$. For all other costs, the bank is ex-ante always better off. The Right Panel of Figure 2 illustrates this point.

To summarize, in most cases the investment bank is ex-ante and interim better off.

4.2 Payoff Comparison for Issuer and Investors

Given our model specification we can only compare the *revenue* that the issuer receives in settings with and without short covering.[15] Suppose with short covering, separation is maintained. If the separation price decreases, $\bar{\mathsf{p}}' < \bar{\mathsf{p}}$, the issuer loses. Suppose now, there is a switch from separation to pooling. The high separation price decreases from $\bar{\mathsf{p}}$ to $p_{1,\frac{1}{2}}$, but at the same time the low separation price rises from $p_{0,0}$ to $p_{1,\frac{1}{2}}$. Comparison of expected payoffs shows that in this case the issuer is better off for *all* parameter values.[16] Investors' profits are directly opposed to the issuer's profit. Whenever the issuer gains (in expectation) investors lose and vice versa.

Even though this section is merely concerned with redistribution, it yields an interesting insight. The investment bank is nearly always better off with aftermarket short covering, in many cases irrespective of its signal. The issuer never gains but often loses if separation is upheld, but always wins if separation morphs into pooling; the effect on investors' payoffs is the opposite.

5 Conclusion

Investment banks legally pursue supposedly price stabilizing activities in the post-offer market. In this paper we analyze how these aftermarket activities influence the setting of the offer price in the first place. We take a different perspective from existing theoretical work as we build the model around the stylized fact that investment banks *can* realize risk-free profits through aftermarket short covering. The current model cannot assess why some investment banks expose themselves to risk and establish 'naked shorts', or why they do not exercise the overallotment option in full even when prices rise above the offer price. This paper only explains the strategic impact of the *possibility* of risk-free profits. The investment bank's behavior must not be perceived as rogue or fraud, but as a rational response to a change in the environment. Investors anticipate the bank's behavior and react rationally to it.

We propose a stylized model of an offering procedure that is in accordance with empirical findings and perceived industry practice. We assume that both the investment bank and investors hold private information about the intrinsic value of the offered security.

[15] This is equivalent to expected profits: Profit here would be defined as the difference between revenue per share and the true value, which, by the LLN, is identical to the aftermarket price. We do not take other factors such as, for example, costs for alternative financing (if the IPO fails) into account.

[16] Recall that we restrict the analysis to per-share profits. Taking into account that the number of securities eventually sold to the market will be lower with short covering it can be the case that whenever, simultaneously, q_i is very small and q_b is very large the issuer is worse off even with pooling.

Prices are set so that rational-expectation investors only order the security if they expect to make a profit, taking into account the behavior of the investment bank. The market price after the offering will adjust according to investors' signals. As these are conditionally i.i.d., the price almost surely reflects the fundamental value of the security. The bank cannot stabilize 'against' this fully efficient price, but, of course, if the price is efficient, it need not and must not be 'stabilized'. So in the best of worlds, one with full transparency, the bank can make an extra profit through short covering. In the real world the IPO process is opaque; neither investors nor regulators nor researchers know precisely the banks' strategies. It is certainly reasonable to assume that in such an 'imperfect world' the strategic impact of the second source of profits is rather more than less important.

There is little empirical support that stabilization is possible and has desirable, positive effects. Indeed it is somewhat surprising that regulators allow price-manipulations. It is sometimes argued that investment banks will not always stabilize to avoid a moral hazard problem with investors who believe being fully protected against over-pricing. It is likely that this reduces the effect of potential aftermarket profits as described in this paper. The result itself, however, obviously still holds — there are still hardly any costs involved. In fact, from the regulators perspective price distortions can easily be ruled out if the bank is prohibited from filling the short position at prices below $1-\beta$ times the offer price. As long as the banks can keep the existence of a short position secret from investors, a moral hazard problem would not occur.

In our setting, the security may turn out to be overpriced. Investors, however, have already taken this into account. Investment banks always set the highest feasible price and thus acts in the issuer's interest. It is important to notice that in our setting the investment bank does not temper prices to rob issuers. The informational asymmetry in the paper arises at a point in time when all official, mandatory information has been released and any other public statement by investment bank or issuer will be perceived as cheap talk. Only actions, that is prices, can carry a meaningful message.

The offering procedure was modelled as a signaling game. The investment bank moves first and strategically chooses the offer price to maximize its profits from both the gross spread of the offer revenue and profits from short covering in the aftermarket. We establish a benchmark by analyzing the situation without aftermarket activities, and identify the conditions under which the equilibrium is both unique and separating. A separating equilibrium is referred to as informationally efficient since the investment bank's information is fully revealed by the offer price. We further show that, on average, securities are underpriced in the separation equilibrium. With the introduction of aftermarket short covering payoff functions and, consequently, the strategic environment change. As a result, either the offer price falls on average, or a pooling equilibrium results. In the first case, an investment bank with favorable information distorts the price downwards and thereby, on average, exacerbates underpricing. In the second case investors are unable to infer the investment bank's signal from the offer price. This equilibrium is informationally inefficient since investors' decisions are based on private signals only and not also on the signal of the investment bank.

The intuition behind the results can be best explained by relating this paper to job-market signaling with two types of workers. In the so-called Riley-outcome, the low type chooses education level zero, and the high type chooses his education just high enough so that it does not pay for the low type to deviate to his level of education. In our paper this corresponds to a low-signal bank choosing a low, risk-free price. At this price all investors want to buy the security and consequently the offering will never fail. Nevertheless, in the aftermarket any offering can turn out to be overpriced. The high-signal bank chooses a high, risky price just low enough so that the risky price does not pay for the low-signal bank. A price is risky when it is so high that only high-signal investors buy; in this case the offering will fail if there are not enough investors with the favorable signal. When introducing profits from short covering, the effect is that of a personal extra benefit from education. Suppose this perk is higher for the low type of worker than for the high type worker. As a result, the high type has to choose a higher level of education to maintain separation. In our model, the low-signal bank considers a price drop in the aftermarket more likely, thus the potential profits from short covering are higher than for the high signal bank. And so the high-signal bank has to distort prices downwards in order to maintain separation. At first sight this is a surprising result, as casual intuition suggests that potential aftermarket profits should result in more *over*-pricing. There may also come a point where it does not pay for the high signal bank to maintain separation, and so it settles for pooling. The result is informational inefficiency.

The investment bank enjoys higher payoffs with short covering for the vast majority of parameter constellations. Looking at per-share profits, the issuer never gains but often loses if separation prevails; but if there is a switch to a pooling equilibrium he is always better off. Investors' payoffs are directly opposed to the issuer's gains or losses. An increase in the investment bank's share of the revenue or an increase in the amount of overalloted securities reduces the parameter-set with informational efficiency.

Our analysis is in accordance with recent empirical analyzes but contrasts the existing theoretical literature which argues that stabilizing activities in the aftermarket serve efficiency. We therefore challenge financial market authorities' view that current regulations simultaneously serve the interests of issuers, investors, and investment banks.

A Aftermarket Price Formation

The finally prevailing market price depends on the number of positive signals about the value of the security. In determining the price we have to distinguish between cases B_1 and $B_{0,1}$.

Consider first case B_1. Since only high-signal investors buy, aggregated demand d indicates the number of high-signal investors. Suppose $d \geq \mathsf{S}$, i.e. the IPO is successful. Investors are assumed to take the aggregated information about signals into account and update their expectations accordingly. At this updated expectation all investors irrespective of their private signals are indifferent between selling and holding or buying and abstaining, depending on whether they own a security or not, respectively. The updated expectation thus becomes the aftermarket price, denoted by $\mathsf{p}^m(d)$. We will later show that case B_1 will occur at the high price of a separating equilibrium only, i.e. investors know that the bank's signal is $s_b = 1$. Taking further into account that the true value of the security is either 0 or 1, we can write $\mathsf{p}^m(d|\mu = 1) = \mathsf{Pr}(V = 1|d, \mu = 1)$. Using Bayes' rule, we can express the aftermarket price as

$$\mathsf{p}^m(d|\mu = 1) = \frac{\mathsf{Pr}(d|V = 1)\mathsf{Pr}(s_b = 1|V = 1)}{\mathsf{Pr}(d|V = 1)\mathsf{Pr}(s_b = 1|V = 1) + \mathsf{Pr}(d|V = 0)\mathsf{Pr}(s_b = 1|V = 0)}. \tag{14}$$

Due to the binomial structure of the prior distributions over signals, the conditional distribution for demand realization d is, for $V = 1$,

$$f(d|V = 1) := \mathsf{Pr}(d|V = 1) = \binom{N}{d} q_i^d (1 - q_i)^{N-d}, \tag{15}$$

and for $V = 0$ analogously. The price-information about s_b is unambiguous in a separating equilibrium. We can therefore replace it with the conditional probability of the bank's signal being correct, which is q_b or $1 - q_b$. Bayes' rule yields

$$\mathsf{p}^m(d|\mu = 1) = \frac{q_b q_i^{2d-N}}{q_b q_i^{2d-N} + (1 - q_b)(1 - q_i)^{2d-N}}. \tag{16}$$

Consider now case $B_{0,1}$ in which all investors order the security, i.e. stated demand is N and securities are allocated at random. The demand is uninformative since it does not reveal the number of high-signal investors. Suppose that we are at the low price of a separating equilibrium. Note that high-signal investors expect the security to be of higher value than low-signal investors. Hence, there exists a price larger than the offer price, $\tilde{\mathsf{p}} > \mathsf{p}^*$ at which high-signal investors who were not allocated a security would be willing to buy the security, and low-signal investors would be willing to sell, in case they were allocated a security. Without modelling the price-finding procedure explicitly we assume that the following intermediate process takes place. Those high-signal investors who did not receive the security in the offering submit a unit market-buy-order. Those low-signal investors who obtained the security in the offering submit a unit market-sell-order. All other investors abstain. The number of investors who want to buy or to sell is denoted by $\tilde{d}$ and $\tilde{S}$, respectively. Aggregate demand of high-signal investors is then $d = \tilde{d} + \mathsf{S} - \tilde{S}$ and the market price p^m can be determined as before. The same procedure can be applied to determine the first period market clearing price in the case of a pooling equilibrium. The conditional expectation which determines the price, however, will then not contain the component about the signal of the investment bank.

B Threshold Prices

Denote by $p_{s_i,\mu}$ the maximum price at which an investor with signal s_i and price information μ buys, given all investors with $\tilde{s}_i \geq s_i$ buy. At this price the investor's expected return from buying the security is zero, normalizing outside investment opportunities accordingly.

Define $\psi(1|1,1) := \mathsf{Pr}(V = 1|s_i = 1, \mu = 1)$ and $\psi(0|1,1) := \mathsf{Pr}(V = 0|s_i = 1, \mu = 1)$. Consider now the structure of the conditional distribution $f(d-1|V)$. For $V = 1$, this is a binomial distribution over $\{0, \dots, N-1\}$ with center $(N-1)q_i$, and likewise for $V = 0$ with center $(N-1)(1-q_i)$. Since by Assumption 2, N is 'large enough' for every q_i, $f(d-1|1) = 0$ for $d < N/2$ and $f(d|0) = 0$ for $d > N/2$. When combining both $f(d-1|1)$ and $f(d-1|0)$, we obtain a bi-modal function. In $g(\cdot|s_i,\mu)$, investors' posterior distribution over demands, these are weighted with $\psi(1|s_i,\mu)$ and $\psi(0|s_i,\mu)$. Assumption 2 now satisfies two purposes. The first is to ensure that we pick N large enough, so that the two modes do not overlap. The second can be seen from the following lemma.

Lemma 3 *For any $q_i > \frac{1}{2}$, there exists a number of investors $N(q_i)$, such that $\mathsf{p}^m(d) \cdot g(d-1|s_i,\mu) \in \{0, g(d-1|s_i,\mu)\}$ almost everywhere.*

The lemma states that market prices are mostly 0 or 1, if they are not, then the weight of this demand is negligible. To see this consider the following heuristic argument.

Proof: $\mathsf{p}^m(d)$ is a s-shaped function in d, given by equation (16). For large N, $\mathsf{p}^m(d) \in \{0,1\}$ almost everywhere. Define $\mathbb{I}^*$ as the interval of d around $N/2$ s.t. for $d \in \mathbb{I}^*$ we have $\mathsf{p}^m(d) \notin \{0,1\}$. $\mathsf{p}^m(d)$ is multiplied with density $g(d-1|s_i,\mu)$, which peaks at $(N-1)(1-q_i)$ and $(N-1)q_i$. For N increasing $\mathbb{I}^*/N \to 0$ and the bi-modal distribution becomes more centered around $(N-1)(1-q_i)$ and $(N-1)q_i$. Hence, for every q_i there is an $(N-1)(q_i)$ such that for $d \in \mathbb{I}^*$, $g(d|s_i,\mu)\cdot \mathsf{p}^m(d) = 0$, i.e. the weight on $\mathsf{p}^m(d) \notin \{0,1\}$ can be made arbitrarily small. □

Using Lemma 3 we can determine the threshold prices as follows. Consider first $p_{1,1}$.

$$
\begin{aligned}
0 &= (1-p_{1,1}) \sum_{d=N/2}^{N-1} \frac{\mathsf{S}}{d+1}\, g(d-1|1,1) - p_{1,1} \sum_{d=\mathsf{S}-1}^{N/2} \frac{\mathsf{S}}{d+1}\, g(d-1|1,1) \\
\Leftrightarrow p_{1,1} &= \frac{\sum_{d=N/2}^{N-1} \frac{\mathsf{S}}{d+1}\, g(d-1|1,1)}{\sum_{d=\mathsf{S}-1}^{N-1} \frac{\mathsf{S}}{d+1}\, g(d-1|1,1)}. \qquad (17)
\end{aligned}
$$

For $d > N/2$, $g(d-1|s_i,\mu) = \psi(1|s_i,\mu)f(d-1|1)$ and for $d < N/2$, $g(d-1|s_i,\mu) = \psi(0|s_i,\mu)f(d-1|0)$. Also define

$$
\Sigma_0 := \sum_{d=\mathsf{S}-1}^{N/2} \frac{f(d-1|0)}{d+1} \quad \text{and likewise} \quad \Sigma_1 := \sum_{d=N/2}^{N-1} \frac{f(d-1|1)}{d+1}, \quad \text{and} \quad \sigma := \Sigma_0/\Sigma_1.
$$

Also write $\ell(\mu) := \psi(0|1,\mu)/\psi(1|1,\mu)$. Thus for the combination of signal s_i and price-information μ with B_1 we can write

$$
p_{1,1} = (1+\sigma\ell(1))^{-1} \quad \text{and likewise} \quad p_{1,\frac{1}{2}} = (1+\sigma\ell(\tfrac{1}{2}))^{-1}. \qquad (18)
$$

Consider now the case for $p_{0,0}$. At this price all agents receive the security with equal probability and we sum from 0 to $N-1$. Thus

$$
0 = (1-p_{0,0}) \sum_{d=N/2}^{N-1} \frac{\mathsf{S}}{N}\, g(d-1|0,0) - p_{0,0} \sum_{d=0}^{N/2} \frac{\mathsf{S}}{N}\, g(d-1|0,0) \Leftrightarrow p_{0,0} = \psi(1|0,0). \qquad (19)
$$

Likewise we have

$$
p_{0,\frac{1}{2}} = \psi(1|0,\tfrac{1}{2}). \qquad (20)
$$

C Approximate Closed Form Solutions

We will now derive *approximate* closed form solutions so that we can solve our model analytically. In this appendix we let d denotes the number of *other* investors with favourable information — this contrasts the exposition of the main text, but it simplifies the notation here. First consider the strategy of agent number N. There are $N-1$ other investors. Given that he invests and the true value is, say, $V=1$, then by the law of large numbers, demand/the number of favorable signals will always be larger than $N/2$. Furthermore, the market price is almost surely $p^m(d) = 1$. If d others order, then when buying he gets the asset with probability $1/(d+1)$. Thus his payoff for price p

$$(1-\mathsf{p}) \sum_{d=(1-q_i)N-1}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d} = (1-\mathsf{p}) \sum_{d=N/2}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d}. \quad (21)$$

To compute the sum we proceed in a similar manner as one would to compute the expected value of a binomial distribution: First observe that because N is large,

$$\sum_{d=N/2}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d} = \sum_{d=0}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d} \quad (22)$$

Then we can compute

$$\begin{aligned} &\sum_{d=0}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d} = \frac{1}{q_i N} \sum_{d=0}^{N-1} \frac{N!}{(N-d)!(d+1)!} {q_i}^{d+1} (1-q_i)^{N-1-d} \\ = \; & \frac{1}{q_i N} \left(\sum_{l=0}^{N} \binom{N}{l} {q_i}^l (1-q_i)^{N-l} - \binom{N}{0} {q_i}^0 (1-q_i)^{N-0} \right) \\ = \; & \frac{1}{q_i N} (1-(1-q_i)^N). \end{aligned} \quad (23)$$

In the second step we made a change of variable, $l = d+1$, but through this change, we had to subtract the element of the sum for $l = 0$. Consequently, for large N, we can say that

$$\sum_{d=N/2}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^d (1-q_i)^{N-1-d} \approx \frac{1}{q_i N}. \quad (24)$$

Using the same arguments, we could also show that

$$\sum_{d=0}^{N-1} \frac{1}{d+1}\binom{N-1}{d} {q_i}^{N-1-d} (1-q_i)^{d} \approx \frac{1}{(1-q_i) N}. \quad (25)$$

Use now familiar notation to denote the combination of private and public beliefs $\phi_{s,\mu}$. Recall that we can write $p_{1,1}$ as

$$p_{1,1} = \frac{1}{1 + \ell(1)\, \frac{\Sigma_0}{\Sigma_1}}. \quad (26)$$

What we now need to find is a closed form for

$$\Sigma_0 = \sum_{d=N(1-q_i)-1}^{N/2} \frac{1}{d+1}\binom{N-1}{d} {q_i}^{N-1-d}(1-q_i)^d. \tag{27}$$

For increasing N one can see that $\frac{1}{d+1}\binom{N-1}{d}{q_i}^{N-1-d}(1-q_i)^d$ gets *numerically* symmetric around $(1-q_i)N-1$. Thus we can express

$$\begin{aligned}\Sigma_0 &= \frac{1}{2}\sum_{d=0}^{N/2}\frac{1}{d+1}\binom{N-1}{d}{q_i}^{N-1-d}(1-q_i)^d = \frac{1}{2}\sum_{d=0}^{N}\frac{1}{d+1}\binom{N-1}{d}{q_i}^{N-1-d}(1-q_i)^d \\ &\approx \frac{1}{2}\frac{1}{(1-q_i)N}. \end{aligned} \tag{28}$$

Putting it all together, we obtain

$$p_{1,1} = \frac{1}{1+\ell(1)\,\frac{\Sigma_0}{\Sigma_1}} \approx \frac{1}{1+\frac{(1-q_i)(1-q_b)}{q_i q_b}\frac{q_i N)}{2(1-q_)N)}} = \frac{2q_b}{1+q_b} \equiv \frac{q_b}{\alpha_1}. \tag{29}$$

By the same token, we get

$$p_{1,\frac{1}{2}} \approx \frac{1}{1+\frac{1-q_i}{q_i}\frac{q_i N}{2(1-q_i)N}} = \frac{2}{3}, \text{ and } p_{0,1} \approx \frac{1-q_b}{\alpha_0}. \tag{30}$$

The information content of a high pooling price is 1/2, and knowing this information, the probability of the offering being successful is 3/4. Thus the interpretation of risky prices is thus the ratio of the expected liquidation value given price-information to the share of successful offerings given this information

$$p_{1,\mu} = \frac{\mathsf{E}[\,V \mid \mu\,]}{\mathsf{Pr}(\text{IPO successful} \mid \mu)}. \tag{31}$$

D Maximal Reputation Costs

If an IPO fails, the worst that can happen is that the investment bank loses all future IPO business, i.e. it is out of the market. Assuming that future business takes place in the same environment (e.g. the quality of signals remains constant), the bank can maximally lose all discounted future profits. Assume that the bank discounts future profits at rate δ. Consider the case of highest potential costs $\bar{C}$ that can occur from a failing IPO in a separating equilibrium. An upper bound for costs is given by the discounted lost future profits if $\bar{\mathsf{p}} = p_{1,1}$. Then ex-ante profits of a single IPO are

$$\Pi(p_{0,0}, p_{1,1}, C) = \frac{1}{2}\,(\mathsf{S}+\mathsf{O})\beta\,(p_{0,0} + \frac{1+q_b}{2}p_{1,1}) - \frac{1-q_b}{4}\,C. \tag{32}$$

Assuming that an investment bank would conduct one IPO each period and accounting for the fact that in a separating equilibrium the ex-ante probability of the IPO to be successful is $(3+q_b)/4$ we get

$$C_{\max} = \sum_{t=0}^{\infty}(1-\delta)^t \cdot ((3+q_b)/4)^t \cdot \Pi(p_{0,0}, p_{1,1}, C_{\max}). \tag{33}$$

Thus maximal possible costs can be solved to be

$$C_{\max} = 2(\mathsf{S}+\mathsf{O})\beta\frac{p_{0,0} + \frac{1+q_b}{2}p_{1,1}}{\delta(3+q_b) + 2(1-q_b)}. \tag{34}$$

Comparing values of $C_{\max}$ to those of $\bar{C}$ shows that for q_i and q_b sufficiently large $\bar{C} \gg C_{\max}$. Furthermore, for reasonable values of the discount rate, the reverse relation holds true only for values of q_i and q_b where we get $\bar{C}' < \bar{C}$. That is, either $\bar{C}' < \bar{C}$ and informational inefficiencies result, or $\bar{C}$ is so large that it lies outside the relevant parameter region in the context of this model.

E Omitted Proofs

Proof of Lemma 1

Suppose $\underline{\mathsf{p}}^* > p_{0,0}$. At this price only high-signal investors buy. A high-signal bank will always set a price where at least high-signal investors buy. Hence, high-signal investors buy at both prices $\underline{\mathsf{p}}^*$ and $\bar{\mathsf{p}}^*$. A low-signal bank can now increase its payoff by setting a higher price as α_0 is not affected by this, a contradiction. □

Proof of Proposition 1

First we will argue that the only separating equilibrium surviving the IC is the one outlined in the proposition. Then we will argue that pooling cannot occur.

Step 1 (*Separating*) First observe that there cannot be a separating price $\bar{\mathsf{p}}^*$ where investors choose $B_{0,1}$ because otherwise the low-signal bank would deviate to this price. Note that no separating price with $\bar{\mathsf{p}}^* > \phi_0(p_{0,0})$ can exist because at this price, the low-signal bank would prefer to deviate. No price $\bar{\mathsf{p}}^* > p_{1,1}$ can exist since not even high-signal investors would buy. Furthermore, $\bar{\mathsf{p}}^* \geq \phi_1(p_{0,0})$ must be satisfied since otherwise the high-signal bank would prefer to deviate to $p_{0,0}$. Finally no price $\bar{\mathsf{p}}^*$ below $p_{1,0}$ is reasonable because the high-signal bank would then deviate to this price. Take $\tilde{p}$, with $\max\{\phi_1(p_{0,0}), p_{1,0}\} \leq \tilde{p} \leq \min\{p_{1,1}, \phi_0(p_{0,0})\}$. Note that such a $\tilde{p}$ always exists as long as $\phi_1(p_{0,0}) \leq p_{1,1}$ and $p_{1,0} \leq \phi_0(p_{0,0})$. The conditions stated in Proposition 1 ensure this is the case because $\phi_1(p_{0,\frac{1}{2}}) > \phi_1(p_{0,0})$ and $p_{1,\frac{1}{2}} > p_{1,0}$.

We analyze the candidate separating equilibrium

$$\{(\underline{\mathsf{p}}^* = p_{0,0}, \mu = 0, B_{0,1}); (\bar{\mathsf{p}}^* = \tilde{p}, \mu = 1, B_1);$$
$$(\mathsf{p}^* \notin \{\underline{\mathsf{p}}^*, \bar{\mathsf{p}}^*\}, \mu = 0, B_{0,1} \text{ if } \mathsf{p} \leq p_{0,0}, B_1 \text{ if } p_{0,0} < \mathsf{p} \leq p_{1,0}, B_\emptyset \text{ else})\}.$$

By definition of $\phi_0(p_{0,0})$ it holds that

$$\beta p_{0,0}\mathsf{S} = \alpha_0\beta\phi_0(p_{0,0})\mathsf{S} - (1-\alpha_0)C > \alpha_0\beta\tilde{p}\mathsf{S} - (1-\alpha_0)C$$

so that the low-signal bank would not deviate to $\tilde{p}$. Since $\max\{\phi_1(p_{0,0}), p_{1,0}\} \leq \tilde{p}$, the high-signal bank would also not deviate. Hence this is a PBE.

Now consider the application of the IC. Suppose a high separation price $\bar{\mathsf{p}} = \tilde{\tilde{p}}$ with $\tilde{p} < \tilde{\tilde{p}} \leq \min\{p_{1,1}, \phi_0(p_{0,0})\}$ is observed. This price is equilibrium dominated for a bank with $s_b = 0$ by definition of $\phi_0(p_{0,0})$. The low-signal bank can therefore be excluded the set of potential deviators. The only remaining agent is the high-signal bank. The best response of high-signal investors then is to buy at $\bar{\mathsf{p}} = \tilde{\tilde{p}}$, i.e. B_1. Hence the PBE with $\bar{\mathsf{p}}^* = \tilde{p}$ does not survive the IC. Applying this reasoning repeatedly, all separating prices with $\bar{\mathsf{p}} < \min\{p_{1,1}, \phi_0(p_{0,0})\}$ can be eliminated.

Step 2a (*Pooling with $B_{0,1}$*) For all investors to buy we must have $\mathsf{p} \leq p_{0,\frac{1}{2}}$. Suppose there was deviation to $\mathsf{p} = \phi_1(p_{0,\frac{1}{2}}) < \phi_0(p_{0,\frac{1}{2}})$. For the low-signal bank this would not be profitable by definition of $\phi_0(p_{0,\frac{1}{2}})$. But for some beliefs about the signal of the bank and corresponding best responses, high-signal investors could be better off. The best response for investors with beliefs on the remaining set of types, i.e. $\mu = 1$, however, is B_1 as we have $\phi_1(p_{0,\frac{1}{2}}) < p_{1,1}$. Hence, applying IC there cannot be a pooling equilibrium with $B_{0,1}$.

Step 2b (*Pooling with B_1*) We must have $\mathsf{p} \leq p_{1,\frac{1}{2}}$. Since $\phi_0(p_{0,0}) > p_{1,\frac{1}{2}}$, the low-signal bank would prefer to deviate to $p_{0,0}$, hence this cannot be an equilibrium.

To summarize, restrictions $\phi_1(p_{0,\frac{1}{2}}) < p_{1,1}$ and $\phi_0(p_{0,0}) > p_{1,\frac{1}{2}}$ ensure that the only equilibrium surviving the IC is the one depicted in Proposition 1. □

Proof of Proposition 2

Consider the highest possible separating offer prices. The market price will by the Law of Large Numbers resemble the true value of the security. Assumptions 1 and 2 imply that the IPO fails with probability 0.5 if the true value is $V = 0$ and the high separation price is set. If the true value is $V = 1$ the IPO never fails. Thus, ex-ante there is underpricing if $\frac{1}{2}(1 - p_{0,0} - \alpha_1 p_{1,1}) > 0$. Substituting in closed form solutions for threshold prices $p_{1,1}$ and $p_{1,\frac{1}{2}}$ from Appendix C this can be written as

$$\frac{(1-q_b)(1-q_i)}{q_b q_i + (1-q_b)(1-q_i)} + q_b \leq 1 \tag{35}$$

Recall that $\alpha_1 = \frac{1+q_b}{2}$. Numerically, it is straightforward to check that the inequality holds for all $q_b, q_i \in (.5, 1)$. □

Proof of Lemma 2

We will analyze two cases. Firstly we will show that at $C = \hat{C}$, $\bar{\mathsf{p}}^* = p_{1,1} = \phi_0(p_{0,0})$ can no longer be a sustained as a separating equilibrium if short covering is possible. Secondly we will show that at $C = \underline{C}$, $\bar{\mathsf{p}}^* = p_{1,\frac{1}{2}} = \phi_0(p_{0,0})$ cannot be sustained as the separating equilibrium.

We will regard situations in which with respect to the offering price the low-signal bank is indifferent between charging $p_{0,0}$ with all investors buying, $B_{0,1}$, and $\bar{\mathsf{p}}^*$ where only high-signal investors buy, B_1. If the payoffs from short covering are higher in the case of deviating to price $\bar{\mathsf{p}}^*$, then this price can no longer be sustained as a separating price and then, naturally, $\phi_0'(p_{0,0}) < \phi_0(p_{0,0})$. To get this we need to show $\Pi^2(\bar{\mathsf{p}}^*|B_1, s_b = 0) > \Pi^2(\underline{\mathsf{p}}^*|B_{0,1}, s_b = 0)$. Defining $\Delta(\mathsf{p})$ s.t. $\forall \quad d \leq \Delta(\mathsf{p})$ the aftermarket price is not above $(1-\beta)\mathsf{p}$ this is equivalent to

$$\sum_{d=\mathsf{s}+\mathsf{o}}^{\Delta(\bar{p}^*)} \mathsf{O} \cdot \{(1-\beta)\bar{\mathsf{p}}^* - \mathsf{p}^m(d)\} \cdot \mathsf{Pr}(d|s_b = 0) \quad > \quad \sum_{d=0}^{\Delta(\underline{p}^*)} \mathsf{O} \cdot \{(1-\beta)\underline{\mathsf{p}}^* - \mathsf{p}^m(d)\} \cdot \mathsf{Pr}(d|s_b = 0)$$

$$\Leftrightarrow \left.\begin{matrix} (1-\beta)\bar{\mathsf{p}}^* \sum_{d=\mathsf{s}+\mathsf{o}}^{\Delta(\bar{p}^*)} \mathsf{Pr}(d|s_b=0) \\ - \sum_{d=\mathsf{s}+\mathsf{o}}^{\Delta(\bar{p}^*)} \mathsf{p}^m(d) \cdot \mathsf{Pr}(d|s_b=0) \end{matrix}\right\} > \left\{\begin{matrix} (1-\beta)\underline{\mathsf{p}}^* \sum_{d=0}^{\Delta(\underline{p}^*)} \mathsf{Pr}(d|s_b=0) \\ - \sum_{d=0}^{\Delta(\underline{p}^*)} \mathsf{p}^m(d) \cdot \mathsf{Pr}(d|s_b=0) \end{matrix}\right.$$

$$\tilde{\Leftrightarrow} \ (1-\beta)\bar{\mathsf{p}}^* \frac{q_b}{2} \quad > \quad (1-\beta)p_{0,0}q_b. \tag{36}$$

The last step follows from Lemma 3 in Appendix B. We can now check what happens at the threshold points. Suppose that $C = \underline{C}$ so that $\bar{\mathsf{p}}^* = p_{1,\frac{1}{2}}$. Then (36) translates to $p_{1,\frac{1}{2}}/2 > p_{0,0}$ which is ensured by Assumption 4. Recall that numerically this assumption requires that not both q_i and q_b are small. Suppose that $C = \hat{C}$ so that $\bar{\mathsf{p}}^* = p_{1,1}$. Then we need that $p_{1,1}/2 > p_{0,0}$. Informativeness of s_b implies $p_{1,1} > p_{1,\frac{1}{2}}$. □

Proof of Proposition 3

The second step of the proof of Lemma 2 ensures that $\underline{C}' \geq \underline{C}$. The model is set-up so that all payoffs $\Pi^1 + \Pi^2$ can be dealt with as one. Hence the aforementioned procedure can be applied here as well. The proof of the pooling outcome goes exactly along the lines of the proof of Proposition 1. Take a separating equilibrium in which both agents make less profit than in the pooling equilibrium. Pareto Efficieny rules this equilibrium out. The existence of $\hat{C}' > \hat{C}$ is again ensured by Lemma 2. By definition, for $C > \hat{C}'$, the highest attainable price is $p_{1,1}$, and it is the only one selected by the IC. □

Proof of Proposition 4

From Proposition 3 we know that a pooling equilibrium results for all $C < \underline{C}'$. $\underline{C}'$ is defined as the value of C for which equation (11) is fulfilled with $\phi_0'(p_{0,0}) = p_{1,\frac{1}{2}}$. Solving for $\underline{C}'$ one obtains

$$\underline{C}' \propto \beta(\mathsf{S}+\mathsf{O})\left(\frac{2-q_b}{2}p_{1,\frac{1}{2}} - p_{0,0}\right) + (1-\beta)\mathsf{O}q_b\left(\frac{p_{1,\frac{1}{2}}}{2} - p_{0,0}\right). \tag{37}$$

Partially differentiating w.r.t. O we obtain

$$\frac{\partial \underline{C}'}{\partial \mathsf{O}} = \beta\left(\frac{2-q_b}{2}p_{1,\frac{1}{2}} - p_{0,0}\right) + (1-\beta)q_b\left(\frac{p_{1,\frac{1}{2}}}{2} - p_{0,0}\right). \tag{38}$$

Both terms in brackets are positive by Assumption 4 as long as $q_b < 1$. Partial differentiation w.r.t. β yields

$$\begin{aligned}\frac{\partial \underline{C}'}{\partial \mathsf{O}} &= (\mathsf{S}+\mathsf{O})\left(\frac{2-q_b}{2}p_{1,\frac{1}{2}} - p_{0,0}\right) - q_b\left(\frac{p_{1,\frac{1}{2}}}{2} - p_{0,0}\right)\\ &\propto \left[\frac{p_{1,\frac{1}{2}}}{2}\left(2 - q_b - \frac{r}{1+r}q_b\right) - p_{0,0}\left(1 - \frac{r}{1+r}q_b\right)\right]. \end{aligned} \tag{39}$$

Since $2 - q_b - \frac{r}{1+r}q_b > 1 - \frac{r}{1+r}q_b$ whenever $q_b < 1$, Assumption 4 ensures that the term is positive. □

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