Aftermarket Short Covering and the Pricing of IPOs

Björn Bartling and Andreas Park*

This version: January 2002

Investment banks legally pursue supposedly price stabilizing activities in the aftermarket of IPOs. We model the offering procedure as a signalling game and analyze how the possibility of potentially profitable trading in the aftermarket influences the investment bank's pricing decision. Banks maximize the sum of both the gross spread of the offer revenue and profits from aftermarket trading. They therefore have an incentive to distort the offer price by strategically using aftermarket short covering and exercise of the overallotment option. This results either in informational inefficiencies or exacerbated underpricing, and a redistribution of wealth mainly in favor of investment banks. Our analysis contrasts the existing theoretical literature which argues that aftermarket activities serve efficiency by assuming them to be costly, a claim which only recently has been rejected by empirical analyses.

JEL Classification: G14, G24, G28.
Keywords: Initial Public Offering, Mispricing, Regulation, Signalling.

* Department of Economics, University of Munich, Ludwigstraße 28, 80539 Munich, Germany, and Churchill College, University of Cambridge, Cambridge, CB3 0DS, U.K., respectively. We are grateful to Parimal Bag, Partha Dasgupta, Chiaki Hara, Oliver Hart, Katya Malinova, James Mirrlees, Hamid Sabourian, and Klaus Schmidt for helpful comments. We would also like to thank participants in seminars at the Universities of Cambridge and Munich, the ESEM 2001, the EEA Conference 2001, and the EDGE Jamboree 2001. The first author would like to thank the Faculty of Economics and Politics, University of Cambridge, and Wolfson College Cambridge for their hospitality during this research was carried out. Financial support from the European Commission's Marie Curie Fellowship Programme within the European Doctoral Group in Economics (EDGE), grant no. HPMT-CT-2000-00056, and from the Swiss National Bank is gratefully acknowledged. The second author gratefully acknowledges financial support from the Economic and Social Research Council (ESCR), grant no. R00429934339, from the Royal Economic Society, and from the Montague Burton Trust Fund.

1. INTRODUCTION

The mispricing of initial public offerings (IPOs) is a well documented but still puzzling phenomenon. On average, shareholders enjoy a substantial first-day return but suffer from underperformance in the long-run.[1] Theoretical explanations why issuers or investment banks rationally offer shares to investors at a price substantially below the immediate market valuation are manifold.[2] Comparatively little research has been done to explain long-run underperformance.[3] Most of the literature however, ignored that aftermarket trading activities by investment banks can affect the choice of the offer price.

Post-offer price stabilisation is legal practice in the U.S. since the Securities Act of 1934. In their latest release from 1997 on price stabilisation in the aftermarket the U.S. Securities and Exchange Commission (SEC) states: "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."[4] On the other hand, Hanley, Kumar and Seguin (1993), p. 194, find it " . . . most surprising that this systematic and deliberate manipulation is completely legal under current securities law."

In this paper, we question the claim that current regulation serves the interests of shareholders, investment banks, and issuers.[5] We propose a

[1]Ibbotson, Sindelar and Ritter (1994), for example, report an average first-day return of 15.3 percent for 10,625 IPOs in the U.S. between 1960 and 1992. Ritter (1991), on the other hand, shows the three-year returns of 1,526 IPOs between 1975 and 1984 to be 27.4 percent lower than those of a matching sample of seasoned firms.

[2]See, for example, Baron (1982), Rock (1986), Beatty and Ritter (1986), Booth and Smith (1986), Tiniç (1988), Benveniste and Spindt (1989), Allen and Faulhaber (1989), Grinblatt and Hwang (1989), Welch (1989), Welch (1992), Booth and Chua (1996), and Brennan and Franks (1997).

[3]For a recent contribution see Teoh, Welch and Wong (1998).

[4]SEC (1997), Regulation M, Release No. 34-38067, p. 81. The Forum of European Securities Commission (FESCO) also just proposed new regulations on stabilisation of securities in public offerings which resemble the SEC regulations. FESCO (2001).

[5]We use the more general term investment bank instead of underwriter since, in the set-up of the model, we abstract from the institutional differences between underwritten and best effort offerings. We however argue that our analysis applies to both firm commitment and best effort contracts. For a detailed discussion see Section 2, especially footnotes 14 and 15.

simple model of the offering procedure in which trading activities in the aftermarket serve as a second profit source for investment banks besides the gross spread revenue.[6] When maximising the sum of both investment banks have an incentive to distort the offer price in the first place. We show that informational inefficiencies or exacerbated underpricing, and redistribution of wealth mainly in favour of investment banks result.

Current regulation allows investment banks to pursue the following three types of aftermarket activities:

1. *Stabilising bids* can be posted at or below the offer price during the distribution period of the shares. Those bids have to be clearly labeled as stabilising bids of the investment bank.

2. Investment banks establish a short position prior to the offering by selling shares in excess of the announced number of shares. *Aftermarket short covering* refers to the practice of filling these short positions in the aftermarket which is done if the price falls below the offer price. If the price rises above offer price the investment bank is hedged by an overallotment option which allows it to obtain up to 15 percent additional shares form the issuer at the offer price. There are no disclosure requirements concerning short covering trades.

3. *Penalty bids* are a means to penalise syndicate members whose customers immediately resell their shares to the aftermarket, so-called "flippers", by taking away their selling concession.

Only recently, new data made it possible to look directly at investment banks' activities in the aftermarket.[7] Aggarwal (2000) reports that underwriters stabilise prices using a combination of aftermarket short covering, penalty bids, and exercise of the overallotment option. Stabilising bids are never observed. Aggarwal further shows that stabilising activities have a permanent impact on prices and that it is not an expensive activity for underwriters to pursue. Ellis, Michaely and O'Hara (2000) report that

[6]Our model, however, makes the idealistic assumption that post-offer market prices immediately reflect all available information and thus trading activities cannot influence the price as only new information can move prices. Regulators, in contrast, may have a different behavioral model of stock prices in minds. We highlight detrimental distortions of aftermarket activities by investment banks, but do not intend to model stabilisation. Thus we abstract from potential beneficial impacts that it may have.

[7]Earlier studies are Hanley et al. (1993), Ruud (1993), and Schultz and Zaman (1994).

the lead underwriter always becomes the dominant market maker. The resulting profits from trading account for about 23 percent of the overall profit of the underwriter in an offering.[8] They further find that large inventory stocks are taken but the inventory risk is reduced by exercise of the overallotment option.

Although on average IPOs have high first-day returns, there is a significant number of IPOs with negative returns. The idea behind stabilising activities then is that in the initial stages after the float investment banks ensure sufficient liquidity for the security. If, for instance, there is selling pressure, the investment banks is supposed to provide liquidity as to prevent sharp drops in prices. Additionally, penalty bits are meant to reduce selling pressure. Essentially, an investment bank that intends to support the asset's price will enter the post-offering market short. If the price increases it becomes very expensive to cover a short position in the market. Therefore, the IPO-contract typically includes a so-called overallotment option (also referred to as the 'Greenshoe') warranted by the issuer, which is a call option at the offer price for, typically, up to 15% of floated shares. This option can indeed insure the investment banks's short position against increasing prices. And in the bulk of cases the investment bank does not establish a short position in excess of the overallotment option. Suppose, on the other hand, that the price drops. Then the investment bank will not exercise the option but cover its 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 for investment banks. In other words, conducting price stabilisation in the aftermarket introduces a second, risk-free profit source for investment banks besides the gross spread revenue.

In this paper, we propose a stylised model of an offering procedure that is in accordance with these empirical findings. It is meant to be illustrative of the distorting effects of aftermarket trading activities on the offer price rather than being descriptive in its institutional details. We assume that investment banks and investors have a private but noisy signal about

[8]Reported profits stem from market making and stabilising activities taken together. It cannot be disentangled whether stabilisation contibuted to or reduced trading profits. The claim that stabilisation is a potentially profitable activity is therefore not rejected by the data.

the intrinsic value of the offered security. In a signalling game setting the investment bank moves first and strategically chooses the offer price in order to maximise its profit form both receiving the gross spread of the offer revenue and trading profits in the aftermarket. In a setting without aftermarket trading activities by investment banks we identify the conditions under which the equilibrium is both unique and separating. That is, we identify the conditions under which the offer price fully reveals the signal of the investment bank about the value of the security. We call this equilibrium *informationally efficient* since the investment bank's information is included in the offer price. However, when aftermarket trading is introduced to the model one of two scenarios results: Either the offer price falls on average or a pooling equilibrium prevails. In the first case, a bank with favorable information distorts the price down thereby, on average, exacerbating underpricing. In the second case investors are unable to infer the signal of the investment bank form the offer price, i.e. buying decisions are based on private private signals only and not also on the signal of the investment bank. Hence, the possibility of aftermarket trading by investment banks generates either stronger underpricing or informational inefficiency.[9]

The intuition for our main result is simple. We assume that an IPO gets cancelled whenever there are not enough investors who are willing to buy the shares on offer. In addition, we assume that there are reputation costs involved for an investment bank whenever an IPO fails.[10] An investment bank with a bad signal about the value of the security on offer is, therefore, more inclined to set a low price since it expects less investors to have favourable signals. By similar arguing, an investment bank with a good signal will set a high price. The possibility of establishing a short position prior to the offer twinned with the overallotment option, however, enables investment banks to make riskless profits in the aftermarket. Whenever the price rises above the offer price, investment banks are hedged by the

[9]A major objective of financial market regulation is market transparency. Without modelling an explicit payoff from higher transparency we simply assume that a state in which prices contain more information about the value of a security is preferred to a state in which less information is contained. In this sense we use the term inefficiency.

[10]What we have in mind are, for instance, opportunity costs arising as a consequence of lost market share when being associated with an unsuccessful IPO, or opportunity costs due to lost or delayed business in case potential issuers decide to postpone the offering or not to go public at all when observing many IPOs to fail.

overallotment option. Whenever the price drops below the offer price, investment banks make profits by buying back shares in the market to fill their short positions. The price drop and hence the profit from filling the short positions in the market are potentially greater for high offer prices. Furthermore, the likelihood of a drop is higher given a bad signal than for a good one. The expected loss from a higher probability of failure when setting a high price will, under certain conditions, be offset by possibly higher aftermarket gains. To uphold separation, the investment with a good signal has to charge a price low enough, so that it does not pay for an investment bank with a low signal to deviate, taking both sources of profit into account. To an extent this result is surprising – absent the informational friction plain intuition suggests that banks should deliberately charge higher prices, leading to overpricing.[11] The information asymmetry in the current model generate the opposite effect. For some parameter constellations, however, it does not pay out for the investment bank to lower the price any further to defend their position, and therefore a pooling equilibrium results. This new equilibrium price will, by definition, be informationally less efficient than separating prices.

We also establish comparative statics results: The higher the share of the revenue or the higher the amount of overalloted shares the more restrictive the conditions for informational efficiency after the introduction of aftermarket short covering to the model. Since the possibility of profits from short-covering leads to a price distortion, wealth will be re-distributed. We analyse the ex ante expected profits (before the distribution of signals), and find that the redistribution favours investment banks. The investment bank will only lose from short covering when signals are very precise. The issuer loses whenever separation is maintained. If the informationally inefficient pooling equilibrium prevails then, for most parameter constellations, the issuer prefers this. Investors' payoffs are directly opposed to the issuer's; they can only profit if information in the model is sufficiently precise.

[11] Nanda and Yun (1997) analyse the impact of IPO mispricing on the market value of investment banks. They find that overpriced offerings result in decreased lead-underwriter market value. We do not model this effect. Including reputation costs of this kind would lower the incentive to deviate to a high risky price. Our qualitative results would, however, not be affected by this.

To the best of our knowledge there are only two theoretical papers, Benveniste, Busaba and Wilhelm Jr. (1996) and Chowdhry and Nanda (1996), which analyse the impact of price support in the aftermarket on the choice of the offer price. In these models, aftermarket price support is costly because it is assumed that investment banks use stabilising bids to intervene in the aftermarket. However, Aggarwal (2000) and Ellis et al. (2000) report that stabilising bits are never observed. Our model is in accordance with this fact since there is no room for stabilising bids in the given set-up. Furthermore, neither from Aggarwal (2000) nor from Ellis et al. (2000) can be inferred that stabilising activities are costly. Our model explicitly accounts for the fact that investment banks can earn money in the aftermarket. In addition, we do not account for penalty bids which exist to discourage the immediate re-selling of securities. This so-called “flipping” is often seen as a cause of poor market performance. However, Krigman, Shaw and Womack (1999) show that “flipping” can be interpreted as a rational response to and not a cause of mispricing. We can argue that our model is in accordance with their findings since “flippers” are shown to have no impact on the equilibrium outcomes in the given set-up.

The remainder of the paper is organised as follows. In Section 2 we introduce the model of a public offering without aftermarket short covering by investment banks as the benchmark case. We identify necessary and sufficient conditions under which the investment bank reveals its private signal through the offering price. We then describe the price formation in the aftermarket. Prices adjust according to investor demand, which, being public observable, is a sufficient statistic for investors’ information. In Section 3 aftermarket short covering by investment banks is introduced to the model. We identify the conditions under which investment banks will now pool in the offer price and thereby hold back their private information. That is, the informationally less efficient outcome results. In Section 4 we discuss ex ante implications on the redistribution of wealth. In Section 5 we extend our model to account for the fact that not all IPO contracts include stabilisation tools. The signalling effect of the investment bank’s contractual choice is analysed. The effect of “flippers” on our model is discussed in Section 6. Section 7 concludes.

2. THE CASE WITHOUT SHORT COVERING

Consider the following stylised setting of an initial public offering. We assume that the security on offer can take on values $V \in \mathbb{V} = \{0, 1\}$, where V indicates the random variable and v a realisation of V. Both values are equally likely but not known to any player at the time of the offering.

Let there be n potential, risk neutral investors who are offered the security. Investors are restricted to buy one unit of the security; they will invest if their expected gain is non-negative. They have a private, i.i.d. signal $s \in \mathbb{S} = \mathbb{V}$ about the value of the security but their information is noisy, i.e. $\mathsf{Pr}(s = v | V = v) = p$ with $p \in (1/2, 1)$. Apart from the signal, investors are identical. The issuer does not know the value of the security.[12] He simply signs a contract with a risk neutral investment bank in which the latter commits itself to float a given amount of securities S of the issuer. As a compensation the investment bank receives a gross spread β of the offer-revenue.[13] The offer price p^* is to be chosen by the investment bank.[14] He also has a private signal s' about the value of the security which is noisy, but more informative than the investors' signals, i.e. $q > p$, where $\mathsf{Pr}(s' = v | V = v) = q$. After receiving the signal the investment bank announces the offer price. Investors then decide whether to invest or abstain and aggregated demand becomes publicly known.

Shares are allotted at random in case of excess demand. If demand is too weak to match supply, i.e. if the number of investors willing to buy

[12]What we have in mind is an innovative start-up that is lead by engineers with brilliant technical knowledge but lack of commercial understanding.

[13]The most common value is 7 percent as shown in Chen and Ritter (2000).

[14] The two most widely used contracts between issuers and investment banks are firm commitment and best efforts contracts. In a firm commitment contract the investment bank underwrites the offer, that is it buys all shares at a price that is agreed upon immediately before the offer is floated. If the issuer and the investment bank cannot agree on that price the offer gets cancelled. In a best efforts contract the investment bank 'does its best' to distribute a minimum amount of shares during a specified period of time. If it fails to do so the offer gets cancelled. 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. The optimal contract choice in such settings has been analysed in Mandelker and Raviv (1977), Baron (1979), and Baron and Holmström (1980), respectively. However, in the present model we abstract form these complications and will argue that in its stylised form the model captures the basic, common features of both contracts.

is less than the number of shares to be sold, we assume the offer to get called off.[15] In addition, we assume this to involve fixed costs C for the investment bank. These costs are external to our formulation and can be thought of as reputation costs.[16] We think of them to capture, for instance, the opportunity costs due to lost market share when being associated with an unsuccessful IPO. In addition, they can be thought of as representing the opportunity costs due to lost or delayed business in case potential issuers decide to postpone the offering or not to go public at all when observing IPOs to fail. The magnitude of these costs will depend, for instance, on the market environment or the degree of competition in the underwriting industry.[17] Apart from the reputation costs we do not specify any costs the offering procedure itself may cause for the investment bank.[18]

[15] Busaba, Benveniste and Guo (2001) report for a sample of 2,510 IPOs filed with the SEC from 1984 to 1994 that 14.3 percent of the offerings got called off. The contract between issuers and investment banks gives the issuer the option to withdraw the offer if the price the investment bank proposes at the end of the road show is perceived as being inacceptably low. During the road show the investment bank learns about investors' valuation of the security. In a firm commitment contract the investment bank uses this information to propose an offer price such that it can find enough investors to sell the entire offer or, in a best efforts contract, such that the distribution of the shares will not be 'too difficult'. Given the proposed offer price, the decision of the issuer to withdraw will depend, among others, on his own valuation of the firm, his outside options to finance a possible project, or his inclination to diversify his risk. However, in the present model, the issuer's option to withdraw is not captured, and, in addition, it gives no room to the investment bank to adjust the offer price after the investors' valuation, i.e. their signals, become known. We however argue that in our setting cancellation by the issuer due to a low offer price is equivalent to cancellation due to insufficient demand at a high offer price. That is, our setting represents in a stylised way the the basic features of both firm commitment and best efforts contracts.

[16]The model could be extended to allow the investment bank to buy all shares that could not be sold to investors. Offers will then never fail. The cost of the investment bank in case of "failure" is then endogenised and results from expensively bought inventory positions. We conjecture that allowing for this extension would not alter our qualitative results.

[17] Even though asymmetric information between issuers and investment banks on the on hand and investors on the other hand is not modelled in this paper, Booth and Smith (1986) argue that in such a context the investment bank as a repeated player in the IPO market certifies that the issue is not overpriced. Following this argument, the assumed reputation cost can be interpreted as measuring the deterioration of the certification value of the investment bank's brand name.

[18]Positive costs would not change the results and are left out for simplicity.

The first 25 days after the offering are known as the so-called 'quiet period', when no new information about the issuer is published. We assume that at the end of the quiet period the private signal of the investment bank becomes publicly known, in case the offer price did not already reveal it. The signals of the investors are assumed to be revealed by demand in a way to be made precise below.

The timing of the offering procedure can be summarised as follows.

t**=-2** The investment bank receives its private signal. The issuer and the investment bank sign a contract in which they agree on the number of shares and the gross spread as underwriting compensation. The offer price p^* is determined.

t**=-1** Potential investors obtain their private signals and decide whether to invest or to abstain.

t**=0** The investment bank publishes the number of interested buyers. In case of excess demand shares are allotted at random among interested investors. If demand is too weak to match supply the offer gets called off.

t**=1** Market trade begins. Prices adjust according to demand.

The focus of this paper is the pricing decision of the investment bank given its signal. In the following we will, therefore, identify the conditions under which investment banks with different signals set different prices when maximising their profits. This will allow investors to infer the signal of the investment bank form the offer price. We define this to be *informationally efficient*.

We allow only for pure strategies and, therefore, all investors with the same signal will pick identical decisions. Thus we aggregate investors' decisions and consider three different cases: firstly, when all investors buy, denoted $B_{0,1}$, secondly, when only investors with signal $s = 1$ buy, denoted B_1, and thirdly when no investor buys, denoted $B_\emptyset$. To summarise the aggregated action set is $\mathbb{B} := \{B_{0,1}, B_1, B_\emptyset\}$. We are interested in the number of buys in B_1, let D denote the number buys in this case, i.e. the number of investors with signal $s = 1$. Suppose further the true value is $V = 1$, then we have

$$\mathsf{Pr}(D \geq \mathsf{S}|B_1) = \sum_{d=\mathsf{S}}^{n} \binom{n}{d} p^d (1-p)^{n-d}. \tag{1}$$

Suppose now the true value is $V = 0$, then we have

$$\mathsf{Pr}(D \geq \mathsf{S}|B_1) = \sum_{d=\mathsf{S}}^{n} \binom{n}{d} (1-p)^d p^{n-d}. \tag{2}$$

Let $\alpha(s', \mathsf{S}, B_1)$ be the probability that there are at least as many investors with the positive signal as securities on offer given private signal s'. Since the investment bank receives its private signal with quality q, we have, for instance, in case of $s' = 1$

$$\begin{aligned} \alpha(s'=1, \mathsf{S}, B_1) &:= \mathsf{Pr}(\text{at least } \mathsf{S} \text{ agents buy at } p^*|s'=1, B_1) \\ &= \mathsf{Pr}(D \geq \mathsf{S}|s'=1, B_1) \\ &= q\sum_{d=\mathsf{S}}^{n} \binom{n}{d} p^d (1-p)^{n-d} + (1-q)\sum_{d=\mathsf{S}}^{n} \binom{n}{d} (1-p)^d p^{n-d}. \end{aligned} \tag{3}$$

For simplicity write $\alpha_1(\mathsf{S}) = \alpha(s'=1, \mathsf{S}, B_1)$ and $\alpha_0(\mathsf{S})$ analogously, suppressing S whenever it has been pre-fixed. For a fixed S, the probability of the offering to be cancelled is, therefore, $1 - \alpha(s', \mathsf{S}, B_1)$. Using this formulation, the expected profit function of the investment bank can be written as

$$\Pi(\mathsf{p}^*|s', B_1) = \alpha(s', \mathsf{S}, B_1)\beta\mathsf{p}^*\mathsf{S} - (1 - \alpha(s', \mathsf{S}, B_1))C. \tag{4}$$

Furthermore, we will argue below that the offer price can be set low enough so that all agents would be willing to buy, regardless of their signal. The profit function of the investment bank then reduces to $\Pi(\mathsf{p}^*|B_{0,1}) = \beta\mathsf{p}^*\mathsf{S}$. In equilibrium, the decisions of investors depends on both the offer price and the beliefs of the investors about the signal of the investment bank.

Let $\mu = \mathsf{Pr}(s' = 1|\mathsf{p})$ denote the beliefs which investors hold about the investment bank having signal $s' = 1$ when they observe price p. Since signals are i.i.d. these beliefs do not differ among investors with different signals. We rule out the possibility that the investment bank plays a mixed strategy. Since the prior is equal, beliefs are therefore confined to be $\mu \in \{0, \frac{1}{2}, 1\}$. We adopt the tie-breaking rule that investors will invest if they are indifferent between buying and abstaining. In the following we will determine those prices which are intuitive cut-off points and resemble the conditional expectation of an individual investor given his private signal and his belief about the signal of the investment bank. These prices are calculated under the assumption that investors are myopic in the sense that they do not take into account expectations about the other investors' signals and, hence, about demand in general.[19] Denote $p_{s,\mu}$ the maximum price at which an agent with signal s and belief μ would be willing to buy. Then for instance, if $\mu = 1$ by Bayes' Rule investors with $s = 1$ are willing to buy an offer price no higher than

$$\begin{aligned} p_{1,1} &= \mathsf{E}[V|s=1,\mu=1] \\ &= 1\cdot\frac{qp}{qp+(1-q)(1-p)} + 0\cdot\frac{(1-q)(1-p)}{qp+(1-q)(1-p)} \\ &= \frac{qp}{qp+(1-q)(1-p)}. \end{aligned} \tag{5}$$

If $\mu = 0$ then all investors buy regardless of their signal at an offer price not higher than

$$p_{0,0} = \frac{(1-q)(1-p)}{(1-q)(1-p)+pq}. \tag{6}$$

If $\mu = 0.5$ then investors with $s = 1$ buy at an offer price not higher than $p_{1,\frac{1}{2}} = p$, and all investors are willing to buy regardless of their signal at an offer price not higher than $p_{0,\frac{1}{2}} = 1 - p$. The ordering of these prices is ambiguous. However, we can establish the following Lemma.

LEMMA 2.1. *If $q/(1-q) > p^2/(1-p)^2$ then prices are ordered as follows:*

$$p_{0,0} < p_{1,0} < 1-p < p < p_{0,1} < p_{1,1}.$$

Proof. The proof follows directly from manipulating and rearranging the definitions of the threshold prices. ▮

[19] Even though investors with a good signal face a winner's curse problem it can be shown that their expected profit from participating in the IPO process is positive. This is, however, not true for investors with the bad signal. But correcting the threshold prices such that investors with the bad signal break even in expectation would not alter our qualitative results. It is rather the case that it becomes more attractive to deviate the the high pooling price.

For simplicity, in what follows we confine ourselves to this ordering of prices.[20] Note also that $q > p$ alone ensures that $p_{1,0} < p_{0,1}$, i.e. the investor puts more weight on the signal of the investment bank than on its own.

A. Equilibrium Analysis

We are interested in informational efficiency. In a signalling game setting this translates into pooling and separating equilibria.[21] Denote $B(\mu) \in \mathbb{B}$ investors' best reply given belief μ. A *pooling equilibrium* is an equilibrium offer price p^*, belief $\mu = 0.5$, and for $\mathsf{p} \neq \mathsf{p}^*$, out-of-equilibrium beliefs are appropriately chosen, and investors's best replies given μ and p^*. A *separating equilibrium* is a system of prices and beliefs such that at $\mathsf{p}^* = \overline{p}^*$ beliefs are $\mu = 1$, and at $\mathsf{p}^* = \underline{p}^*$ beliefs are $\mu = 0$, and for $\mathsf{p} \notin \{\bar{\mathsf{p}}^*, \underline{\mathsf{p}}^*\}$ out-of-equilibrium beliefs are appropriately chosen. Table 1 summarises investors' best-responses given prices and beliefs, using the aforementioned cut-off prices.

Table 1.

Investors' behaviour given their beliefs and the offer price p^*.

	$s = 1$			$s = 0$		
	$\mu = 1$	$\mu = 0$	$\mu = \frac{1}{2}$	$\mu = 1$	$\mu = 0$	$\mu = \frac{1}{2}$
$\mathsf{p}^* \in (p_{0,1}, p_{1,1}]$	buy	–	–	–	–	–
$\mathsf{p}^* \in (p, p_{0,1}]$	buy	–	–	buy	–	–
$\mathsf{p}^* \in (1-p, p]$	buy	–	buy	buy	–	–
$\mathsf{p}^* \in (p_{1,0}, 1-p]$	buy	–	buy	buy	–	buy
$\mathsf{p}^* \in (p_{0,0}, p_{1,0}]$	buy	buy	buy	buy	–	buy
$\mathsf{p}^* = p_{0,0}$	buy	buy	buy	buy	buy	buy

Looking carefully at the outlined behaviour we can establish the following result.

[20]If the direction of the inequality changes then $p_{1,0}$ and $p_{0,1}$ lie within $(1-p, p)$. Our results are robust to the choice of the ordering.

[21]The underlying equilibrium concept is, of course, the Perfect Bayesian Equilibrium (PBE), which requires that both all agents' actions and their beliefs are specified.

Lemma 2.2. *There exists no separating price with $\underline{p}^* > p_{0,0}$.*

Proof. Suppose $\underline{p}^* > p_{0,0}$. At this price beliefs are $\mu = 1$ and, therefore, only investors with signal $s = 1$ buy. An investment bank with signal $s' = 1$ will always set a price $\overline{p}$ where at least investors with signal $s = 1$ buy. Hence, investors with signal $s = 1$ buy at both prices $\underline{p}$ and $\overline{p}$. An investment bank with signal $s' = 0$ can increase its payoff by deviating to a higher price because α_0 is not affected by this. Hence, he will mimic the investment bank with signal $s' = 1$, a contradiction. ▌

In any separating equilibrium, therefore, the low price must be such that all investors buy, and the highest such separating price given investor belief $\mu = 0$ is $\underline{p}^* = p_{0,0}$.

Since we are looking for informational efficiency we focus on conditions which allow for separating equilibria. In principle, there are three kinds of signalling equilibria imaginable. The already mentioned separating equilibrium, a pooling equilibrium in which only investors with $s = 1$ buy, and a pooling price at which all agents are willing to buy. In the following, we identify the conditions under which the pooling equilibria can be ruled out, i.e. conditions for informational efficiency. However, when we introduce aftermarket short covering by investment banks in Section III, we find that separation may not be sustained any longer. That is, we show that aftermarket short covering can undermine informational efficiency.

The equilibrium concept we employ is the Perfect Bayesian Equilibrium (PBE). However, in order to obtain robust results, we will immediately refine these equilibria with the *Intuitive Criterion* due to Cho and Kreps (1987). Using this forward induction argument we can single out conditions under which the only equilibrium surviving the Intuitive Criterion is a separating equilibrium. A formal definition of this concept is delegated to the appendix.

Fix a $\tilde{\mathsf{p}} \in [p_{0,0}, 1-p]$. Define $\phi_1(\tilde{\mathsf{p}})$ as the price at which the investment bank with signal $s' = 1$ would be indifferent between charging $\phi_1(\tilde{\mathsf{p}})$ given B_1 and the pooling price $\tilde{\mathsf{p}}$ with $B_{0,1}$. Formally,

$$\phi_1(\tilde{\mathsf{p}}) \;=\; \frac{\tilde{\mathsf{p}}}{\alpha_1} + \frac{1-\alpha_1}{\alpha_1}\frac{C}{\beta \mathsf{S}}. \tag{7}$$

Defining $\phi_0(\tilde{\mathsf{p}})$ analogously for the investment bank with $s' = 0$, we get

$$\phi_0(\tilde{\mathsf{p}}) \;=\; \frac{\tilde{\mathsf{p}}}{\alpha_0} + \frac{1-\alpha_0}{\alpha_0}\frac{C}{\beta \mathsf{S}}. \tag{8}$$

$\phi_{s'}$ can be interpreted as the lowest price at which for the best-case scenario in terms of investors best response, type s' is willing to deviate. It is immediately obvious that $\phi_0(\tilde{\mathsf{p}}) > \phi_1(\tilde{\mathsf{p}})$ for all $\tilde{\mathsf{p}} \in [p_{0,0}, 1-p]$. In addition, $\partial\phi_i(\tilde{\mathsf{p}})/\partial\tilde{\mathsf{p}} > 0$, $i \in \{0,1\}$, which implies that for higher pooling prices, the price needed to induce a profitable deviation has to increase. Using this, we can establish the following result.

Lemma 2.3. *Under the Intuitive Criterion $\phi_1(1-p) < p_{1,1}$ is a necessary and sufficient condition to rule out all pooling equilibria in prices $\in [p_{0,0}, 1-p]$ with $B(.5) = B_{0,1}$.*

Proof. Take pooling equilibrium $(\mathsf{p}^* = 1-p, \mu = \frac{1}{2}, B_{0,1}), (\mathsf{p} \neq 1-p, \mu = 0, B_1$ if $\mathsf{p} \leq p_{1,0})$. Consider a deviation to $\phi_1(\tilde{\mathsf{p}}) < p_{1,1}$. Since $\phi_1(1-p) < \phi_0(1-p)$, this deviation can be only profitable for an investment bank with signal $s' = 1$ at which all agents with signal $s = 1$ buy with beliefs $\mu = 1$. Having identified $s' = 0$ as equilibrium dominated, the agent with $s' = 1$ is strictly better off for investors' best-responses on the set of equilibrium undominated investment banks. Hence this equilibrium does not satisfy the intuitive criterion. Since $\phi_1(\tilde{\mathsf{p}})$ is increasing in $\tilde{\mathsf{p}}$, it suffices to require this for the highest potential pooling price. If the investment bank with signal $s' = 1$ is always equilibrium undominated, no pooling price in $[p_{0,0}, 1-p]$ survives the Intuitive Criterion. ∎

Denote $\tilde{\tilde{\mathsf{p}}}$ the price for which $\phi_1(\tilde{\tilde{\mathsf{p}}}) = p_{1,1}$. If $\tilde{\tilde{\mathsf{p}}} \leq 1-p$, then we could have pooling in prices $\mathsf{p} \in [\max\{p_{0,0}, \tilde{\tilde{\mathsf{p}}}\}, 1-p]$. Using the stronger notion of the intuitive criterion, depicted in the appendix, and the above arguing, Corollary 1 follows immediately.

Corollary 2.1. *If $\tilde{\tilde{\mathsf{p}}} \leq 1-p$, then there exists a unique, Strong Intuitive Criterion proof PBE which is the pooling equilibrium $\{\mathsf{p}^* = 1-p, \mu = \frac{1}{2}\}$.*

We do not, however, aim at fully characterising possible pooling equilibria, but identifying the conditions under which only separating equilibria prevail. The following Lemma establishes the desired result.

Lemma 2.4. *A sufficient condition to rule out pooling equilibria under the Intuitive Criterion is satisfied if $\phi_1(1-p) < p_{1,1}$ and $\phi_0(p_{0,0}) > p$.*

Proof. $\phi_0(p_{0,0}) > p$ implies that for the lowest pooling price the investment bank with signal $s' = 0$ cannot profitably deviate to p. $\phi_1(1-p) < p_{1,1}$ implies that the investment bank with signal $s' = 1$ prefers to deviate to a higher price. Since $\phi_0(p_{0,0}) > \phi_1(p_{0,0})$, the investment bank with signal $s' = 1$ can always deviate to $\phi_0(p_{0,0})$, ensure separation and maximise profits. ▮

Note that Lemma I.4. also implies that pooling equilibria in which only investors with signal $s = 1$ buy, that is pooling equilibria in $\mathsf{p}^* \in (1-p, p]$, cannot be sustained. This is because an investment bank with signal $s' = 0$ would deviate to $p_{0,0}$.

Finally, consider a separating equilibrium $\{\underline{p}^*, \overline{p}^*\}$. Recall from Lemma 1 that the only separation price which an investment bank with signal $s' = 0$ can charge is $\underline{p}^* = p_{0,0}$. The proof of Lemma 4 implies that potential high separation prices are all $\overline{p} \in [\phi_1(p_{0,0}), \phi_0(p_{0,0})]$. However, the Intuitive Criterion also ensures that there cannot be a price smaller than $\phi_0(p_{0,0})$.

Lemma 2.5. *Under the Intuitive Criterion* $\bar{\mathsf{p}}^* = \min\{\phi_0(p_{0,0}), p_{1,1}\}$.

Proof. Consider only the case where $\phi_0(p_{0,0}) < p_{1,1}$. Suppose there is a separating equilibrium in which $\bar{\mathsf{p}}^* < \phi_0(p_{0,0})$. Then at $\phi_0(p_{0,0})$, the $s' = 0$ investment bank is still equilibrium dominated. When incorporating this into beliefs, the investors best response is B_1 at $\phi_0(p_{0,0})$. Hence no equilibrium price $\bar{\mathsf{p}}^*$ below $\phi_0(p_{0,0})$ survives the Intuitive Criterion. ▮

Hence investment banks always charge the highest price possible, i.e. the investment bank with signal $s' = 1$ will choose $\overline{p}^* = \min\{p_{1,1}, \phi_0(p_{0,0})\}$, provided this is feasible. To summarise these findings we establish the following proposition.[22]

Proposition 2.1. *If $\phi_1(1-p) < p_{1,1}$ and $\phi_0(p_{0,0}) > p$, there exists a unique, Intuitive Criterion proof PBE which is the separating equilibrium* $\{(\underline{p}^* = p_{0,0}, \mu = 0), (\overline{p}^* = \min\{p_{1,1}, \phi_0(p_{0,0})\}, \mu = 1); p \neq \{\underline{p}^*, \overline{p}^*\}, \mu = 0\}$.

Proof. Follows directly from Lemmas 2.2, 2.3, 2.4, and 2.5. ▮

Note that if $\phi_0(p_{0,0}) > p_{1,1}$ the maximal potential separating price $p_{1,1}$ can be sustained. If this is not the case and $\overline{p}^* < p_{1,1}$ then the investment bank with $s' = 1$ charges a price which is lower than what investors with signal $s = 1$ would be willing to pay in a separating equilibrium. The

[22] The appendix on the Intuitive Criterion contains a more elaborate exposition of the proof, which contains all the details, especially of the equilibrium specification.

investment bank however, has to choose this price so that he cannot be mistaken as an investment bank with signal $s' = 0$.

B. Interpretation

In the previous equilibrium analysis the threshold prices ϕ_0 and ϕ_1 were heavily used. In the following we provide a possible interpretation for these threshold prices.

The number of potentially interested investors n is, to a certain extent, a choice variable of the investment bank because it is the number of people he intends to reach during the road-show. Since we abstract from distribution effort of investment banks and the possibly involved incentive problem, the number of potential investors is considered to be fixed in this model. The number of shares S has to be seen directly in connection with n. The more shares the investment bank has to bring to the market, the more intense he has to pursue its efforts during the road-show. Since we abstract from distribution activities by investment banks we will, by the same arguing, consider S to be fixed at a level that gives, in relation with n, some meaning to this model. The gross spread β, by convention, seems to be fixed somewhere around 7 percent, as stated above. Also, within this model, the quality of the signals cannot be influenced endogenously. If we, hence, consider n, S, β, p, and q to be fixed then the reputation costs C have the major influence on the properties of the equilibrium. Recall the discussion of these costs in the set-up of the model.

In particular, if C is so high that

$$\phi_1(1-p) = \frac{1-p}{\alpha_1} + \frac{1-\alpha_1}{\alpha_1}\frac{C}{\beta\mathsf{S}} > p_{1,1} \tag{9}$$

then a separating equilibrium cannot be sustained. In other words, if the costs of a failure of an IPO are too high, then even an investment bank with signal $s = 1$ prefers to sell the security at a price where all investors buy. Moreover, if C is so low that

$$\phi_0(p_{0,0}) = \frac{p_{0,0}}{\alpha_0} + \frac{1-\alpha_0}{\alpha_0}\frac{C}{\beta\mathsf{S}} < p \tag{10}$$

then a separating equilibrium, again, cannot be sustained. In this case, the costs of a potential failure of the IPO are so low that even an investment bank with signal $s' = 0$ is willing to take the risk of such failure and choose a high pooling price. The investment bank with signal $s' = 1$, in this case, cannot credibly signal its information. We can characterise the bounds on

C in more detail. If C is high enough so that $\phi_0(p_{0,0}) > p_{1,1}$ then even at the highest separating price, $p_{1,1}$, it does not pay for the low-type to deviate. This bound on C is given by

$$\hat{C} := \frac{\alpha_0 p_{1,1} - p_{0,0}}{1-\alpha_0}\,\beta\mathsf{S}. \tag{11}$$

If we define, in addition, $\bar{C}$ and $\underline{C}$ such that equations (9) and (10) are binding we get, respectively,

$$\bar{C} := \frac{\alpha_1 p_{1,1} - (1-p)}{1-\alpha_1}\,\beta\mathsf{S} \tag{12}$$

and

$$\underline{C} := \frac{\alpha_0 p - p_{0,0}}{1-\alpha_0}\,\beta\mathsf{S}. \tag{13}$$

The following Corollary summarises the above interpretation.

Corollary 2.2. *If $C \in (\underline{C}, \bar{C}]$ then the unique equilibrium is the separating equilibrium stated in Proposition 2.1. If $C \in [\hat{C}, \bar{C}]$ then $\bar{\mathsf{p}}^* = p_{1,1}$.*

Proof. Resembles Proposition 2.1 stated in terms of C instead of ϕ. ▮

In the appendix we show that indeed $[\hat{C}, \bar{C}]$ is not empty.

C. Aftermarket Trade and Price Formation

After the announcement of the offer price by the investment bank in $t = -2$ investors decide in $t = -1$ in accordance with their private signals whether to order or to abstain. In $t = 0$, the number of orders becomes publicly known and shares are allocated as described in the set-up of the model. In characterising trade and the price finding mechanism in $t = 1$ we have to distinguish between the case in which investors with signal $s = 1$ only and the case in which all investors order the security on offer.

Suppose the investment bank sets the high separating price $\overline{p}^*$. Investors form their expectation according to the revealed signal of the investment bank and their private signals about the value of the security. At $\overline{p}^*$ only investors with signal $s = 1$ buy and, therefore, aggregated demand D indicates the number of investors with the 'high' signal. Suppose further that $D \geq \mathsf{S}$, i.e. that the IPO is successful. Investors are assumed to take the aggregated information about signals into account and update their expectation 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 share or not, respectively. The updated expectation, therefore, becomes the aftermarket price in $t = 1$, denoted by p_1.

Since in a separating equilibrium the belief about the signal of the investment bank is unambiguous we can replace this belief with the conditional probability of the investment bank's signal being correct, which is q or $1-q$. Formally this is

$$\begin{aligned} \mathsf{p}_1 = \mathsf{E}[V|D] &= 1 \cdot \mathsf{Pr}(V = 1|D, s' = 1) + 0 \cdot \mathsf{Pr}(V = 0|D, s' = 1) \\ &= \mathsf{Pr}(V = 1|D, s' = 1), \end{aligned} \tag{14}$$

which can be expressed as

$$\mathsf{Pr}(V = 1|D, s' = 1) = \frac{\mathsf{Pr}(D|V = 1)\mathsf{Pr}(V = 1)\mathsf{Pr}(s' = 1|V = 1)}{\begin{array}{c}\mathsf{Pr}(D|V = 1)\mathsf{Pr}(V = 1))\mathsf{Pr}(s' = 1|V = 1) \\ +\mathsf{Pr}(D|V = 0)\mathsf{Pr}(V = 0)\mathsf{Pr}(s' = 1|V = 0)\end{array}}. \tag{15}$$

Using the binomial structure of the prior distributions over signals, the conditional probabilities for the demands can be stated as

$$\mathsf{Pr}(D = d|V = 1) = \binom{n}{d} p^d (1-p)^{n-d} \tag{16}$$

for $V = 1$, and for $V = 0$ analogously. Using Bayes' formula, in case stated demand $d \geq n/2$

$$\mathsf{p}_1(d) = \frac{qp^{2d-n}}{qp^{2d-n} + (1-q)(1-p)^{2d-n}}. \tag{17}$$

In case $d < n/2$, the equality changes to

$$\mathsf{p}_1(d) = \frac{q(1-p)^{n-2d}}{q(1-p)^{n-2d} + (1-q)p^{n-2d}}. \tag{18}$$

For later use, define $\Delta(\overline{p}^*)$ as the demand realisation d such that the aftermarket price resembles exactly the offer price, i.e. $\mathsf{p}_1(\Delta(\overline{p}^*)) = \bar{p}^*$. The definition of $\Delta(\overline{p}^*)$ implies that for aggregated demand $D < \Delta(\overline{p}^*)$ prices drop below the offering price and for demand $D > \Delta(\overline{p}^*)$ prices rise.

Suppose now that the investment bank sets the low separating price $\underline{p}^*$. As argued above, at this price all agents will order the security, stated demand, hence, is $D = n$, and shares are allocated at random. In this case, demand is uninformative since it does not reveal the number of 'high' signals. Investors with signal $s = 1$ who were not allocated a share would, however, still be willing to buy the asset at any price $\tilde{\mathsf{p}} \in [\underline{p}^*, p_{1,0}]$. Investors with signal $s = 0$, in turn, are willing to sell for such prices in case they were allocated a share. Without modeling the price-finding procedure explicitly we assume that the following intermediate process takes place. Those investors with signal $s = 1$ who did not receive the security in the offering submit a unit market-buy-order. Those investors with signal $s = 0$ who obtained the security in the offering submit a unit market-sell-order. All other agents abstain. The number of investors who want to buy or to sell is denoted by $\tilde{D}$ and $\tilde{S}$, respectively. Aggregated demand of investors with signal $s = 1$ is then $D = \tilde{D} + \mathsf{S} - \tilde{S}$, and the clearing price p_1 and its relation to $\underline{p}^*$ 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 in which all agents buy. The conditional expectation which determines the price, however, does not contain the component about the signal of the investment bank.

3. THE CASE WITH SHORT COVERING

In this section we analyse the effect of the introduction of aftermarket short covering on the pricing decision of the investment bank. In the previous section we identified conditions for a separating equilibrium in which investment banks with different signals set different offer prices. We defined this outcome to be *informationally efficient* since investors are able to infer the signal of the investment bank form the offer price. We then described the conditions in terms of the exogenous cost of failure of an IPO. In this section we will therefore focus on the interval of costs which yields a separating equilibrium without short covering and analyse how equilibrium prices react to the introduction of aftermarket short covering. In particular we will ask if and if so when the outcome is now triggered to become a pooling equilibrium. That is, we identify the conditions under which informational efficiency is undermined by aftermarket short covering by investment bank.

Apart from the contracted amount of securities S, the investment bank has now the opportunity to allot a predetermined amount of up to O shares to the public. This amount O is referred to as the *overallotment facility*, and it typically constitutes of about 15 percent of S.[23] Here we take O to be $r \cdot \mathsf{S}$. Investment banks go short in that position. If the price falls below the offer price the short positions are filled in the aftermarket. This practice is referred to as *aftermarket short covering.* If the price rises above the offer price the investment bank executes a so-called *overallotment option* which gives him the right to obtain up to O shares from the the issuer at the offering price in case these shares were previously allotted.

This new offering procedure can be summarised as follows.

***t*=-2** The investment bank receives its private signal. The issuer and the investment bank sign a contract in which they agree on the number of shares, the gross spread as underwriting compensation, the overallotment of O shares, and p^* is determined.

***t*=-1** Potential investors obtain their private signals and decide whether to invest or to abstain.

***t*=0** The investment bank publishes the number of interested buyers. In case of excess demand the investment bank will execute the overallotment facility. Shares are allotted at random among interested investors. If demand is too weak to match supply the offer gets called off.

***t*=1** Market trade begins. Prices adjust according to demand. In case the overallotment facility was executed, the investment bank covers the short position either by executing its option or by acquiring shares in the market.

In order to simplify the analysis and notation, we make the following assumptions which will not affect our results. We assume that the number of shares allocated with the overallotment, $\mathsf{S}+\mathsf{O}$, and the number of shares allocated when the investment bank commits itself not to pursue short covering are identical. We further assume that either the entire amount of $\mathsf{S}+\mathsf{O}$ shares can be allocated or the IPO fails.[24]

The pricing decision of the investment bank is influenced by the fact that aftermarket short covering introduces a second source of profits besides the gross spread of the offer revenue. The possibility of establishing a short position prior to the offer twinned with the overallotment option enables the investment bank to make riskless profits in the aftermarket. Whenever the price rises above the offer price, the investment bank is hedged by the

[23]In practise the overallotment option is better know as the Greenshoe; the name stems from the US company which first used an overallotment facility.

[24]This assumption is seconded by the fact that the overallotment is nearly always fully executed as reported in Ellis et al. (2000).

overallotment option. Whenever the price drops below the offer price, the investment bank will make profits by buying back shares in the market to fill its short positions. If, however, the investment bank executes the overallotment facility and buys back shares in the market, the contract implies that the investment bank only receives revenue as if he floated S and not $\mathsf{S}+\mathsf{O}$ shares. In case the overallotment option is executed, the investment bank receives the gross spread revenue for having floated $\mathsf{S}+\mathsf{O}$ shares.

The price drop and hence the profit from filling the short positions in the market are potentially greater for a high offer price at which only investors with $s = 1$ buy. Note that the ultimately prevailing price does not depend on the offer price but only on the number of investors with signal $s = 1$, modulo the signal of the investment bank. In the separating case, investment banks with signal $s' = 0$ are prevented from mimicking an investment bank with signal $s' = 1$ because expected costs from a failure of the IPO were sufficiently high. If they choose the low price, the risk of a failure is 0, at the high price only investors with signal $s = 1$ are willing to buy, so the risk is positive. When setting a high, risky price instead of a low, safe price at which all investors buy, the expected loss from a possible failure of the offering can, under certain conditions, be offset by potentially higher aftermarket gains. It may then pay for the investment bank with the 'low' signal to pool with the investment bank with the 'high' signal in a high offer price.[25] The introduction of a second profit center by aftermarket short covering, therefore, can affect the equilibrium outcome in a way that is rigorously analysed in what follows.

A. Equilibrium Analysis

Given the new set-up of the offering process, only the profit function of the investment bank changes. Recall that investors were modelled such that they took their order decision based on their private signals and beliefs only. We do not consider that short covering (and potential price stabilisation) in the aftermarket may be of value to investors and, therefore, may influence their decision.

Denote by $\Pi^1(\mathsf{p}^*, s', B)$ the expected profits the investment bank makes from receiving the gross spread of the offering revenue when investors

[25] We restrict our analysis to the case in which there will be pooling in the high price. Potentially there could also be pooling in $(1-p)$. We restrict the analysis to keep it tractable. Our results are not driven by this qualification they are rather restricted since there would be even more pooling if we allowed for switching to $(1-p)$.

choose B, which is a best response to their beliefs, and his own signal is s'. In case of a separating equilibrium the profits of the investment bank with signal $s' = 1$ can be written as

$$\Pi^1(\overline{p}^*, B_1, s' = 1) = \alpha_1 \overline{p}^* \beta(\mathsf{S} + \mathsf{O}) - (1 - \alpha_1)C. \tag{19}$$

For the investment bank with signal $s' = 0$ profits are

$$\Pi^1(\underline{p}^*, B_{0,1}, s' = 0) = \underline{p}^* \beta(\mathsf{S} + \mathsf{O}). \tag{20}$$

Denote by $\Pi^2(\mathsf{p}^*, B, s')$ the second period profit stemming from filling the short position at lower prices. Again, in case of a separating equilibrium, this is for investment banks with the respective signals

$$\Pi^2(\overline{p}^*, B_1, s' = 1) = \sum_{d=\mathsf{S}+\mathsf{O}}^{\Delta(\overline{p}^*)} \mathsf{O} \cdot \{\overline{p}^* - \mathsf{E}[V|D = d, \mu = 1] - \overline{p}^*\beta\} \cdot \mathsf{Pr}(D = d|s' = 1) \tag{21}$$

and

$$\Pi^2(\underline{p}^*, B_{0,1}, s' = 0) = \sum_{d=0}^{\Delta(\underline{p}^*)} \mathsf{O} \cdot \left\{\underline{p}^* - \mathsf{E}[V|D = d, \mu = 0] - \underline{p}^*\beta\right\} \cdot \mathsf{Pr}(D = d|s' = 0). \tag{22}$$

In case of the low price, $\Delta(\underline{p}^*)$ does not denote the demand realisation in $t = 0$ but the number of investors with signal $s = 1$ that is revealed in the aftermarket trade as described in the previous section. The conditional probabilities of the specific demands depend on the signal of the investment bank and are, respectively, given by

$$\mathsf{Pr}(D = d|s' = 1) = \binom{n}{d} \cdot \left\{qp^d(1-p)^{n-d} + (1-q)p^{n-d}(1-p)^d\right\} \tag{23}$$

and

$$\mathsf{Pr}(D = d|s' = 0) = \binom{n}{d} \cdot \left\{(1-q)p^d(1-p)^{n-d} + qp^{n-d}(1-p)^d\right\}. \tag{24}$$

Note that for the investment bank with signal $s' = 1$ we sum from $\mathsf{S} + \mathsf{O}$, since demands below that would lead to a failure of the IPO. For the investment bank with $s' = 0$, on the other hand, we sum from 0 since the IPO is always successful. We also have to deduct the fees which the investment bank loses when buying back cheaply in the market.

In order to uphold separation in the case with short covering the investment bank with signal $s' = 1$ needs to find the highest possible price such that the low type would not want to deviate from the low, riskless price to the high, risky price. I.e. the investment bank has to determine $\Phi_0(p_{0,0})$ such that

$$\left.\begin{array}{l}\Pi_1(\Phi_0(p_{0,0})|s'=0,B_1)\\+\Pi_2(\Phi_0(p_{0,0})|s'=0)\end{array}\right\}=\left\{\begin{array}{l}\Pi_1(p_{0,0}|s'=0,B_{0,1})\\+\Pi_2(p_{0,0}|s'=0).\end{array}\right. \tag{25}$$

For computational convenience, from now on we make the following three assumptions. The first simplifies the computations, the second requires that p and q do not become small jointly. Finally, large n is needed to avoid problems with the shapes of the underlying distributions.

Assumption 3.1. $\mathsf{S}+\mathsf{O}=n(1-p)$.

Assumption 3.2. $(2-p)(1-p)(1-q)/(qp^2)<1$.[26]

Assumption 3.3. *n is large.*

Since we also assume that the IPO fails whenever $D < \mathsf{S}+\mathsf{O}$, the direct implication of this assumption is, that $\alpha_1 = \frac{1+q}{2}$, and that $\alpha_0 = \frac{2-q}{2}$. Furthermore, since $\mathsf{S}+\mathsf{O}=(1+r)\mathsf{S}$ we have $\mathsf{O}=\frac{r}{1+r}n(1-p)$.

Lemma 3.1. $\phi_0(\mathsf{p}) \geq \Phi_0(\mathsf{p})\ \forall \mathsf{p} \in [p_{0,0}, p_{1,1}]$.

Observe that it suffices to show that given $\phi_0(p_{0,0})$ the second period profits from short covering for $s'=0$ are higher for the high, risky price. The details of the proof are delegated to the appendix. Although the details of the proof require the use of the parameter restriction, the intuition is straightforward. The low type considers it more likely that the price drops, hence his potential gain from the overallotment is large. In particular it is large relative to what he can gain from retrading at the low price. In order to prevent the low type from mimicking, the investment bank with the high signal therefore has to lower the price. The parameter restriction then ensures that the the low and high separating price are 'far enough' apart.

We can establish the following result.

[26]This assumption would, for instance, always be satisfied if $q > 3/4$.

PROPOSITION 3.1.

1. There exists $\underline{C}' > \underline{C}$ *such that for all* $C \in [\underline{C}', \bar{C}]$ *the unique equilibrium that survives the Intuitive Criterion is a separating equilibrium. For the high separating price* $\bar{\mathsf{p}}^*$ *it holds that there exists a* $\hat{C}' \geq \hat{C}$ *such that for* $C \in [\underline{C}', \hat{C}')$ *we have* $\bar{\mathsf{p}}^* = \Phi_0(p_{0,0})$ *with* $p < \Phi_0(p_{0,0}) < p_{1,1}$ *and for* $C \in [\hat{C}', \bar{C}]$ *we have* $\bar{\mathsf{p}}^* = p_{1,1}$.

2. For all $C < \underline{C}'$, *the only equilibrium that survives the* Strong *Intuitive Criterion is a pooling equilibrium with* $\mathsf{p}^* = p$.

The proof of the proposition can be found in the appendix.

The first part of the proposition states that for a certain parameter range, separation can be sustained. Since $\underline{C}' > \underline{C}$ this parameter range shrinks relative to the case where there was no overallotment. Furthermore, for all costs smaller than the threshold $\hat{C}'$, the investment bank with the good signal charges $\Phi_0(p_{0,0})$, which, by Lemma 3.1, is smaller than the price charged in that parameter region without overallotment. In other words, from $\underline{C}'$ to $\hat{C}'$ we face decreased prices. This is a surprising result since the second period gains are potentially higher the higher the offer price, so one would expect that all agents set higher prices.

Finally, for all costs smaller than $\underline{C}'$, both investment banks prefer to pool and hence prices are informationally inefficient. Since $\underline{C}' > \underline{C}$ pooling occurs for a region of parameters where there was separation without the overallotment. That is, the parameter region for which we get informational efficiency becomes more restrictive.

We can also establish some additional results.

PROPOSITION 3.2. *Comparative statics: The conditions for informational efficiency become more restrictive for the share of the revenue,* β, *or the amount of the overallotment facility,* r, *increasing.*

In other words, higher first period profits through a higher share of the revenue, β, or higher profits in the second period through an increased overallotment facility, r, enlarge the potential region of pooling. The proof of the first part of the proposition follows from the respective partial derivatives and is delegated to the appendix.

Defining underpricing as the difference between post-offer market price and offer price we can establish the following result.

COROLLARY 3.1. *For $C \in [\underline{C}', \hat{C}')$ on average there is more underpricing.*

Proof. By arguments given in the proof of Proposition 3.1 and Section 4, if $V = 0$, an offer with price $\Phi(p_{0,0})$ is only successful with probability $1/2$, if $V = 1$ the probability is 1. Furthermore, in the first case, the post offer price is, by the law of large numbers, almost surely 0, in the second case it is 1. Hence, when $\phi(p_{0,0})$ is charged average *ex ante* underpricing is

$$\frac{1}{2}\left((1-\phi(p_{0,0})) + \frac{1}{2}(-\phi(p_{0,0}))\right) := (*),$$

whereas with price $\Phi(p_{0,0}) < \phi(p_{0,0})$ it is

$$\frac{1}{2}\left((1-\Phi(p_{0,0})) + \frac{1}{2}(-\Phi(p_{0,0}))\right) > (*).$$

∎

Since we restrict the analysis to pooling in a high price (see footnote 25) we can establish the following remark.

Remark 3. 1. The ex ante probability for an IPO to fail is higher in the model with short covering than in the model without short covering.

This can be seen as follows. In a separating equilibrium an investment bank with $s' = 0$ will set a price such that all investors order, i.e. the IPO never fails. If the separating equilibrium is triggered to a pooling with B_1, the $s' = 0$ investment banks take the risk of failure which increases the number of potentially failing in more IPOs.

B. Discussion

Apart from aftermarket short covering, regulating authorities allow investment banks to pursue explicit stabilisation trades. As laid out in the introduction, investment banks are allowed to pursue clearly labeled stabilisation trades until the end of the quiet period which lasts for around 25 days. However, trades which are pursued to fill short positions do not necessarily have be declared as a stabilising trades. Since the investment bank has to fill its short positions investors expect to see O buys from the investment bank in any case, so these trades, at least in our model, do not have an effect on prices.

In our model, stabilising bids clearly cannot have an effect on prices in a separating equilibrium. This is because all price movements occur exclusively as a reaction to information based trades, and all the information of the investment bank is already incorporated into the offering-price. Only if we were to observe a pooling equilibrium – possibly being triggered through the potential second period gains of the overallotment – active stabilisation could have an effect on prices. Suppose the investment bank has exercised the overallotment facility, so that it has to cover its short positions. Consider the following two cases.

1. Suppose the price rises after the offering. The investment bank has to cover its short position and will, therefore, execute the *overallotment option*. Only if the investment bank short-sells further shares, it reveals more information. If it does not short-sell, then the market takes this as a signal that the investment bank had signal $s' = 1$ and the price will rise even further.

2. Suppose now the price falls below the offer price. The investment bank has to cover its short position and will buy-in at the lower price. Only if it buys further securities, it can credibly signal that it has received signal $s' = 1$. If the investment bank does buy, then it makes a gain. If, however, it does not buy, then the investors would take this as a signal that the investment bank's signal was $s' = 0$ and the price will fall even lower.

According to Aggarwal (2000) such clearly labeled stabilising bids never occur, so we decided not expand on this in the present model.

In order to understand the impact of signalling consider the case where the investment bank does not get a signal at all, which is equivalent to the case of a neutral prior, i.e. $q = 1/2$. α, the probability that there are at least S investors with the positive signal is

$$\alpha = \sum_{d=\mathsf{S}}^{n} \binom{n}{d} \frac{1}{2} \left(p^d (1-p)^{n-d} + (1-p)^d p^{n-d} \right).$$

An investor cannot derive further information from the price. If he has signal $s = 1$, he would buy the asset if $\mathsf{p} \leq p$, if he had $s = 0$ he would buy if $\mathsf{p} \leq 1 - p$. The decision of the investment bank is then reduced to set price p if

$$\alpha\beta\mathsf{S}p - (1-\alpha)C \geq \beta\mathsf{S}(1-p), \tag{26}$$

and $1-p$ else. By the same reasoning as in the preceding section, $\Pi_2(p) > \Pi_2(1-p)$, and therefore there exists a cost $\hat{C}$, such that for all costs $C \leq \hat{C}$, the investment bank would charge the high price p, and for all $C > \hat{C}$, it would play save and charge $1 - p$. However, once short covering is introduced, this second profit opportunity may enable the investment bank to charge a higher price. In other words there exits a $\hat{C}' > \hat{C}$ such that for all $C \leq \hat{C}'$ the investment bank would charge the higher price p. If one interprets the choice of $1 - p$ as underpricing, then the results from this setting can be thought to coincide with Benveniste, Erdal and Wilhelm Jr. (1998). They claim that in absence of stabilisation (i.e. short covering) underpricing should be more pronounced. Our signalling model therefore provides a stark contrast – for a non trivial region of parameters we would expect to observe decreasing prices and, by the same token, for non-trivial parameter regions, we expect informational inefficiency.

4. WELFARE ANALYSIS

One reason regulators provide for allowing aftermarket price stabilisation by investment banks is that they consider it in the public interest that the volatility of the asset price is reduced in the first weeks after the IPO. Our model does not attempt to model the aftermarket trading procedures, and we do not model volatility. We also acknowledge that regulators may have a different model of the investor in mind. However, the major objective of financial market regulation concerns market transparency. Without modeling an explicit payoff from higher transparency we simply assume that a state in which prices contain more information about the value of a security is preferred to a state in which less information is contained. The current regulation of the IPO process allows investment banks to pursue profit generation activities in the aftermarket which, under certain conditions, trigger a separating offer price to a pooling offer price. However, in a pooling equilibrium, by definition prices do not incorporate the private information of the investment bank. In this respect our model uncovers the potential for what we call informational inefficiency.

Apart from informational efficiency we can also consider whether market participants incur a pay-off related loss due to the presence of the over-allotment facility relative to the case without it. Even though gains and losses are merely zero-sum, it is, however, interesting to observe whether investment banks and issuers have an upside potential.

We consider welfare *ex ante*, i.e. we look at the expected profits before any signals are received.

The Investment Bank

We will only consider the case of $C \in [\underline{C}, \bar{C}]$. Ex ante, the investment bank will charge price ϕ in case it has signal $s' = 1$, and it will charge $p_{0,0}$ if $s' = 0$. If $V = 1$, the ex ante probability a successful IPO is 1, if $V = 0$ the probability is only 1/2. In case $V = 1$, the investment bank's overall payoff per share is therefore $q\phi + (1-q)p_{0,0}$. If $V = 0$, then it would have to incur cost C with probability 1/2 if it charges the risky ϕ. Hence its overall profit per share for $V = 0$ is $(1-q)(\phi/2 - c/2) + qp_{0,0}$, where $c = C/(\beta n(1-p))$. Together this yields per share profits (omitting the prior on V)

$$\frac{1+q}{2}\ \phi + p_{0,0} - \frac{1}{2}(1-q)c. \tag{27}$$

With aftermarket short covering ("stabilisation"), there are two cases to consider: First, the investment bank could maintain separation and charge Φ when confronted with $s' = 1$; this is the case if $\Phi > p$. If, secondly, $\Phi < p$, it would switch to pooling and charge p regardless of the private signal. If $V = 0$ then the ex ante probability of a successful offering is 1/2, but if it is successful, then short covering will take place with certainty. On the other hand short covering will never take place if $V = 1$ since final demand will always be higher than $n/2$. Hence his payoffs with short covering in separation and pooling respectively are

$$\frac{1+q}{2}\ \Phi + (1-q)\frac{\kappa}{2}\Phi + p_{0,0}(1+\kappa q) - \frac{1}{2}(1-q)c, \tag{28}$$
$$\frac{3+\kappa}{2}\ p - \frac{1}{2}c. \tag{29}$$

It is straightforward to check that ex ante, at $C = \underline{C}'$, i.e. at the lowest point when the investment bank starts to pool, profits in (29) and (28) coincide. Subtracting (27) from (28), we obtain

$$\frac{1+q}{2}\ (\Phi - \phi) + \kappa\frac{1-q}{2}\Phi + p_{0,0}\kappa q, \tag{30}$$

and we are henceforth interested in conditions which ensure that this inequality is positive. Φ and ϕ are defined relative to the costs C, hence is (30) is a function in C. Substituting in the definitions of Φ and ϕ, one finds that the slope in C is proportional to $1 - 2q < 0$. Hence (30) is decreasing in C, and given the general structure of prices it will be smallest

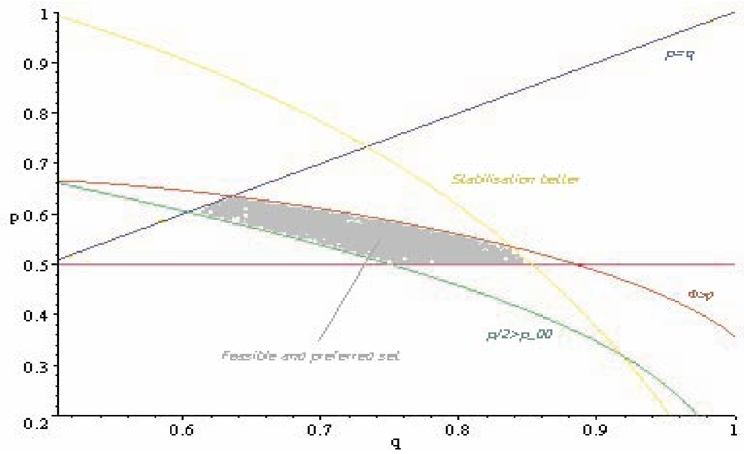

Figure 1. *Ex ante* Profits of the Investment Bank: Plot of p given q such that $\Phi > p$, $\kappa = 1.8$.

for $C = \hat{C}$. Then there are two cases to consider: First, if $\underline{C}' < \hat{C}$ then at $\hat{C}$ the investment bank charges separation price Φ. The condition is also equivalent to $\Phi > p$. Second, if $\underline{C}' > \hat{C}$, then with short covering it would charge pooling price p at $\hat{C}$.

Figure 1 considers the first case with $\Phi > p$; the shaded area identifies those combinations of p and q, which are feasible and for which (30) is satisfied for $\phi = p_{1,1}$ (which coincides with $C = \hat{C}$). Figure 2 looks at the situation where $\Phi < p$. As the investment bank charges p at $\hat{C}$ then if (30) > 0 for $\Phi = p$ and $\phi = p_{1,1}$, i.e. the largest gap, it is always satisfied. The shaded area identifies those combinations of p and q for which this is true. All graphs are plotted for the empirically observed case of $\kappa = 1.8$.

The graphical analysis yields that in nearly all cases when the parameters are such that $\underline{C}' < \hat{C}$ the investment bank is *ex ante* strictly better off with short covering. If $\underline{C}' > \hat{C}$, then there is a large set of parameters, such that the investment bank is always better off. The graph has to be interpreted with some care: In the unshaded region it is not the case that the investment bank is always worse off. It is certainly true that for very high and very small values of C it is always better off, but we cannot say that it is always better off with short covering. All other potential constellations however can be derived from these principles.

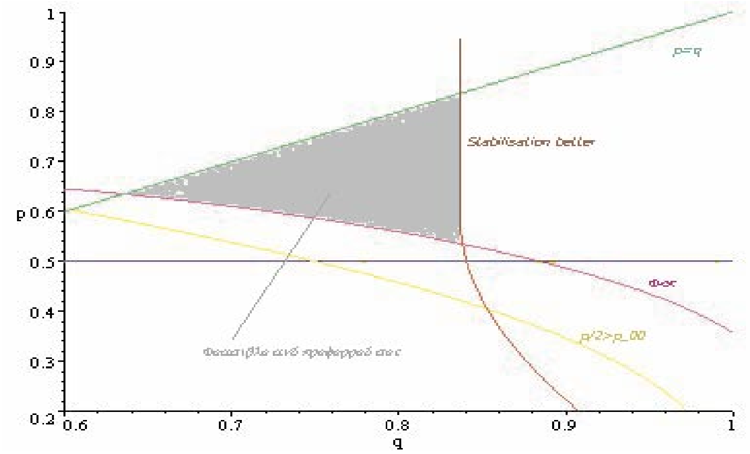

Figure 2. *Ex ante* Profits of the Investment Bank: Plot of p given q such that $\Phi < p$, $\kappa = 1.8$.

The Issuer

Using the same reasoning we can determine the *ex ante* profits for the issuer. We assume here that the issuer's prior is also neutral, and that the private information that he will eventually obtain is identical to the information of the investment bank. We will focus on the profit that is potentially created and abstain from taking other factors such as costs for alternative financing etc. into account. Profit here is the difference between the revenue per share that was generated and the true value.

Ex ante, the profit per share of the issuer depends on the signal of the investment bank and the ex ante probability of a successful offering. In the case without short covering, this is

$$\begin{aligned} & (1-\beta)(\phi q + p_{0,0}(1-q)) - 1 + \frac{1}{2}(1-\beta)\phi(1-q) + p_{0,0}q \\ = \; & (1-\beta)\left(\frac{1+q}{2}\phi - p_{0,0}\right) - 1. \end{aligned} \tag{31}$$

With short covering and separation, the profits are analogously defined by

$$(1-\beta)\left(\frac{1+q}{2}\Phi - p_{0,0}\right) - 1, \tag{32}$$

whereas under the pooling regime profits turn out to be

$$(1-\beta)(qp + (1-q)p) - 1 + (1-\beta)\left(\frac{1}{2}(1-q)p + \frac{1}{2}qp\right)$$

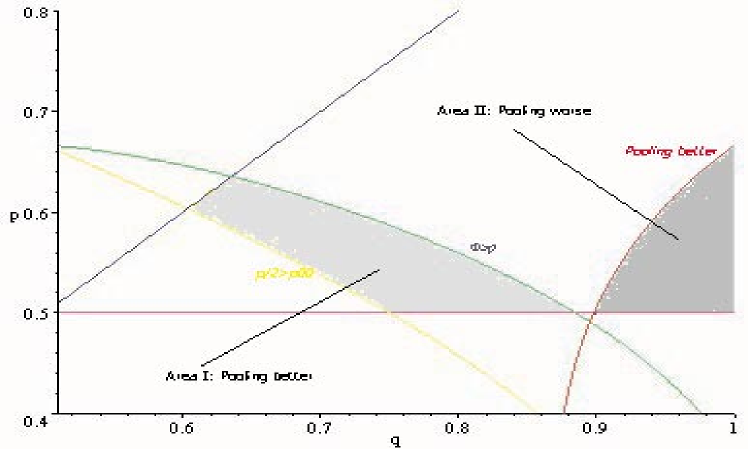

Figure 3. *Ex ante* Revenue of the Issuer: Plot of p given q such that (34)> 0, for $\kappa = 1.8$.

$$= (1-\beta)\frac{3}{2}p - 1. \tag{33}$$

When comparing (31) for $\phi = p$ with (33), it is immediately obvious that at $C = \underline{C}$ the issuer prefers pooling and short covering to separation without short covering.[27] On the other hand, whenever separation is maintained, the issuer loses, because he only receives price $\Phi < \phi$. Subtracting (33) and (31) gives

$$\frac{1}{2}\left(3p - (1+q)\phi\right) + p_{0,0}. \tag{34}$$

As before, we now consider two different cases. If $\hat{C} < \underline{C}'$, then the investment bank switched straight between separation without short covering to pooling with short covering. If in this case the issuer is always better off , i.e. if for some parameters at $\phi = p_{1,1}$, (34)> 0, then for all $C \in [\underline{C}, \underline{C}']$, he will be better off. If $\hat{C} > \underline{C}'$ and at $\phi = p_{1,1}$ it holds that (34)> 0, then whenever the investment bank switches to pooling, the issuer is better off ex ante.

Figure 3 captures these considerations. Everything to the left of the curve 'pooling better' captures those parameters for which the issuer is *always* better off if it comes to pooling. For $\underline{C}' < \hat{C}$ the shaded Area

[27]Hence there must exist a $C \in [\underline{C}', \hat{C}']$, which yields indifference.

I summarises those parameters where he is always better off; these are effectively all feasible parameters. For $\underline{C}' > \hat{C}$ the shaded Area II includes all parameters for which the issuer loses in pooling.

To summarise: Informational inefficiency yields the issuer superior profits. On the other hand we stress that when charging a separating price he loses as $\Phi < \phi$.

The Investors

Aggregated investors' profits are directly opposed to the profits of the issuer. Whenever the issuer gains from informational inefficiency, investors as a group will lose *ex ante*.

5. EXTENSION I: THE SIGNALLING EFFECT OF NOT GOING SHORT

When looking at IPO data and contracts one observes that not all contracts include an overallotment option and facility. In a signalling context this choice has also signalling power. We complete the analysis by including this decision into our model.

In contrast to the preceding section, we now assume that the investment bank can decide not to establish a short position. In this case, the counterparties decide to exclude an overallotment facility (and option). The investment bank's decision is therefore twofold – it must decide whether to go short or not, denoted by action choice $a(s') \in \{a_s, a_{ns}\}$, and then decide on the price.

An investment bank who decides not to go short, gets, of course, merely its share of the revenue. The following lemma will simplify the succeeding analysis.

Lemma 5.1. *An investment bank with signal $s' = 0$ will always go short.*

Proof. Suppose there is a separating equilibrium. Then $\underline{p}^* = p_{0,0}$. But $\mathsf{E}[\mathsf{O}(\underline{p}^* - \mathsf{p}_1)|d \geq \Delta(\underline{p}^*)] > 0$, and $a(s' = 0) = a_s$ yields strictly higher payoff. Suppose that there was a pooling equilibrium, i.e. $a(s' = 1) = a(s' = 0)$. However, for the parameter region that we focus on, for $a(s') = a_{ns}$ the model outcome is identical to the model without overallotment, and there pooling was not an equilibrium. Hence if there was a pooling equilibrium, $a(s' = 0) = a(s' = 1) = a_s$. ∎

If the investment bank decides not to establish a short position it has to choose a price $\phi_0'(p_{0,0})$ so that the low type is indifferent between charging the riskless price and getting the implied short covering payoffs, and charging a risky, high price without the short covering profit. I.e. it has to find the price which balances

$$\Pi_1(\phi_0'(p_{0,0})|s' = 0, B_1) = \Pi_1(p_{0,0}|s' = 0, B_{0,1}) + \Pi_2(p_{0,0}|s' = 0). \quad (35)$$

As in Section 2, we can straightforwardly define threshold costs $\underline{\tilde{C}}, \tilde{\hat{C}}$, so that for costs in $[\underline{\tilde{C}}, \tilde{\hat{C}}]$, the investment bank charges ϕ'; for all $C > \tilde{\hat{C}}$ it charges $p_{1,1}$, for $C < \underline{\tilde{C}}$ it charges p. Concerning the deviation prices ϕ' we can prove

LEMMA 5.2. $\phi_0'(\mathsf{p}) \geq \phi_0(\mathsf{p})\ \forall \mathsf{p} \in [p_{0,0}, p_{1,1}]$.

In other words, when deciding not to go short the investment bank with signal $s' = 1$ can, in fact, charge a higher price than in absence of the possibility to go short.

Proof. Comparing equation (35) and (7) immediately delivers the inequality. ∎

As we will argue below, when applying the Intuitive Criterion, the decision rule of the investment bank $s' = 1$ is reduced to picking the price–action pair which will yield maximal profits.

It is conceptually easiest to analyse the profit function with respect to costs C, i.e. for every C one has to determine the potential high separating price $\min\{p_{1,1}, \phi_0'(p_{0,0}\}$ with $a(s' = 1) = a_{ns}$, and $\min\{p_{1,1}, \Phi_0(p_{0,0}\}$ with $a(s' = 1) = a_s$. The decision rule therefore implies that the investment bank acts so that it is always on the higher of the profit curves described by C.

In slight abuse of notation, we now write $\phi'(C)$ and $\Phi(C)$ for the prices which yield separation for given C. Denote the model where the agent goes short as *Case s*, and where the agent could but does not go short as *Case ns*. Then

$$\pi^s(C|s' = 1) := \begin{cases} \Pi_1(p_{1,1}|s' = 1, B_1) + \Pi_2(p_{1,1}|s' = 1) & \text{for } C > \hat{C}' \\ \Pi_1(\Phi(C)|s' = 1, B_1) + \Pi_2(\Phi(C)|s' = 1) & \text{for } C \in [\underline{C}', \hat{C}'] \\ \Pi_1(p|s' = 1, B_1) + \Pi_2(p|s' = 1) & \text{for } C < \underline{C}' \end{cases}$$

$$\pi^{ns}(C|s' = 1) := \begin{cases} \Pi_1(p_{1,1}|s' = 1, B_1) & \text{for } C > \tilde{\hat{C}} \\ \Pi_1(\phi'(C)|s' = 1, B_1) & \text{for } C \in [\underline{\tilde{C}}, \tilde{\hat{C}}] \\ \Pi_1(p|s' = 1, B_1) & \text{for } C < \underline{C}' \end{cases}$$

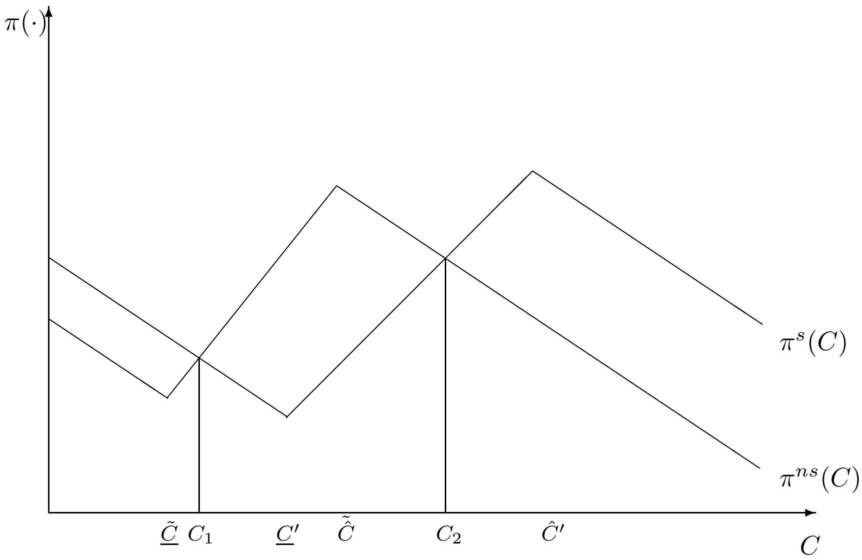

Figure 4. Profit Functions in C

LEMMA 5.3. $\pi^s(\hat{C}') = \pi^{ns}(\tilde{\hat{C}})$, $\pi^s(\underline{C}') = \pi^{ns}(\underline{\tilde{C}})$.

The lemma states that for the threshold costs at which an investment bank is able to charge the highest price $p_{1,1}$, profits in Case s and ns are identical, and the same holds for the thresholds at which the high pooling price p is charged. The proofs of the lemma as well as of the following proposition are delegated to the appendix. Figure 4 depicts the profit function described in the proposition, Figure 5 shows the optimal choice of $\bar{\mathsf{p}}^*$.

PROPOSITION 5.1. *There exist C_1, C_2 with $\underline{\tilde{C}} \leq C_1 \leq \underline{C}'$ and $\tilde{\hat{C}} \leq C_2 \leq \hat{C}'$, $(\underline{p}^* = p_{0,0}, a(s' = 1) = a_s; \mu = 0, B_{0,1})$, and*

•for $C > \hat{C}'$, separation with $\bar{\mathsf{p}}^* = p_{1,1}$, $a(s' = 1) = a_s$; $\mu = 1, B_1$,

•for $C \in [C_2, \hat{C}']$, separation with $\bar{\mathsf{p}}^* = \Phi_0(p_{0,0})$ and $a(s' = 1) = a_s$; $\mu = 1, B_1$

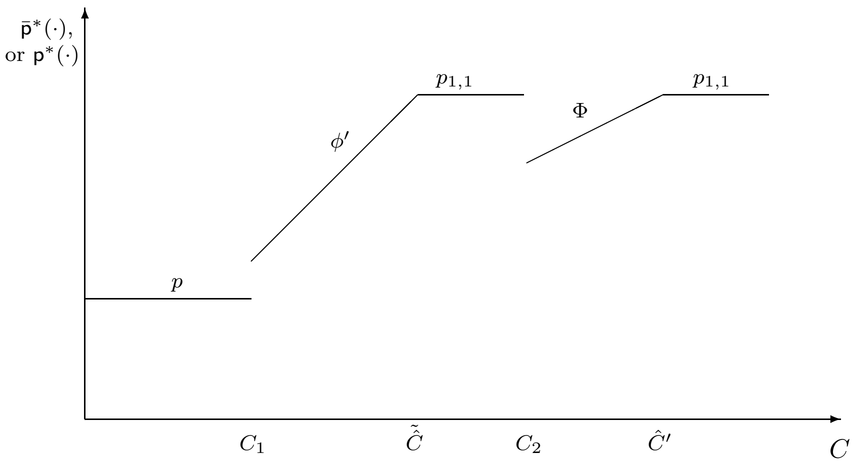

Figure 5. Optimal Price Choice by $s' = 1$ in C

•*for* $C \in [C_1, C_2]$, *separation with* $\bar{\mathsf{p}}^* = \phi_0'(p_{0,0})$ *and* $a(s' = 1) = a_{ns}$*;* $\mu = 1, B_1$,

$(\mathsf{p} \notin \{\bar{\mathsf{p}}^*, p_{0,0}\}; \mu = 0, (B_1 \text{ or } B_\emptyset))$, *are the respective unique (for every* C*) equilibria that survive the Intuitive Criterion. For* $C < C_1$*, the pooling equilibrium* $(\mathsf{p}^* = p, a(s' = 1) = a(s' = 0) = a_s; \mu = .5, B_1)$ *is the only equilibrium that survives the strong intuitive criterion.*

In the described scenario the following happens: In the first interval, the investment bank charges the highest possible separating price, just as expected. In the second interval, the effect of short covering profits is stronger than the effect of ϕ', which is higher than Φ. However, the profit functions will intersect, hence for costs below some C_2, it is more attractive for the investment bank to forfeit short covering profits and instead charge a higher price ϕ'. The high price together with the commitment not to go short signal the value of the asset. For some threshold C_1 on, however, it does not pay out any longer to defend against the low type – it is now better to pool with this type. Hence informational inefficiency arises. As in Section 3, comparative statics yield that the size of the pooling area, i.e. the position of C_1, increases in contract variable β. The results of comparative statics on r, the size of the overallotment option, are mixed, i.e. they depend on the size of p and q.

PROPOSITION 5.2. $\frac{\partial C_1}{\partial \beta} > 0$. *There exists a* q^* *such that* $\forall q \leq q^*$ $\frac{\partial C_1}{\partial r} < 0$. *For every* $q > q^*$ *there exists a* $p^*(q)$ *such that* $\forall p \in [p^*(q), q]$ $\frac{\partial C_1}{\partial r} > 0$, *and* $\forall p \in [.5, p^*(q))$ $\frac{\partial C_1}{\partial r} < 0$.

This result is again surprising, yet it complies to the finding in preceding sections: If the investment bank gets less of the first period profit, it is more willing to generate separation. If C_1 decreases in r this indicates that it gets easier to defend a high price against the low type, because for this type it gets more expensive to deviate from the safe price.

6. EXTENSION II: THE CASE WITH FLIPPERS

In this section we show that the result of our model are robust to the introduction of so-called 'flippers'. This kind of noise traders caught the attention of both researchers and regulators in recent years. A flipper is defined as an investor who orders shares in an offering and sells them immediately in the aftermarket. There is not much literature explaining what exactly their strategy and motivation is and on their impact on prices after an IPO. In the eyes of regulators and of the general public, however, these flippers are perceived to be harmful. Furthermore, penalty bids allow investment banks to punish institutional investors who do not keep their allotted shares for a certain period of time. However, a recent article by Krigman et al. (1999) suggests that 'flipping' is a rational response to mispricing by investment banks and that their behaviour is a good indicator of the future performance of the security.

In our model, we consider a flipper to be an agent who may order a security in the offering period without having received a private signal. In case he bought the security, his intention is to sell it immediately after the offering. Suppose that an investor has received a private signal with probability $1 - \mu$, and that with probablity μ he is a flipper. Furthermore assume that a flipper decides to order the security with probability $\mu/2$. In our model two events are imaginable: All agents buy, modulo the flippers who don't decide to order, or the buy-decision is triggered by an informed trader with signal $s = 1$ or by a flipper. The setup of the model only changes with respect to the probabilities of success, α_1 and α_0. For instance

$$\alpha_1 = \begin{cases} q \sum_{d \geq \mathsf{S}}^{n} \binom{n}{d} ((1-\mu)p + \frac{\mu}{2})^d ((1-\mu)(1-p) + \frac{\mu}{2})^{n-d} \\ +(1-q) \sum_{d \geq \mathsf{S}}^{n} \binom{n}{d} ((1-\mu)(1-p) + \frac{\mu}{2})^d ((1-\mu)p + \frac{\mu}{2})^{n-d}. \end{cases} \tag{36}$$

Consider the case of a separating equilibrium. In $t = 1$, prices adjust according to the information contained in the demand. Suppose, for instance, $D > (1 - \frac{\mu}{2})\Delta(\mathsf{p}^*)$. Then

$$\mathsf{Pr}(V = 1 | D, \mathsf{p}^* = p_{1,1}) = \frac{q(1-\mu)p + \frac{\mu}{2})^{2d-\bar{n}}}{q(1-\mu)p + \frac{\mu}{2})^{2d-\bar{n}} + (1-q)((1-\mu)(1-p) + \frac{\mu}{2})^{2d-\bar{n}}} \tag{37}$$

$$\mathsf{Pr}(V = 1 | D, \mathsf{p}^* = p_{0,0}) = \frac{(1-q)(1-\mu)p + \frac{\mu}{2})^{2d-\bar{n}}}{(1-q)(1-\mu)p + \frac{\mu}{2})^{2d-\bar{n}} + q((1-\mu)(1-p) + \frac{\mu}{2})^{2d-\bar{n}}} \tag{38}$$

where the conditional probabilities are equal to the price, and $\bar{n} := \lfloor (1 - \frac{\mu}{2})n \rfloor$ denotes the integer contained in the expression. However, the flippers will now unload their holdings and sell them to the market. We assume, for simplicity, that they do so regardless of whether the price increased or decreased after the IPO. In the case of $p^* = p_{1,1}$, S_f shares have been allotted to flippers, and $\overline{S}$ went to informed investors with signal $s = 1$. All investors with signal $s = 1$ who did not receive a share in the offering will be willing to buy, so that prices will adjust as laid out in Subsection C of Section I. In particular, if, say, $D > (1 - \frac{\mu}{2})\Delta(\mathsf{p}^*)$,

$$\mathsf{Pr}(V = 1 | D, \mathsf{p}^* = p_{1,1}) = \frac{qp^{2d-\bar{n}}}{qp^{2d-\bar{n}} + (1-q)(1-p)^{2d-\bar{n}}} \tag{39}$$

$$\mathsf{Pr}(V = 1 | D, \mathsf{p}^* = p_{0,0}) = \frac{(1-q)p^{2d-\bar{n}}}{(1-q)p^{2d-\bar{n}} + q(1-p)^{2d-\bar{n}}}. \tag{40}$$

The considerations in case of a pooling equilibrium follow by analogy. Overall, our results are robust to the the introduction of noise by flippers into the present model.

7. CONCLUSION

Investment banks legally pursue supposedly price stabilising activities in the post-offer market. We have proposed a simple signalling model of an offering procedure to highlight the distorting effects that aftermarket short covering has on the choice of the offer price by investment banks. Aftermarket short covering introduces an additional profit centre for investment banks. They strategically set the offer price in order to maximise profits from both receiving the gross spread of the offer revenue and short covering in the aftermarket. In a setting without the possibility of aftermarket short covering we identified the conditions under which offer prices reveal the private information of the investment bank. This was called *informationally efficient* since the investment's information was included in the offer price. After introducing the possibility of short covering in the aftermarket we identified the conditions under which a pooling equilibrium, i.e an informationally inefficient equilibrium results. Investors are no longer able to infer the information of the investment bank form the offer price. Their decision has to be based on their private signal only and not on the signal of the underwriter as well. In the case the seperating equilibrium could still be sustained it was shown that this goes along with exacerbated underpricing. Some comparative statics results were established. The higher the share of the revenue or the higher the amount of overalloted shares the more restrictive the conditions for informational efficiency after the introduction of aftermarket short covering. The possibility of profits from short-covering was shown to lead to a re-distribution of wealth. We analysed the ex ante expected profits and found that this redistribution favours investment banks. The investment bank will only lose from short covering when signals are very precise. The issuer loses whenever separation is maintained. If the informationally inefficient pooling equilibrium prevails then, for most parameter constellations, the issuer prefers this. Investors' payoffs are directly opposed to the issuer's; they can only profit if information in the model is sufficiently precise. By introducing the choice of whether or not to go short we completed the analysis; investment banks could use the choice not to go short to reveal their signal's value. We have finally shown the results to be robust to the introduction of flippers to the model. Our analysis is in accordance with recent empirical analyses and contrasts the existing literature which argues that stabilisation serves efficiency.

Appendix: FORWARD INDUCTION

An extensive form signalling model typically poses the difficulty of multiple equilibria – given appropriate out-of-equilibrium beliefs typically a continuum of equilibria can be sustained. However, if one applies the Intuitive Criterion (developed by Cho and Kreps (1987)), the set of candidate equilibria shrinks considerably. In this appendix we will review the definition of the Intuitive Criterion, propose a strengthening which we use in certain parts of the paper, and explain how the results are applied.

The intuition for the intuitive criterion is the following. Take any candidate equilibrium. Fix an action. De-select those types of the first-move agents, who are equilibrium dominated, i.e. who can do no better than in equilibrium, no matter what the beliefs and corresponding best-responses of the second-mover are. If in the remaining set of types of first-movers there exists a player such that he would always do better for all beliefs for which the second player puts weight only on this set, then the candidate equilibrium does not satisfy the *Intuitive Criterion.* Formally (following Fudenberg and Tirole (1991), p.448): Investment banks' types are identified by their signals. Denote $T \subseteq \{s' = 0, s' = 1\}$. Define $\mathsf{BR}(T, \mathsf{p})$ the set of pure-strategy best replies for the investors to price p for beliefs $\mu(\cdot|\mathsf{p})$ such that $\mu(T|\mathsf{p}) = 1$,

$$\mathsf{BR}(T, \mathsf{p}) = \bigcup_{\mu:\mu(T|\mathsf{p})=1} \mathsf{BR}(\mu, \mathsf{p}),$$

where $\mathsf{BR}(\mu, \mathsf{p})$ =buy if $\mathsf{E}[V|s, \mu] \geq \mathsf{p}$ for the given μ.

Definition A.1. [Intuitive Criterion] Fix the vectors of equilibrium payoffs $\Pi^*(\cdot)$ for the investment bank. For each price p let $J(\mathsf{p})$ be the set of all equilibrium dominated s', i.e.

$$\Pi^*(s') > \max_{B \in \mathsf{BR}(\{s' \in \{0,1\}\}, \mathsf{p})} \Pi(\mathsf{p}, B, s').$$

If for some p there exists a type s', such that

$$\Pi^*(s') < \min_{B \in \mathsf{BR}(\{s' \in \{0,1\}\} \setminus J(\mathsf{p}), \mathsf{p})} \Pi(\mathsf{p}, B, s'),$$

then the equilibrium fails the *Intuitive Criterion.*

In the first part of the paper this definition is sufficient to describe the set of equilibria which are of interest for our arguments. However, when introducing short covering we are confronted with the situation that eventually it may be better for both types of investment banks to switch to a pooling equilibrium. The intuitive criterion typically selects in favour of separating equilibria, for the mere reason that in the first part of the definition all types with equilibrium dominant actions are deselected. In the pooling equilibria that we generate, however, both types of investment banks would prefer the pooling outcome to any feasible separating equilibrium. Intuitively however, we cannot see any reason why investors should expect any other price than the one which maximises investment banks profits, yet the Intuitive Criterion has no bite in such situations. In other words, suppose we look at a separating equilibrium where the out of equilibrium belief is that a deviation must come form type $s' = 0$. Suppose however, that in this equilibrium in the best-case scenario of investors' beliefs and corresponding best-responses both investment banks would like to deviate. No agent is equilibirum dominated, so $J(\mathsf{p}) = \emptyset$. But how can we justify the out of equilibrium belief that it must have been the low type who deviated? We therefore propose the following strengthening. Define

$$\mathsf{BR'}(T, \mathsf{p}) = \bigcup_{\substack{\mu:\mu(T|\mathsf{p})=1 \\ \mu(T|\mathsf{p})>0}} \mathsf{BR'}(\mu, \mathsf{p}).$$

In other words we require that μ has full support on T.

Definition A.2. [Strong Intuitive Criterion] Fix the vectors of equilibrium payoffs $\Pi^*(\cdot)$ for the investment banks. For each price p let $J(\mathsf{p})$ be the set of all s' such that

$$\Pi^*(s') > \max_{B \in \mathsf{BR}(\{s' \in \{0,1\}\}, \mathsf{p})} \Pi(\mathsf{p}, B, s').$$

If then for some p there exists a type s', such that

$$\Pi^*(s') < \min_{B \in \mathsf{BR'}(\{s' \in \{0,1\}\} \setminus J(\mathsf{p}), \mathsf{p})} \Pi(\mathsf{p}, B, s'),$$

then the equilibrium fails the *Strong* Intuitive Criterion.

Recall that we consider only pure strategies of all agents. Therefore, if $J(\mathsf{p}) = \emptyset$, i.e. both agents would prefer to deviate, then in the second step, belief $\mu = 0$ is ruled out. With only pure strategies, the only belief placing positive weight on both types and that satisfies Bayes' Rules is $\mu = .5$. The outcome which would be generated in a pooling equilibrium becomes the point of comparison. If pooling is preferred by both types of investment banks, a deviation to it from any other equilibrium is feasible. In this model, it is also true that for $J(\mathsf{p}) \neq \emptyset$, the Strong Intuitive Criterion is identical to the 'normal' Intuitive Criterion.

We will now apply the reasoning of the standard definition to Proposition 2.1. Suppose that the conditions from the proposition hold, i.e.

$$\phi_1(p_{0,\frac{1}{2}}) < p_{1,1} \tag{A.1}$$

$$\phi_0(p_{0,0}) > p_{1,\frac{1}{2}}. \tag{A.2}$$

First we will argue that the only separating equilibrium surviving the intuitive criterion is the one outlined in the proposition. Then we will argue that pooling cannot occur. These steps resemble Lemmas 2.5 , 2.3, and 2.4 from the main text.

Step 1 Separating First observe that there cannot be a separating price $\bar{\mathsf{p}}^*$ where investors choose $B_{0,1}$, because otherwise the type with $s' = 0$ could always deviate to this price and benefit. Note that no separating price with $\bar{\mathsf{p}}^* > \phi_0(p_{0,0})$ can exist because at this price, the investment bank of type $s' = 0$ would prefer to deviate. Furthermore, $\bar{\mathsf{p}}^* \geq \phi_1(p_{0,0})$ must be satisfied since otherwise type $s' = 1$ would prefer to deviate to the lower price. Finally no price $\bar{\mathsf{p}}^*$ below $p_{1,0}$ is reasonable, because otherwise type $s' = 1$ can always deviate to this price and ensure a higher profit. Hence $\bar{\mathsf{p}}^* \geq \max\{\phi_1(p_{0,0}), p_{1,0}\}$.
Take $\tilde{p}$, with $\max\{\phi_1(p_{0,0}), p_{1,0}\} \leq \tilde{p} < \phi_0(p_{0,0})$. We analyse the separating equilibrium

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

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

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

so that the type with signal $s' = 0$ would not deviate to $\tilde{p}$. Furthermore, since $\tilde{p} > \phi_1(p_{0,0}) > p_{1,0}$, type $s' = 1$ would also not deviate. Hence this is an equilibrium. Now consider the application of the Intuitive Criterion. Suppose price $\mathsf{p} = \phi_0(p_{0,0}) \leq p_{1,1}$ is observed. At this price, the investment bank with $s' = 0$ is equilibrium dominated by the definition of ϕ_0, so we exclude him from the set of potential deviators. The only remaining agent however is the investment bank with signal $s' = 1$. The best response of investors with signal $s = 1$ then is to buy at the $\phi_0(p_{0,0})$, i.e. B_1. Hence this equilibrium does not survive the Intuitive Criterion. Applying this reasoning repeatedly, all separating prices $\bar{\mathsf{p}}^*$ with $\bar{\mathsf{p}}^* < \phi_0(p_{0,0})$ can be eliminated.

Step 2a Pooling with $B_{0,1}$ implies that $\mathsf{p}^* \leq p_{0,\frac{1}{2}}$. Hence

$$(\mathsf{p}^*; \mu = \frac{1}{2}, B_{0,1}), (\mathsf{p} \neq \mathsf{p}^*, \mu = 0, s = 1 \text{ buy only if } \mathsf{p} < p_{1,0}).$$

Suppose there was a deviation to $\mathsf{p} = \phi_1(p_{0,\frac{1}{2}}) < \phi_0(p_{0,\frac{1}{2}})$. Then type $s' = 0$ would not be better of, so it would not have deviated, but for some beliefs and correspoding best responses $s' = 1$ could be better off. The best response for investors with beliefs on the remaining set of types, i.e. $\mu = 1$, however, B_1. Hence this equilibrium does not survive the Intuitive Criterion.

Step 2b Pooling with B_1 implies that $\mathsf{p}^* \leq p_{1,\frac{1}{2}}$. By (A.2) type $s' = 0$ would prefer to deviate to $p_{0,0}$, hence this cannot be an equilibrium.

To summarise, given conditions (A.1) and (A.2), the only equilibrium surviving the Intuitive Criterion is the one depicted in the proposition.

Note also that Step 2b and restrictions (A.1) and (A.2) guarantee that an application of the Strong Intuitive Criterion would not affect the unique equilibrium. To see this consider the unique equilibrium and suppose there was a deviation to $\mathsf{p} > \phi_0(p_{0,0}) > p_{1,\frac{1}{2}}$. Both agents would have preferred this deviation. In the second step the best reply to belief $\mu = \frac{1}{2}$ for all agents is not to buy, i.e. $B_\emptyset$, yielding lower profits to both types of investment banks. So the equilibrium does satisfy the Strong Intuitive Criterion.

Appendix: OMITTED PROOFS

Addition to Corollary 2.2

Note that since $\mathsf{S} = n(1-p)$, $\alpha_1 = (1+q)/2$, $\alpha_0 = (2-q)/2$. Hence $\alpha_1/(1-\alpha_1) = (1+q)/(1-q)$ and $\alpha_0/(1-\alpha_0) = (2-q)/q$. Then

$$\begin{aligned}
\hat{C} &< \bar{C} \\
\Leftrightarrow \frac{\alpha_0 p_h - p_{0,0}}{1-\alpha_0} &< \frac{\alpha_1 p_{1,1} - (1-p)}{1-\alpha_1} \\
\Leftrightarrow \frac{2(1-p)}{1-q} - \frac{2p_{0,0}}{q} &< \left(\frac{1+q}{1-q} - \frac{2-q}{q}\right) p_{1,1} \\
\Leftrightarrow (1-p)q - (1-q)p_{0,0} &< (2q-1)p_{1,1} \\
(1-q)(p_{1,1} - p_{0,0}) &< q(p_{1,1} - (1-p)).
\end{aligned}$$

Substituting the formulae for prices $p_{1,1}$ and $p_{0,0}$ and simplifying we obtain

$$\begin{aligned}
(1-q)[pq - (1-p)(1-q)] &< q[pq - (1-p)(pq + (1-p)(1-q))] \\
\Leftrightarrow (1-q)(1-p)[q(2-p) - 1] &< pq[q(1+p) - 1].
\end{aligned}$$

Since $p > 1-p$ and $q > 1-q$. Note also that $1+p > 2-p$ implies $p > .5$ which is true by assumption and therefore delivers the result that $[\hat{C}, \bar{C}] \neq \emptyset$.

Proof of Lemma 3.1

We will proceed in two steps. First we will show that at $C = \hat{C}$, $\overline{\mathsf{p}}^* = p_{1,1} = \phi_0(p_{0,0})$ can no longer be a sustained as a separating equilibrium if short covering is possible. Likewise we will show that at $C = \underline{C}$, $\overline{\mathsf{p}}^* = p = \phi_0(p_{0,0})$ cannot be sustained as the separating equilibrium.

We will regard situations in which with respect to the offering price the low-type investment bank is indifferent between charging $p_{0,0}$ with all investors buying, $B_{0,1}$, and $\overline{\mathsf{p}}^*$ where only agents with signal $s = 1$ buy, B_1. If the payoffs from short covering are higher in the case of deviating to price $\overline{\mathsf{p}}^*$, then this price can no longer be sustained as a separating price and then, naturally, $\Phi_0(p_{0,0}) < \phi_0(p_{0,0})$ Formally

$$\Pi^2(\overline{\mathsf{p}}^*|B_1, s' = 0) \; > \; \Pi^2(\underline{\mathsf{p}}^*|B_{0,1}, s' = 0) \tag{A.1}$$

$$\Leftrightarrow \sum_{d=\mathsf{S}+\mathsf{O}}^{\Delta(\overline{p}^*)} \begin{matrix} \mathsf{O} \cdot \{(1-\beta)\overline{\mathsf{p}}^* \\ -\mathsf{E}[V|\overline{\mathsf{p}}^*, d]\} \cdot \mathsf{Pr}(d|s' = 0) \end{matrix} \; > \; \sum_{d=0}^{\Delta(\underline{p}^*)} \begin{matrix} \mathsf{O} \cdot \{(1-\beta)\underline{\mathsf{p}}^* \\ -\mathsf{E}[V|\underline{\mathsf{p}}^*, d]\} \cdot \mathsf{Pr}(d|s' = 0) \end{matrix}$$

$$\Leftrightarrow \left. \begin{matrix} (1-\beta)\overline{\mathsf{p}}^* \sum\limits_{d=\mathsf{S}+\mathsf{O}}^{\Delta(\overline{p}^*)} \mathsf{Pr}(d|s'=0) \\ - \sum\limits_{d=\mathsf{S}+\mathsf{O}}^{\Delta(\overline{p}^*)} \mathsf{E}[V|\overline{\mathsf{p}}^*, d] \cdot \mathsf{Pr}(d|s'=0) \end{matrix} \right\} > \left\{ \begin{matrix} (1-\beta)\underline{\mathsf{p}}^* \sum\limits_{d=0}^{\Delta(\underline{p}^*)} \mathsf{Pr}(d|s'=0) \\ - \sum\limits_{d=0}^{\Delta(\underline{p}^*)} \mathsf{E}[V|\underline{\mathsf{p}}^*, d] \cdot \mathsf{Pr}(d|s'=0) \end{matrix} \right.$$

$$\tilde{\Leftrightarrow} \; (1-\beta)\overline{\mathsf{p}}^* \frac{q}{2} \; > \; (1-\beta) p_{0,0} q. \tag{A.2}$$

To see the last step, first recall that $\sum_{d=\mathsf{S}+\mathsf{O}}^{\Delta(\overline{p}^*)} \mathsf{Pr}(d|s' = 0)$ is the weight the agent assigns to demands between $\mathsf{S}+\mathsf{O}$ and $\Delta(\overline{p}^*)$. Inspecting the distribution function given by $\mathsf{Pr}(d|s' = 0)$ one observes that, for n large, it is bimodal, with one peak at $n(1-p)$, and the other at np. The overall weight of the two peaks are q and $1-q$ respectively. $\mathsf{S}+\mathsf{O}$ has been chosen to be in the centre of the first peak, so the weight to the left of this centre and 'to the right of the far-right peak' is exactly $q/2$. Furthermore, note by the same reasoning $\sum_{d=0}^{\Delta(\underline{p}^*)} \mathsf{Pr}(d|s' = 0) = q$. $\mathsf{E}[V|\overline{\mathsf{p}}^*, d]$ is a s-shaped function in d, given by equation (18). This function has a turning point at $\bar{d} := (n/2\ln((1-p)/p) - 0.5\ln((1-q)/q))/(\ln((1-p)/p))$. This point is, for n big enough, very close to $\Delta(\overline{p}^*)$. It is almost zero for $d < \Delta(\overline{p}^*) - 3 \cdot \bar{d}$. In contrast this function is multiplied with the density $\mathsf{Pr}(d|s' = 0)$, which is peaked at $n(1-p)$. For p not too close to $\frac{1}{2}$, (Assumption 3.2 can be interpreted in this sense), this implies that the product of $\mathsf{Pr}(d|s' = 0)$ and $\mathsf{E}[V|\overline{\mathsf{p}}^*, d]$ is zero for almost all d. As long as the conditions which are set on

(A.2) are strong enough, the expectation terms can therefore be neglected. Now to the interesting cases

Step 1: Suppose that $C = \hat{C}$ so that $\overline{\mathsf{p}}^* = p_{1,1}$. Then (A.2) translates to

$$\begin{aligned} (1-\beta)p_{1,1}\frac{q}{2} &> (1-\beta)p_{0,0}q \\ \Leftrightarrow \frac{pq}{2} &> (1-p)(1-q) \\ \Leftrightarrow 1 &> 2\frac{1-p}{p}\,\frac{1-q}{q}. \end{aligned}$$

Clearly, the last inequality is fulfilled by assumption. The condition basically means that p and q must not become too small jointly.

Step 2: Suppose that $C = \underline{C}$ so that $\overline{\mathsf{p}}^* = p$. Then (A.2) translates to

$$\begin{aligned} (1-\beta)p\frac{q}{2} &> (1-\beta)p_{0,0}q \\ \Leftrightarrow \frac{p}{2} &> \frac{(1-p)(1-q)}{pq+(1-p)(1-q)} \\ \Leftrightarrow p^2q + p(1-p)(1-q) &> 2(1-p)(1-q) \\ \Leftrightarrow 1 &> \frac{2-p}{p}\,\frac{1-p}{p}\,\frac{1-q}{q}, \end{aligned}$$

which is again satisfied by assumption.

These two steps complete the argument.

Proof of Proposition 3.1

• The second step of the proof of Lemma 3.1 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 as before.

• The existence of $\hat{C}' > \hat{C}$ is again ensured by Lemma 3.1. By definition, for $C > \hat{C}'$, the highest attainable price is $p_{1,1}$.

• Proof of the second part of the proposition goes exactly along the lines of the argument in Appendix I. Take a separating equilibrium in which in equilibrium both agents make less profit than in the pooling equilibrium. The the Strong Intuitive Criterion demands that also for full-support beliefs of the investors, the investment bank must be better of in equilibrium. Here, this clearly is not the case.

Proof of Proposition 3.2

From Proposition 3.1 we know that a pooling equilibrium results for all $C < \underline{C}'$. $\underline{C}'$ is defined as the value of C for which equation (25) is fulfilled with $\Phi_0(p_{0,0}) = p$. Solving for $\underline{C}'$ and partially differentiating w.r.t. r we obtain

$$\frac{2n(1-p)(1-\beta)}{(1-r)^2}\left(\frac{p}{2} - p_{0,0}\right)$$

which is positive as long as $p/2 > p_{0,0}$ which is true by the Assumption 3.2.

Partially differentiation w.r.t. β we get

$$\frac{2n(1-p)}{q}\left[\frac{p}{2}\left(2 - q - \frac{r}{1+r}q\right) - p_{0,0}\left(1 - \frac{r}{1+r}q\right)\right]$$

which is positive iff

$$(2-q)\frac{p}{2} - p_{0,0} > 0.$$

Using again Assumption 3.2 this holds true for $q < 1$.

Proof of Lemma 5.3

Define $\kappa = (1-\beta)/\beta \cdot r/(1+r)$. Analysis of the definitions for $\hat{C}', \underline{C}', \tilde{\hat{C}}, \tilde{\underline{C}}$ yields

$$\tilde{\underline{C}} = \frac{\beta n(1-p)}{1-\alpha_0}\left(p\alpha_0 - p_{0,0}(1+\kappa q)\right), \tag{A.3}$$

$$\underline{C}' = \frac{\beta n(1-p)}{1-\alpha_0}\left(p(\alpha_0 + \kappa\frac{q}{2}) - p_{0,0}(1+\kappa q)\right), \tag{A.4}$$

$$\tilde{\hat{C}} = \frac{\beta n(1-p)}{1-\alpha_0}\left(p_{1,1}\alpha_0 - p_{0,0}(1+\kappa q)\right), \tag{A.5}$$

$$\hat{C}' = \frac{\beta n(1-p)}{1-\alpha_0}\left(p_{1,1}(\alpha_0 + \kappa\frac{q}{2}) - p_{0,0}(1+\kappa q)\right). \tag{A.6}$$

Then compute

$$\begin{aligned}
\pi^s(\hat{C}') &= \pi^{ns}(\tilde{\hat{C}}) \\
\Leftrightarrow \begin{array}{l}\alpha_1\beta(\mathsf{S}+\mathsf{O})p_{1,1} \\ -(1-\alpha_1)\hat{C}' + \frac{1-q}{2}(1-\beta)\mathsf{O}p_{1,1}\end{array} &= \alpha_1\beta(\mathsf{S}+\mathsf{O})p_{1,1} - (1-\alpha_1)\tilde{\hat{C}} \\
\Leftrightarrow \begin{array}{l}p_{1,1}\frac{1-q}{2}\kappa \\ -\frac{1-\alpha_1}{1-\alpha_0}\left(p_{1,1}(\alpha_0 + \kappa\frac{q}{2}) - p_{0,0}(1+\kappa q)\right)\end{array} &= -\frac{1-\alpha_1}{1-\alpha_0}\left(p_{1,1}\alpha_0 - p_{0,0}(1+\kappa q)\right)
\end{aligned}$$

$$\begin{aligned}\Leftrightarrow p_{1,1}\frac{1-q}{2}\kappa &= \frac{q}{2}\frac{1-\alpha_1}{1-\alpha_0}\kappa p_{1,1}\\ \Leftrightarrow \frac{1-q}{2} &= \frac{q}{2}\ \frac{1-q}{2}\ \frac{2}{q}.\end{aligned}$$

The proof for $\pi^s(\underline{C}') = \pi^{ns}(\underline{\tilde{C}})$ uses the same manipulations and simplifications.

Proof of Proposition 5.1

First we will determine the slopes of the profit functions in C under the assumption that the statement of the proposition holds. In *Case s*, for $C > \hat{C}'$, $p_{1,1}$ will be charged. Hence, the slope of the profit function w.r.t. C is merely $-(1-\alpha_1) < 0$. For $C < \underline{C}'$, the investment bank chooses p, and therefore the profit function is again downward sloping in C with $-(1-\alpha_1)$. The same argument holds for *Case ns* for the respective ranges for $C < \underline{\tilde{C}}$ and $C > \tilde{\hat{C}}$.

Take *Case s*. Suppose $C \in [\underline{C}', \hat{C}']$. Then $\Phi(\cdot)$ is defined by

$$\alpha_0\Phi\beta(\mathsf{S}+\mathsf{O}) - (1-\alpha_0)C + \frac{q}{2}(1-\beta)\mathsf{O}\Phi = p_{0,0}(\beta(\mathsf{S}+\mathsf{O}) + (1-\beta)\mathsf{O}q).$$

Use again $\kappa := \frac{1-\beta}{\beta}\ \frac{r}{1+r}$. The and substitute for the assumed value of $\mathsf{S}+\mathsf{O}$ to obtain

$$\Leftrightarrow \Phi \propto \frac{q}{n(1-p)\beta(2+q(\kappa-1))}\ C.$$

This will be substituted back into the profit function. Collecting terms containing C we obtain the slope of the profit function w.r.t. C to be

$$\begin{aligned}&(\alpha_1\beta(\mathsf{S}+\mathsf{O}) + \frac{q}{2}(1-\beta)\mathsf{O})\frac{q}{n(1-p)\beta(2+q(\kappa-1))} - (1-\alpha_1)\\ =\ &\frac{1}{2}\ q\ \frac{1+q(\kappa+1)}{2+q(\kappa-1)} - \frac{1-q}{2}\\ =\ &\frac{1}{2}\frac{(2q-1)(2+q\kappa)}{2+q(\kappa-1)}.\end{aligned} \tag{A.7}$$

Note that $\kappa > 0$. The numerator of the last fraction is therefore clearly positive. The denominator can only get negative if $\kappa < (q-2)/q < 0$, a contradiction. Hence the slope is positive.

Consider now *Case ns* for $C \in [\underline{\tilde{C}}, \tilde{\hat{C}}]$. $\phi_0'(p_{0,0})$ is defined as $\phi_0'(p_{0,0}) = \frac{p_{0,0}(1+\kappa q)}{\alpha_0} + (1-\alpha_0)/\alpha_0 \cdot C/\beta\mathsf{S}$. Substituting into the profit function and rearranging yields

$$\begin{aligned}\Pi(\phi_0'(p_{0,0})|s'=1,B_1) &\propto \frac{\alpha_1}{\alpha_0}(1-\alpha_0)C-(1-\alpha_1)C\\ &= \underbrace{\frac{\alpha_1-\alpha_0}{\alpha_0}}_{>0}C.\end{aligned}$$

To determine the type (separating or pooling) of equilibrium we proceed in two steps. In the first we will show that the threshold costs C_1 and C_2 exist; furthermore the argumentation will immediately deliver which of the profit functions dominates the other for given costs. In Step 2 we will argue why the (Strong) Intuitive Criterion supports only the described prices.

Step 1 Inspection A.3 to A.6 immediately yields $\hat{C}' > \tilde{\hat{C}}$ and $\underline{C}' > \underline{\tilde{C}}$. Therefore, for $C > \hat{C}'$, $\pi^s(C) = \pi^{ns}(C) + \Pi_2(p_{1,1}|C, s'=1) > \pi^{ns}(C)$. For $C \in (\tilde{C}, \hat{C}')$, $\partial\pi^{ns}(C)/\partial C < 0$, and $\partial\pi^s(C)/\partial C > 0$. Since both functions are linear and because Lemma 5.3 the existence of C_2 is trivial. As similar argument guarantees the existence of C_1.

Step 2 We will focus on several exemplary cases, all other cases follow by analogy. By Lemma 5.1, in any separating equilibrium $\underline{\mathsf{p}}^* = p_{0,0}$ and $a(s'=0) = a_s$. Fix a $C \geq \hat{C}'$ and a separating equilibrium with $\bar{\mathsf{p}}^* = p_{1,1}$, $a(s'=1) = a_{ns}$, and out of equilibrium belief $\mu = 0$. Suppose there was a deviation to $\mathsf{p} \leq p_{1,1}$ and $a = a_s$. Out of equilibrium beliefs would conclude that the low type deviated, and hence the investors' best response is $B_\emptyset$. The definition of $\Phi(C) = p_{1,1}$, however, implies that the $s'=0$ type would note desire to deviate from this price to $\underline{\mathsf{p}}^*$. If this type is excluded from the set of possible deviators, the investor's belief turns $\mu = 1$, and his best response is to buy at $p_{1,1}$. This would yield the $s' = 1$-investment bank higher profits, so such an equilibrium does not satisfy the Intuitive Criterion.

Now fix $C_1 < C < C_2$. Consider a separating equilibrium with $\bar{\mathsf{p}}^* = \Phi(C)$ and $a(s'=1) = a_s$, and out of equilibrium belief $\mu = 0$. Suppose there was a deviation to $\mathsf{p} = \phi'(C) > \Phi(C)$ and $a = a_{ns}$. An investment bank with $s' = 0$ would still not deviate to this behaviour, and hence, when this type is excluded the best-response at ϕ' to $\mu = 1$, is B_1. yielding the investment bank with $s' = 1$ a higher payoff. Hence this equilibrium does not survive the Intuitive Criterion.

Finally consider a $\underline{\tilde{C}} < C < C_1$. Consider a separating equilibrium with $\bar{\mathsf{p}}^* = \phi' > p$, $a(s'=1) = a_{ns}$, and out of equilibrium belief $\mu = 0$. Suppose there was a deviation to $\mathsf{p} = p$ and $a = a_s$. Both investment banks would prefer this deviation for some belief-best-response combination. At the resulting Strong Intuitive Criterion imposed belief of $\mu = .5$, investors' best response is B_1, yielding both agents higher payoffs. Hence such a separation equilibrium does not survive the Strong Intuitive Criterion.

In contrast to the above cases, it is immediately obvious that the only equilibria surviving the strong or the weak intuitive criterion respectively are those price-action pairs where the investment bank with $s' = 1$ is guaranteed maximal profit.

All other cases follow by analogy.

Proof of Lemma 5.2

First, we need to determine C_1 explicitly. At C_1,

$$\phi'(C_1) = \frac{1-\alpha_0}{\alpha_0}\frac{1}{n(1-p)}\frac{1}{\beta}C_1 + \frac{p_{0,0}}{\alpha_0}\left(\beta + q(1-\beta)\frac{r}{1+r}\right). \quad \text{(A.8)}$$

At C_1, pooling in $\mathsf{p}^* = p$ with $a(s'=1) = a(s'=0) = a_s$ yields the same profits as separating with $\bar{\mathsf{p}}^* = \phi'(C_1)$ and $a(s'=1) = a_{ns}$. We can then use A.8 to simplify and solve the following equation for C_1 as a function of β

$$\begin{aligned} \pi^n(C_1) &= \pi^{ns}(C_1) \qquad \text{(A.9)} \\ \Leftrightarrow C_1 &\propto \beta \cdot \left(\frac{p}{2}\left(2 - \frac{1-q}{\alpha_1}\frac{r}{1+r}\right) - p_{0,0}\left(\frac{1}{\alpha_0} - \frac{q}{\alpha_0}\frac{r}{1+r}\right)\right). \end{aligned}$$

By Assumption 3.2, $p/2 - p_{0,0} > 0$. It therefore suffices to show that

$$\begin{aligned} 2 - \frac{1-q}{\alpha_1}\frac{r}{1+r} &> \frac{1}{\alpha_0} - \frac{q}{\alpha_0}\frac{r}{1+r} \\ \Leftrightarrow 1 - \frac{1}{2-q} &> \left(\frac{1-q}{1+q} - \frac{q}{2-q}\right)\frac{r}{1+r} \\ \Leftrightarrow 1 - q^2 &> 2(1-2q)\frac{r}{1+r}. \end{aligned}$$

But $1 - q^2 > 0$, whereas $1 - 2q < 0$. Hence the derivative of C_1 with respect to β is positive.

We can also simplify A.9 with respect to $r/(1+r)$ to obtain

$$\Leftrightarrow C_1 \propto \frac{r}{1+r}\left(\frac{p}{2}(1-q) - p_{0,0}\left(\frac{\alpha_1}{\alpha_0}q\right)\right). \quad \text{(A.10)}$$

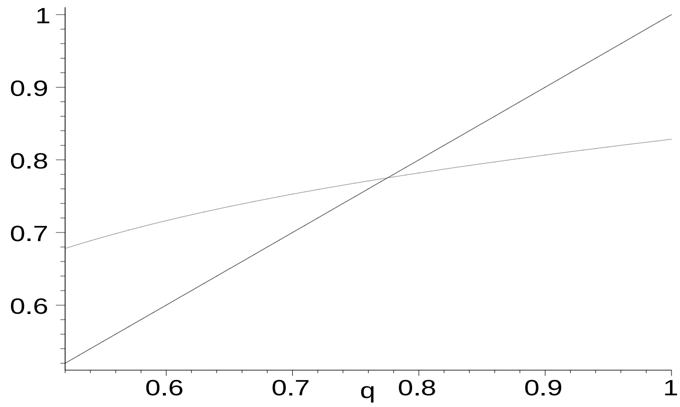

Figure 1. Plot for the Zero Slope in Equation A.10

The sign of this slope in r, however, is not immediately obvious. Figure 1 displays the ratio of p to q for which the slope is zero. For any given q, all points above the plotted line indicate points for which the slope is positive in r; the identity line indicates which of these cases are feasible. The point where the identity intersects the plot of p against q is the threshold point q^*, such that for $q < q^*$, the slope is ultimately negative. For each $q > q^*$ the described level p^* is exactly $p(q)$.

REFERENCES

Aggarwal, R. (2000). Stabilization activities by underwriters after initial public offerings, *Journal of Finance* **55**: 1075–1103.

Allen, F. and Faulhaber, G. (1989). Signalling by underpricing in the ipo market, *Journal of Financial Economics* **23**: 303–323.

Baron, D. P. (1979). The incentive problem and the design of investment banking contracts, *Journal of Banking and Finance* **3**: 157–175.

Baron, D. P. (1982). A model of the demand for investment banking advising and distributing services for new issues, *Journal of Finance* **37**: 955–976.

Baron, D. P. and Holmström, B. (1980). The investment banking contract for new issues under asymmetric information: Delegation and the incentive problem, *Journal of Finance* **35**: 1115–1138.

Beatty, R. P. and Ritter, J. R. (1986). Investment banking, reputation, and underpricing of initial public offerings, *Journal of Financial Economics* **15**: 213–232.

Benveniste, L. and Spindt, P. A. (1989). How investment bankers determine the offer price and allocation of initial public offerings, *Journal of Financial Economics* **24**: 343–362.

Benveniste, L., Busaba, W. and Wilhelm Jr., W. (1996). Price stabilization as a bonding mechanism in equity issues, *Journal of Financial Economics* **42**: 223–255.

Benveniste, L. M., Erdal, S. M. and Wilhelm Jr., W. J. (1998). Who benefits from secondary market price stabilization of ipos?, *Journal of Banking and Finance* **22**: 741–767.

Booth, J. R. and Chua, L. (1996). Ownership dispersion, costly information, and ipo underpricing, *Journal of Financial Economics* **41**: 291–310.

Booth, J. R. and Smith, R. L. (1986). Capital raising, underwriting and the certification hypothesis, *Journal of Financial Economics* **15**: 261–281.

Brennan, M. J. and Franks, J. (1997). Underpricing, ownership and control in initial public offerings of equity securities in the uk, *Journal of Financial Economics* **45**: 391–413.

Busaba, W. Y., Benveniste, L. M. and Guo, R.-J. (2001). The option to withdraw ipos during the premarket: empirical analysis, *Journal of Financial Economics* **60**: 73–102.

Chen, H.-C. and Ritter, J. (2000). The seven percent solution, *Journal of Finance* **55**: 1105–1131.

Cho, I.-K. and Kreps, D. (1987). Signaling games and stable equilibria, *Quarterly Journal of Economics* **102**: 179–222.

Chowdhry, B. and Nanda, V. (1996). Stabilization, syndication, and pricing of ipos, *Journal of Financial and Quantitative Analysis* **31**: 25–42.

Ellis, K., Michaely, R. and O'Hara, M. (2000). When the underwriter is the market maker: An examination of trading in the ipo aftermarket, *Journal of Finance* **55**: 1039–1074.

FESCO (2001). Stabilisation and allotment, *Consultative paper, fesco/01-037b*, The Forum of European Securities Commissions.

Fudenberg, D. and Tirole, J. (1991). *Game Theory*, MIT-Press, Cambridge, Massachusetts.

Grinblatt, M. and Hwang, C. Y. (1989). Signalling and the pricing of new issues, *Journal of Finance* **44**: 393–420.

Hanley, K. W., Kumar, A. and Seguin, P. (1993). Price stabilisation in the market for new issues, *Journal of Financial Economics* **34**: 177–197.

Ibbotson, R. G., Sindelar, J. G. and Ritter, J. (1994). The market's problems with the pricing of initial public offerings, *Journal of Applied Corporate Finance* **7**: 66–74.

Krigman, L., Shaw, W. H. and Womack, K. L. (1999). The persistence of ipo mispricing and the predictive power of flipping, *Journal of Finance* **54**: 1015–1044.

Mandelker, G. and Raviv, A. (1977). Investment banking: An economic analysis of optimal underwriting contracts, *Journal of Finance* **32**: 683–694.

Nanda, V. and Yun, Y. (1997). Reputation and financial intermediation: An empirical investigation of the impact of ipo mispricing on underwriter market value, *Journal of Financial Intermediation* **6**: 39–63.

Ritter, J. (1991). The long-run performance of initial public offerings, *Journal of Finance* **46**: 3–28.

Rock, K. (1986). Why new issues are underpriced, *Journal of Financial Economics* **15**: 187–212.

Ruud, J. S. (1993). Underwriter price support and the ipo underpricing puzzle, *Journal of Financial Economics* **34**: 135–151.

Schultz, P. H. and Zaman, M. A. (1994). Aftermarket support and underpricing of initial public offerings, *Journal of Financial Economics* **35**: 199–219.

SEC (1997). Regulation m, *Release no. 34-38067*, Securities and Exchange Commission (SEC).

Teoh, S. H., Welch, I. and Wong, T. J. (1998). Earnings management and the long-run market performance of initial public offerings, *Journal of Finance* **53**: 1935–1974.

Tiniç, S. M. (1988). Anatomy of initial public offerings of common stock, *Journal of Finance* **43**: 789–822.

Welch, I. (1989). Seasoned offerings, imitation costs, and the underpricing of initial public offerings, *Journal of Finance* **44**: 421–449.

Welch, I. (1992). Sequential sales, learning, and cascades, *Journal of Finance* **47**: 695–732.