# Ownership Structure and the Life-Cycle of the Firm: A Theory of the Decision to go Public

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**Abstract**

This paper presents a theory of initial public offerings based on the idea that the optimal ownership structure of a company changes over the life cycle of the firm. Insiders take the company public when they have lost the comparative advantage over outsiders in gathering information to evaluate the firm's growth prospects. The size of the share sold to the public depends on the relative abilities of the market and insiders to gather this information and on the frictions in the going-public process. Intermediaries help to reduce these frictions and lead to a more efficient allocation if IPOs are conducted more frequently. Discrimination between different classes of investors may be beneficial. Learning by the market about projects in a new industry can lead to a clustering of new issues (hot issue markets).



**JEL Classification:** G24, G32

**Keywords: Initial Public Offerings, Going Public, Underwriting**

# 1 Introduction

This paper presents a theory of initial public offerings based on the idea that the optimal ownership structure of a company changes over the life cycle of the firm. During some phases of the firm's development it is optimal to keep the company private. However, as the firm progresses through different stages of its life cycle, the optimal ownership structure also changes. The hypothesis of this paper is that going public becomes optimal whenever outside investors have a comparative advantage in collecting information that is useful for future capital budgeting decisions. During those phases of the company's life cycle where *firm-specific* information is most critical, insiders have an advantage to gather information about the company. However, whenever industry or *market-specific* information is more important, investors' incremental costs for gathering information about any particular firm are small. Then public firms can usefully employ the stock market's ability to aggregate information, and the stock price communicates this information back to the firm and helps it to make more informed decisions. The argument here therefore implies that an initial public offering marks a stage in the life cycle of the firm, as is the case for venture capital firms, reverse LBOs, and, typically, equity carve-outs.[1]

We consider the decision-making problem of an entrepreneur who is the sole owner of a company. For each stage in the firm's life cycle, the entrepreneur has to choose between staying private and going public.[2] The main cost of staying

[1]The institutional structure of US venture capital institutions was described in detail by Sahlman (1990). The pattern of stage financing was documented by Gompers (1995). For reverse LBOs see Degeorge and Zeckhauser (1993) and Muscarella and Vetsuypens (1989), (1990). On equity carve-outs see, e. .g, Klein, Rosenfeld, and Beranek (1991) and Schipper and Smith (1989). Some funds use unlevered equity investments. *Investcorp's* strategy was cited as buying "medium-term recovery stocks" and then "working with management to improve the company's performance until it is ready for sale or flotation," see: *Financial Times, October 23 1995, p. 23.*

[2]Gompers (1995) observes that many venture capitalists finance companies in stages, and

private is the strong commitment to incur the cost of gathering information for future decisions. The main cost of going public comes from IPO underpricing: information collection by some investors leads to an adverse selection discount. Hence, the approach advocated here integrates a theory of IPO underpricing into a theory of the decision to go public. This is important, since previous theories of IPO underpricing explain only why underpricing occurs if the offer is conducted using a *given* mechanism and the firm has to go public for other reasons.[3] However, empirical evidence suggests that using other mechanisms and conducting public offerings of equity such as competitive auctions could eliminate most underpricing typically observed.[4] Moreover, underpricing in public equity offerings could be avoided in many cases by placing equity privately, or by raising debt. Hence, theories of underpricing are incomplete if they cannot explain why companies do not choose one of these alternatives that could avoid the cost from underpricing. Conventionally, models in corporate finance have emphasized the transmission of information from management to the market. This model emphasizes the collection of information by the market that is then communicated to the company through the share price and ultimately affects the value of the company itself.

One interesting implication of this model is that the process of going public can change the comparative advantages of investors relative to entrepreneurs. The first issuers in a new industry encounter the problem that investors find the new firms difficult to evaluate, creating a significant hurdle for the first firms that issue stock, since they have to compensate investors for this learning process. Subsequent issuers benefit from this learning process, since it increases the advantage of investors in gathering information, and reduces the hurdle for future public offer-

entrepreneurs and venture capitalists make a decision on going public versus refinancing through private placements or borrowing at every stage of the company's life-cycle.

[3]E. g. a fixed price offering (Rock (1986)), or bookbuilding (Benveniste and Spindt (1989)).

[4]See Jacquillat and McDonald (1974) for France, Kandel, Sarig and Wohl (1997) for Israel and Su and Fleisher (1997) for Chinese IPOs.

ings. As a result, a clustering of issues in 'hot issue markets' can develop, where some early offerings trigger a wave of later offerings in the same industry.[5]

The main role of intermediaries in this context is to reduce the frictions inherent in the going public process. Informed investors obtain informational rents which increase the costs of going public for the entrepreneur above the social costs of going public. As a result the company will be taken public inefficiently late, and the share offered to the public will be inefficiently small. Intermediaries can help to reduce these informational rents and move the allocation closer to the social optimum.

The remainder of the paper is organized as follows. Section 2 discusses the literature. Section 3 explains the setup of the model and section 4 analyzes the main features. Section 5 analyzes the decision to go public. Section 6 derives the main empirical predictions. Section 7 shows why an intermediary may be important and Section 8 concludes. Proofs are deferred to the appendix. A table of symbols can be found on page 29.

## 2 Discussion of the Literature

Some papers have recently addressed the decision to go public.[6] Pagano (1993) argues that a firm's decision to go public improves the benefits from diversification. This has an externality for other firms which may lead to coordination failure. Shah and Thakor (1988) also discuss the question of private versus public incorporation of an asset and emphasize the benefit of going public if risk is diversifiable. Pagano and Roëll (1998) argue that going public may reduce the interest of large shareholders to overmonitor the company. Chemmanur and Fulghieri (1999) analyze the decision of an entrepreneur to place shares privately with a venture capitalist, or to go public. Their set-up provides a different model of the

[5] For a related notion, see Subrahmanyam and Titman (1999).

[6] For a survey, see also Roëll (1996).

decision to go public from the model here, since we assume that private venture capital finance precedes the IPO, and the IPO is a form for the VC to (partially) exit the firm, whereas they treat going public as an alternative to venture capital finance.[7] Also, they assume that costly information observed by several investors would simply be wasteful duplication, whereas here the information observed by investors also complements the information observed by the entrepreneur. Finally, they do not develop a theory of underpricing, whereas the model here produces a model that explains why firms go public even though they have to accept adverse selection discounts on newly issued stock. Rajan (1992) shows that the costs of bank lending may be reduced if banks face competition from the equity market after a firm goes public, thereby formulating an alternative theory of the going public decision. Zingales (1995) argues that going public reduces the bargaining power of a bidder who has a higher valuation of the company, so the IPO increases the payoff from the transaction for the seller. Benveniste, Busaba and Wilhelm (1997) argue that firms learn industry information through the offering process of *other* firms.

While all of these papers emphasize important aspects of the decision to go public, they do not account for underpricing. Moreover, this paper is distinct in its emphasis on the flow of information from the stock market to the capital budgeting process of the company and it also integrates the theory of underpricing with an explanation of the decision to go public. Holmström and Tirole (1993) argue that companies can benefit from going public because the information aggregated in the stock price improves managerial compensation contracts. Their framework is extended by Stoughton, Wong and Zechner (1997) who relate the decision to go public to the signaling of quality in the product market. Holmström and Tirole (1993) as well as Stoughton, Wong and Zechner (1997) model underpricing through

[7] Gompers (1995) documents that venture capitalists usually fund investment projects through several rounds, and then exit either through an IPO or an acquisition by a third party (if the company does not stay private or is liquidated).

adverse selection in the secondary market, although it is difficult to see how this can account for the immediate price reaction in the first day of trading typically associated with IPOs. Subrahmanyam and Titman (1999) develop a model of the decision to go public that emphasizes the microstructure of the secondary market where information of investors is aggregated. They contrast the “serendipitous” information collected by investors with the costly information better collected by private financiers. The differences between information collected by the entrepreneur and information collected by outsiders is reflected here in the exogenous costs associated with information collection.

There are several approaches to account for IPO underpricing.[8] One approach regards underpricing as a signaling cost (Allen and Faulhaber (1989), Grinblatt and Hwang (1989), Welch (1989)). The issuer has to incur these costs in order to distinguish her quality and obtain preferential treatment in the future, e. g., in secondary offerings. Another approach is the adverse selection model of Rock (1986), which shows that underpriced shares compensate uninformed investors for the losses they sustain because they have a higher likelihood of receiving shares in overpriced issues. Chemmanur (1993) develops a theory of IPO underpricing that also focuses on the motivation for information production by outside investors. His model bears some similarity to signaling arguments since the motivation for costly signaling comes from future secondary offerings. Van Bommel (1997) extends this framework to a capital budgeting problem in order to analyze the feedback of market prices to managerial decisions. Michaely and Shaw (1994) find more support for the adverse selection argument for underpricing, and conclude that there is little support for signaling theories. Stoughton and Zechner (1998) analyze the relationship between ownership structure and IPO-mechanisms and show how IPO underpricing can result from the entrepreneur’s desire to induce a large shareholder

[8] The literature on IPOs and particularly underpricing is vast and this section does not attempt to give a comprehensive survey. See the recent surveys by Jenkinson and Ljungqvist (1996) and Anderson, Beard and Born (1995).

to hold a larger stake and thereby increase future monitoring. Their assumption is similar to Mello and Parsons (1998) who also assume that the major concern at the IPO stage is to motivate an outside investor to *become* a large blockholder through purchasing a major stake, whereas this paper takes the perspective of an already *existing* blockholder to retain her stake. This approach is consistent with the results of Brennan and Franks (1997) who argue that entrepreneurs underprice IPOs because the resulting oversubscription of new issues allows them to increase the stake held by *small* investors and to protect the control benefits of the entrepreneur against monitoring by a large shareholder.

# 3 Setup of the Model

Consider a privately held company where initially the entrepreneur ($E$) owns all the shares of the company. The model also applies to firms where a major block of shares is owned by a venture capitalist, an LBO-fund, or where parent companies take a subsidiary public in an equity-carveout. In these cases the place of the 'entrepreneur' would be the venture capitalist or the parent company.[9] The total number of shares in the company is normalized to one. The entrepreneur considers to take the company public by floating a fraction $\beta$ of the shares on the stock market. If the firm continues to operate, the assets of the firm generate a random return $\tilde{N}$, where:

$$\tilde{N} = \begin{cases} G > 0 & \textit{with probability} \quad x \\ B < 0 & \textit{with probability} \quad 1 - x \end{cases} \tag{1}$$

[9] In this case additional agency problems between the venture capitalist or the parent company and the entrepreneur or the subsidiary's would arise. The model described below can be given an agency interpretation as follows: the management prefers to continue operations and invest in all states of the world, and the parent or venture capitalist monitors the company and prevents managers from overinvesting. These agency problems are not modeled explicitly.

and $xG + (1 - x)B > 0$. If the firm does not proceed to the next stage, then the payoff is normalized to zero. We shall refer to the decision about whether or not to continue operations and proceed to the next stage of the firm's life cycle as 'the project,' and to $\tilde{N}$ as the payoff of this project. $E$ has some expertise with the project and collects additional information in order to reduce the uncertainty about future payoffs. This information takes the form of a signal $\sigma \in \{\underline{\sigma}, \bar{\sigma}\}$ observed by $E$ that satisfies the following conditions:

$$\Pr(\bar{\sigma} | G) = 1 - \epsilon \quad \Pr(\underline{\sigma} | G) = \epsilon \quad \Pr(\underline{\sigma} | B) = 1 \tag{2}$$

In order to acquire this information $E$ incurs costs of $\frac{d}{2}(1 - \epsilon)^2$, where $d > 0$. We refer to $\epsilon$ as the *error* and to $1 - \epsilon$ as the *precision* of $E$'s signal. Clearly, if $\epsilon = 0$, the precision of the signal is 1 and the signal is perfect.

An external investor will research the firm and consider investing in it. Only this investor can observe a signal $\Sigma$ about the value of the project, whereas all other investors are uninformed. The signal $\Sigma \in \{L, H\}$ observed by the informed investor satisfies:

$$\Pr(H | G) = 1 - \eta \quad \Pr(L | G) = \eta \quad \Pr(L | B) = 1 \tag{3}$$

The informed investor incurs costs of $\frac{c}{2}(1 - \eta)^2$ for acquiring this information, where $c > 0$. The intensity of monitoring by the informed investor is reflected in the precision of the signal $\Sigma$ and is measured by $1 - \eta$, analogous to the signal acquired by $E$.[10] We could also model the information collection by the market as a process where many investors become informed, who can acquire information at costs that vary across investors. In this sense the informed investor here is a representative investor. For tractability, we do not model the information aggregation role of the market explicitly.

[10] In the following we use the term "monitoring" synonymously with "gathering information" for brevity.

The informed investor will use his information to decide on the quantity of shares he applies for in the initial public offering. If the informed investor's signal indicates that buying shares in the IPO is profitable, i. e. the offering price at which he can buy shares does not exceed his estimate of their intrinsic value, he applies for $Q_I$ shares. Otherwise he applies for no shares at all.[11] Uninformed investors rely only on publicly available information and do not observe $\Sigma$ or $\sigma$. They apply for $Q_U$ shares only if they do not expect to make a loss by participating in the IPO.[12] The number of shares sold, $\beta$, may depend on the information acquired by investors, and we write $\beta^L$, $\beta^H$ for the signal-contingent number of shares sold after the informed investor has observed the high and the low signal, respectively. Assume also that $Q_U > \beta^H$, so that any offering is fully subscribed if uninformed investors decide to apply.[13] Note that apart from this - arguably mild - restriction, our formulation is completely general, in that it covers firm commitment offerings with overallotment options, best-effort offerings, and even offerings that fail if investors observe a bad signal (so that $\beta^L = 0$).[14]

If the offering is oversubscribed, then $q$ shares are allocated to the informed investor.[15] The remaining $\beta^H - q$ shares are allocated pro rata to uninformed investors, who buy all $\beta^L$ shares if the informed investor does not apply. This setup is familiar from Rock's (1986) model, the only different assumption in his model being pro-rata rationing in case of oversubscription. In our model the degree

[11] Keloharju (1997) has documented for a sample of Finnish IPOs that some investors vary their demand in IPOs depending on their information.

[12] These constraints are modeled explicitly in the appendix, see equations (30) and (9).

[13] The assumption that $Q_U > \beta^H$ is stronger than required for this model. We only need that $Q_U \geq \beta^H$ so that the offering never fails, even if investors have learned bad news.

[14] In a firm-commitment offering without an overallotment option, the number of shares sold could not be contingent on the signal observed by investors and we would need $\beta^H = \beta^L$ as an additional restriction.

[15] Note that this already anticipates the result that the informed investor does not apply (and therefore does not receive) any shares after observing the low signal. We will relax this assumption later.

of adverse selection depends on the number of shares uninformed investors buy in the bad state ($\beta^L$) relative to the number they buy in the good state. (namely, $\beta^H - q$.)

$E$ learns the total demand in the IPO. We will see that this is generally equivalent to observing the information of the informed investor directly. The entrepreneur must reveal all information about the company she has *prior* to the IPO in the offering documents. Hence, we assume that there is no asymmetric information between $E$ and investors before the IPO. We can summarize the extensive form of the model as follows:

1. $E$ announces the offering and chooses the offering parameters ($\beta^L$, $\beta^H$, $q$, $P_0$). $E$ also decides how much information to collect ($\varepsilon$). The decision about $\varepsilon$ is not observable by outsiders.

2. Uninformed investors decide whether to apply for shares or not. Some investor decides how much information to collect ($\eta$). Then the investor observes the signal $\Sigma \in \{L, H\}$ and decides whether to apply for shares or not.

3. $E$ observes the demand for the company's stock and allocates the shares to investors at the offering price $P_0$. If the informed investor applies, $E$ allocates $\beta^H$ shares, $\beta^H - q$ to uninformed investors and $q$ to the informed investor. If only uninformed investors apply, they receive $\beta^L$ shares. Investors in the secondary market observe the offering terms and shares trade at the secondary market price $P^S$.

4. $E$ observes a private signal $\sigma \in \{\underline{\sigma}, \bar{\sigma}\}$ and decides whether to continue the project or not. Then the payoff $\tilde{v} \in \{B, G, 0\}$ is realized.

Our specification makes the information of the entrepreneur and outside investors substitutes. This does not necessarily imply that they learn the *same* information, since they can decide to learn about different aspects of the company's project. All differences in the informative signals observed by $E$ and the investor are expressed through the parameters of information acquisition costs, $d$, $c$ and not through the structure of the signals themselves. One interpretation is that there are some aspects of the business that are easier for the entrepreneur to learn, and others that are easier to learn for outside investors. All information (signals and the outcomes of decisions) becomes publicly available information before any secondary offering the firm may undertake. Hence, any shares offered in a possible seasoned offering after the IPO can be sold at their intrinsic value, and we do not have to distinguish between shares held to maturity and shares offered in a subsequent seasoned offering.

# 4 Analysis of the Model

Denote by $P^S$, $s \in \{L,\ H\}$ , the valuation of the company contingent on the signal of the informed investor. Note that this is also the price prevailing in secondary markets after the information acquired by the informed investor is fully incorporated into prices, but before the true state or the signal collected by the entrepreneur is known. Whenever the informed investor participates and buys only in the good state, his information is revealed through the degree of oversubscription in the offering, and is generally incorporated into the price on the first trading day.[16] Denote the joint probability of observing the high signal $H$ by $\pi = x(1-\eta)$.[17]

The informed investor will never apply for shares in the low state because they are overpriced conditional on his signal. If the informed investor observes the high

[16]However, whether this actually happens is immaterial for the analysis of the model. The only thing that is important is that the entrepreneur learns the degree of oversubscription before she makes a decision on the project.

[17]The stochastic structure of the model is summarized in more detail in table 1 in the appendix, see p. 31.

signal, he receives $q$ shares and uninformed investors receive the remaining $\beta^H - q$ shares. If the informed investor observes the low signal, he does not apply, and uninformed investors receive all $\beta^L$ shares at $P_0$ in the offering.[18] His incentives are given from obtaining underpriced shares in the good state. Hence, he maximizes:

$$V_I = q\pi \left(P^H - P_0\right) - \frac{c}{2}\left(1-\eta\right)^2 \quad . \tag{4}$$

However, the investor may choose to remain uninformed and apply for shares to receive:

$$q\left(x\left(P^H - P_0\right) + (1-x)\left(P^L - P_0\right)\right) \quad . \tag{5}$$

Then we can describe the investor's decision rule:

**Proposition 1** *: For any given number of shares offered $\beta^H, \beta^L \in [0,1]$, there exists a minimum price $\underline{P} \geq P^L$ so that the investor will only become informed if $P_0 > \underline{P}$. For any given offering price $P_0 > P_L$ the investor becomes informed only if the number of shares offered to him exceeds some lower bound $\underline{q}$. If the payoff from remaining uninformed is strictly positive, then $\underline{q} > 0$. If the informed investor acquires information, he chooses the precision of his signal so that:*

$$\eta^* = Max\left[1 - \frac{qx}{c}\left(P^H - P_0\right),\ 0\right] \quad . \tag{6}$$

Note that $P_0 > P^H$ leads to zero demand for shares in the IPO. This case is therefore not considered here. It is easy to see that the investor collects more information if $q$ is higher, if $P^H - P_0$ is higher, and less information if $c$ is higher. This information is then revealed to $E$ and to secondary markets, since they can observe the total demand for the IPO. The lower bound for $q$ is necessary because it induces a minimal amount of information acquisition by the investor. Acquiring very small amounts of information is ruled out because the investor would then

[18] This assumes that $P^L \leq P_0 < P^H$. If $P_0 \geq P^H$, the informed investor would never apply. If $P^L > P_0$, the investor would never become informed. It will become clear from the analysis below that both of these cases cannot occur in equilibrium, so the analysis will focus on $P^L \leq P_0 < P^H$.

prefer not to acquire any information and apply for all IPOs, which are on average underpriced. Hence, small IPOs with deeply discounted shares are ruled out by this result.

$E$ updates her beliefs about the probability of the good state from her prior $x$ to $b$, where $b$ depends on the information revealed in the IPO and on the signal observed by $E$ herself. If $b$ falls below some critical value $\hat{b}$, $E$ decides to stop the project (discontinue operations). Hence, $E$ has to decide whether and how much information to collect in view of her intention to use this information in the future.

*E's* objective when deciding on her degree of information collection is to maximize her net payoff from the offering, i. e. the value of her claims net of monitoring costs. *E's* objective consists of the price $P_0$ she receives for the $\beta^S$ shares she sells in the offering, the payoff on the $1-\beta^S$ shares she retains, and her monitoring costs:

$$V = \pi \left(\beta^H P_0 + \left(1-\beta^H\right) P^H\right) + (1-\pi)\left(\beta^L P_0 + \left(1-\beta^L\right) P^L\right) - \frac{d}{2}(1-\varepsilon)^2 \quad (7)$$

After the IPO, outsiders cannot observe E's information collection, hence she can reduce the precision of her information without any implication for the revenues she receives in the IPO, although outside investors will anticipate her incentives to do so. This gives immediately:

**Proposition 2** *: E acquires additional information if and only if (a) she stops the project with positive probability and (b) if the investor's information is imperfect, but sufficiently precise (i. e., for some threshold $\overline{\eta} \leq 1$ we have $0 < \eta \leq \overline{\eta}$). Then the optimal error for her signal $\sigma$ is given by:*

$$\epsilon^* = Max\left[1 - \frac{\left(1-\beta^L\right) x\eta G}{d},\ 0\right] \quad (8)$$

*She will stop the project if and only if both signals are unfavorable ($\sigma = \underline{\sigma}$ and $\Sigma = L$).*

Condition (a) is intuitive and simply says that $E$ only pays for costly information if she intends to use it. Condition (b) arises from the specification of the information structure: if the outside investor becomes perfectly informed, then any additional information is worthless, hence $E$ remains uninformed. Also, for $E$ to discontinue operations, she has to be reasonably sure in her assessment of the negative outcome. Equation (8) shows that the entrepreneur becomes better informed if the informed investor becomes less informed, if her information gathering costs are lower and if she retains a larger stake after the IPO. If the information revealed through the IPO is imprecise, and if $E$ has high information gathering costs, then the investor's and $E$'s information combined is insufficient to justify stopping the project, hence $E$ decides to stay uninformed in that case.

Uninformed investors will participate in the offering only if the expected losses they sustain from purchasing overpriced shares are not larger than the expected gains from purchasing underpriced shares. This requirement can be expressed as:

$$\pi\left(\beta^H - q\right)\left(P^H - P_0\right) + (1-\pi)\,\beta^L\left(P^L - P_0\right) \geq 0 \tag{9}$$

We will show below (Proposition [19]) that this constraint is always binding as an equality. We define expected IPO underpricing $\Delta$ as:

$$\Delta \equiv \pi\beta^H\left(P^H - P_0\right) + (1-\pi)\,\beta^L\left(P^L - P_0\right) \tag{10}$$

This definition of underpricing is the expected difference between the secondary market price $P^S$ and the offering price $P_0$, weighted by the number of shares sold to outside investors.[20] Then the entrepreneur's objective (7) can now be rewritten as:

$$V = \pi P^H + (1-\pi)\,P^L - \Delta - \frac{d}{2}\,(1-\epsilon)^2 \tag{11}$$

[19] Optimum objective

[20] Note that this is proportional to the dollar return of an investor who purchases a constant fraction of the shares offered in each IPO.

where the objective depends on $P_0$ since $\Delta$ is a function of $P_0$ from (10). Equation (11) gives the main trade-off of the model. The entrepreneur has two sources of monitoring information: (a) the information collected by the informed investor and revealed through the demand for shares in the IPO, and (b) the information she collects herself. The following result establishes the main aspect of this trade-off and follows directly from Proposition 2:

**Corollary 3** *: Information collection by outside investors and information collection by E are substitute activities ($\partial\varepsilon/\partial\eta < 0$). E gathers more costly information if she expects the error $\eta$ associated with the investor's signal $\Sigma$ to be larger.*

Hence, *E's* expected monitoring costs decrease in the precision of the information revealed in the IPO. By going public she can use the information collection capacity of the stock market in order to reduce her costs from acquiring information. IPO underpricing can then be understood as a cost she has to pay for the information collected by the market. We have the following implication:

**Proposition 4** *: The objective (11) can be rewritten as:*

$$V = xG\left(1-\eta^{*}\epsilon^{*}\right) - c\left(1-\eta^{*}\right)^{2} - \frac{d}{2}\left(1-\epsilon^{*}\right)^{2} \tag{12}$$

*The informed investor extracts a rent net of his costs of collecting information equal to $\frac{c}{2}\left(1-\eta^{*}\right)^{2}$. Uninformed investors do not receive a rent from purchasing underpriced shares.*

Expression (12) allows us to understand how $E$ trades off the value of information collected by outsiders against the costs of underpricing. Suppose, $E$ could identify the informed investor and information were contractible. Then $E$ could simply contract with the investor to collect information and disclose it.[21] In this

[21] Recall that we interpret the investor here as a representative of many investors whose information is aggregated in the market. The literal case of one investor would be more akin to a private placement. (See Chemmanur and Fulghieri (1999)). If information is not contractible, the employee would still extract an informational rent.

case the signal $\Sigma$ would be produced by an employee and $E$ would have to reimburse this employee for the costs $\frac{c}{2}(1-\eta)^2$ incurred. However, the informed investor also extracts an informational rent in addition to being reimbursed for his costs, so that the total transfer to the informed investor is $c(1-\eta)^2$. The rent arises from the fact that information production cannot be contracted upon. Uninformed investors do not receive a rent here, since the entrepreneur can adjust the terms of the offering so that (9) is binding: if (9) were slack, then the entrepreneur could for example increase the offering price or reduce $\beta^H$ in order to reduce the rents extracted by uninformed investors.

We can now infer the terms of the public share offering from Proposition 4 and the maximization of (12):

**Proposition 5** *Offering Terms: If the entrepreneur takes the company public, she will offer the shares at a price*

$$P_0 = P^H - \frac{c(1-\eta)}{qx} = G - \frac{V_I}{q\pi/2} \tag{13}$$

*Then the entrepreneur will always choose to remain imperfectly informed ($\varepsilon > 0$), the investor will always acquire some information ($\eta > 1$).*

Proposition 5 has some interesting implications. Firstly, whenever the entrepreneur wishes the investor to become better informed (reduce $\eta$), she needs to either discount the offering more strongly (reduce $P_0$), or sell more underpriced shares to the informed investor (increase $q$). The second part of equation (13) also shows that the offering price is decreasing in the rent extracted by the informed investor. The other results are implications of the previous analysis: if the entrepreneur became perfectly informed, she would not require any additional input for her decision, and she would not take the company public as private ownership would be perfectly sufficient. Conversely, if the investor did not become informed, the entrepreneur would also refrain from going public.

# 5 The Decision to Go Public

In the previous section we have shown that going public is costly for the entrepreneur, because she needs to underprice the shares she offers. We maintain that the entrepreneur has other sources of finance she could use that are not modeled here, so we exclude financing requirements as a motivation to go public. We argue now that the main reason $E$ prefers to go public is that the stock market has a comparative advantage at evaluating the prospects of investments in the company. While $E$ has sufficient expertise to run the company, it may be optimal for her to use the information gathering capacity of the stock market. We can show:

**Proposition 6** ***Going Public:*** *There exists a critical value $\hat{d}$ such that it is optimal for $E$ to go public whenever $d \geq \hat{d}$ and it is optimal to stay private otherwise. The cutoff point $\hat{d}$ is increasing in $c$.*

This result is intuitive. It states that whenever the entrepreneur is sufficiently inefficient at gathering information ($d \geq \hat{d}$), then it is optimal for the company to go public and exploit the information gathering capacity of the stock market. Moreover, the cutoff point for the entrepreneur's information gathering costs above which it is optimal for the entrepreneur to go public depends on the efficiency of the stock market to monitor the firm, and the more efficient the stock market is, the more likely is it that the entrepreneur goes public. Hence, the cutoff point $\hat{d}$ above which the entrepreneur is sufficiently disadvantaged at gathering information to prefer going public defines the point above which the stock market has a sufficient comparative advantage relative to the entrepreneur. The efficiency of the stock market from the entrepreneur's point of view depends on the information gathering costs of the stock market. This is a measure of the ability of stock market analysts to understand the technology and the market the firm is in and analyze its earning prospects.

We do not present comparative static results in terms of $\beta^L$, $\beta^H$ here, since these are generally ambiguous for the current model. One would expect that a larger $\beta^S$ is optimal if the entrepreneur is less efficient and the stock market is more efficient. However, the dependence of $\varepsilon$ and $\eta$ from (6) introduces countervailing effects, and they are not necessarily second order effects. Hence, from here on we treat $\beta^S$ as an exogenous parameter that must satisfy the conditions given in Proposition 1.[22]

Proposition 6 refers to the general notion that companies go through life cycles. In the early stages of the company's life-cycle, evaluation of its investment projects rests crucially on the technical expertise of the entrepreneur and, possibly, specialist investors like venture capitalists who have an understanding of the specific technologies and markets the entrepreneur wishes to enter. In some circumstances this situation recurs when the company is in need of major restructuring. We interpret the signal $\sigma$ observed by the entrepreneur as the firm-specific information.[23] However, at the point where the market and the technology are more established, outside investors have the ability to learn about the specifics of this market, product and technology, and thereby erode the unique position of the entrepreneur. We refer to the signal $\Sigma$ collected by the investor as this market-specific information. It is plausible to assume that investors' incremental cost of acquiring this information on one particular company are lower if there are more similar public companies in the same industry. Then it is optimal for the company to enlist the information gathering capacity of the stock market. Generally, it is optimal for both, the entrepreneur and the investor to become informed.

[22] An alternative would be to eliminate the indirect effect by assuming that the precision of the investor's signal is exogenously given.

[23] For example, the restructuring of Safeway after their LBO required firm-specific insights into the relative profitabilities of different operations that are unlikely to be available to the market, but did become available to the partners of KKR during the restructuring phase while the company was private. After restructuring, this information was less critical and the company went public again. (See Denis (1994).)

**Proposition 7** *: In case the company goes public the errors $\eta$ and $\varepsilon$ are higher than those values that maximize the unconstrained objective (12) where the entrepreneur can contract on the optimal levels of $\varepsilon$ and $\eta$ directly.*

Proposition 7 reflects the "moral hazard in teams" problem associated with this setup. For any ownership structure, the entrepreneur and the investor each capture only a fraction of the benefits of their information acquisition. The investor captures a fraction $q$, whereas the entrepreneur captures $1 - \beta^S$. Hence, both of them underinvest in information acquisition relative to the optimal solution which could be implemented only through a contract where the investor and the entrepreneur contract with the firm to provide monitoring services. This inefficiency arises from the fact that such a contract cannot be written.

This analysis has some immediate implications for the optimal way to conduct the initial public offering. Firstly, the following proposition explores the possibility of reducing the friction caused by informational rents extracted by investors in the offering:

**Proposition 8** *Assume the entrepreneur could avoid paying an informational rent to investors. Then she would go public for some $d < \hat{d}$.*

Consider a situation where the entrepreneur can contract with the informed investor about the monitoring service without having to share any of the surplus with him. Then the information acquired through going public would be cheaper to her, and the entrepreneur would give a larger role to outside investors and go public earlier than if the investor can also extract a rent.

The same intuition holds for the next result where we introduce an additional friction into the stock market. So far we assumed that all the information acquired by investors is transmitted without error to the entrepreneur. This is clearly unrealistic, since there is noise in stock prices and the offering process, for example because uninformed investors have random demands and the identity of the investors applying for shares in the IPO is not known to the entrepreneur. We relax this assumption now and maintain that the entrepreneur learns the information of the investor with some probability $\lambda$:

**Proposition 9** *: Assume the equity market reveals the information acquired by informed investors only with some probability $\lambda$. Then the cutoff point $\hat{d}$ for going public is higher for $\lambda < 1$ than for $\lambda = 1$.*

Since the objective of going public is that the entrepreneur learns the information of outside investors, it follows that any friction in this process makes going public less valuable. Therefore, if the market is less transparent the likelihood of going public is reduced and it is more important for the entrepreneur to maintain her own incentives to monitor and to retain a larger stake in the company.

## 5.1 Hot Issue Markets

Not only the parameter $d$ is subject to change and depends crucially on the stage of the company's life cycle. The same holds for the cost parameter of the capital market $c$. Acquiring information about companies will typically require a substantial fixed investment to understand technology, investment projects and product markets. Once a few companies have decided to go public, outside investors have sunk these fixed costs and have probably reduced their marginal costs for acquiring additional information about a new public issue. Hence, $c$ depends on the amount of experience investors have already accumulated for a particular technology or market. This fact represents "learning by doing" of the market in the broadest sense, and may help to understand the hot issue phenomenon. To see this, suppose that an industry has $I$ firms, with $r$ private firms and $I - r$ firms that have already gone public in the past. Also, assume that the parameter $d$ for a private firm is not publicly known and distributed as a random variable $\tilde{d}$ with cumulative distribution function $F\left(\tilde{d}\right)$. Assume that $F$ is defined for all positive real values of $d$ and has a density so that $F\left(\tilde{d}\right) < 1$ for all $d < \infty$. Hence, large values of $d$ are at least possible. For simplicity, assume that $c$ is a deterministic variable that depends only on the number of public firms in the same industry:

$$c = g\left(I - r\right) \qquad g' < 0 \tag{14}$$

The fact that $g$ is falling in the number of *public* companies $I - r$ represents the learning effect of the market.[24]

We want to abstract from strategic interactions between IPO firms and investors by assuming that firms make their decision to go public sequentially, i. e., at most one firm each period. This assumption of sequentiality simplifies the analysis relative to the case where companies decide to go public simultaneously. Then we have:

**Proposition 10** ***Hot Issue Markets:*** *Suppose that the market is in equilibrium so that it is optimal for all private companies to stay private. Assume that one company in this market observes a random change to its parameters and decides to go public. Then there is a positive probability that some or all of the remaining* $r - 1$ *companies go public subsequently.*

This result shows how one of the salient features of hot issue markets emerges from this model: a clustering of issues, where the going public decision by one company induces one or more other companies to go public.[25] All companies prefer to stay private as long as $c$ is high. However, once the first, or the first few companies have gone public, the market develops an understanding of the new industry, hence

[24] Using the number of companies is obviously an approximation and not entirely realistic. We could equally well assume that $g$ is a function of the market capitalization or the number of analysts following a particular industry.

[25] Cf. Ritter (1984) for an empirical analysis. Hansen and Lee (1996) suggest successful market timing as an alternative explanation.

$c$ drops and more companies in the same industry find it advantageous to go public. Hence, on the basis of this theory, hot issue markets should be an industry-driven phenomenon. Note that the argument used here is different from an 'informational cascade' argument about public offerings, even though there is a similarity in that the cascade argument as well as the market learning argument developed here are based on the notion of sequential decision making.[26] The results of informational cascade models rely crucially on later investor's ability to infer information from the decisions of earlier investors, whereas the argument in this section is based on the reduced *costs* later investors have for acquiring signals about later IPOs.[27] Also, here the sequential choices relate to decisions made by firms, not decisions made by investors. Chemmanur and Fulghieri (1999) also have a theory of hot issue markets that relies on correlated productivity shocks across firms. Their perspective complements the perspective developed here, which emphasizes the learning process of investors in new industries.

# 6 Comparative Static Analysis: Empirical Implications

In this section we derive comparative static results of our model. We accomplish this by repeatedly referring to the following result:

**Proposition 11** *: The IPO discount $\Delta$ increases in the precision of the signal $(1 - \eta^*)$ observed by the informed investor.*

Proposition 11 can now be used for comparative static analysis to derive the following results:

[26] For a theory of informational cascades see Bikhchandani, Hirshleifer and Welch (1990). For an application to IPOs see Welch (1992).

[27] Benveniste, Busaba and Wilhelm (1997) analyze an externality closer to the one analyzed here. They argue that investment banks resolve this externality by bundling IPOs.

**Result 1** : Assume the solution for $\eta$ is interior and the conditions for the investor to become informed are satisfied. *Then entrepreneurs with lower costs of information acquisition have lower discounts in initial public offerings* ($\frac{\partial \Delta}{\partial d} > 0$).

This result is intuitive. $E$ has two options to monitor: Directly by acquiring information, and indirectly by obtaining information from outside investors. Both options are costly, and the trade-off depends on their relative advantage. In a cross-section of entrepreneurs those with higher costs to acquire information will find it more important to reduce the burden from their involvement in these companies. Accordingly, they face a greater adverse selection problem when they go public since outside investors collect more information.

The parameter $d$ may be easier to evaluate for those situations where the issuer is not a single owner-entrepreneur but either a venture capitalist or a parent company. In the first case $d$ measures the experience of the venture capitalist. The more experienced $VC$ is in monitoring this or a similar company, the easier $VC$ will find it to evaluate information and assess projects and reports of the incumbent management correctly. Experience in this sense can be measured, e. g., by (1) the number of years $VC$ has served on a board, (2) the number of years $VC$ has been monitoring similar businesses or, more crudely, (3) the lifetime of the $VC$ fund, or (4) survey measures of reputation. These results have been found by Barry et. al. (1990) for U. S. data and confirmed (although some with small or no statistical significance) by Bergström et. al. (1995) for Swedish data. In the case of equity-carveouts, result 1 could be tested by looking at the degree of diversification of the holding company, hypothesizing that the parameter $d$ is lower in more focused companies that have stronger skills in monitoring their subsidiaries, and higher if the subsidiary is in a different industry than its parent.

We now derive comparative static results for the operating performance of the company as a function of observable IPO parameters. Operating performance in terms of this model is measured as the probability of *not* mistakenly abandoning the project if it is good, and always rejecting it in the bad state. Hence, we define the negative of $\epsilon\eta$ as our performance measure and obtain:

**Result 2** : *Post-IPO operating performance is decreasing in the number of shares sold to the public.(i. e.,* $\partial\epsilon\eta/\partial\beta^L > 0$.*)*

In this model, increasing the number of shares sold to outside investors reduces the incentives of the entrepreneur to become informed, so performance deteriorates.

# 7 The Role of the Underwriter

The discussion so far has been conducted in the context of a one shot game where the informed investor and $E$ meet only once. However, some empirical regularities cannot be understood in this context. Weiss and Wilhelm (1995) found that large, institutional investors sometimes participate in overpriced IPOs, i.e. transactions where they stand to make a loss. This indicates that the participation constraint of the informed investor may not always be binding. This observation can be understood in the context of a repeated game, where $E$ uses an intermediary who interacts with the same group of investors repeatedly. The intermediary can reward the informed investor with gains in future periods for losses in the current period. We refer to the intermediary as the "bank," although it could also be another intermediary, for example a venture capitalist. Formally, $q$ depends on the signal $\Sigma$ now, we denote this by the superscript $S \in \{L, H\}$. We do not have that $q^L = 0$ anymore.

Note that the informed investor extracts a rent from the information he acquires, so that the relationship with the bank generates value for him. The rent for the IPO analyzed above is:

$$V_I \equiv \pi q^H \left(P^H - P_0\right) + (1-\pi)\, q^L \left(P^L - P_0\right) - \frac{c}{2}\,(1-\eta)^2 \qquad (15)$$

Using the optimal solution for $\eta^*$ of (15), assuming an interior solution, and substituting gives:

$$V_I = q^L \left(P^L - P_0\right) + \frac{c}{2} \left(1 - \eta^*\right)^2 \tag{16}$$

Hence, if $q^L = 0$ as before, then $V_I$ is exactly equal to the costs of information collection. This is consistent with Proposition 4 above. Now assume that the bank can credibly commit not to allocate any shares to an informed investor who has refused to take up his allocation in an overpriced IPO.[28] Then the bank can use this leverage over the informed investor in order to increase $P_0$. Whenever the informed investor has observed the negative signal $L$ he would then consider whether to take up his allocation in order to participate in future IPOs, or whether to decline participating and give up the rents from his relationship with the bank. In order to evaluate the expected value of all future rents, assume that the discount factor of the informed investor is $\delta$, where $\delta$ depends on the cost of capital of the informed investor, but also on the probability of the bank continuing to offer securities in IPOs. For simplicity, assume that all future IPOs have exactly the same structure as the one analyzed so far, so that the rents of the informed investor are identical. Then the informed investor will purchase shares in the low state if and only if:

$$\begin{aligned} & q^L \left(P^L - P_0\right) + \frac{\delta}{1-\delta} \left[q^L \left(P^L - P_0\right) + \frac{c}{2} \left(1 - \eta^*\right)^2\right] \geq 0 \\ \Leftrightarrow \quad & q^L \left(P_0 - P^L\right) \leq \frac{c\delta}{2} \left(1 - \eta^*\right)^2 \end{aligned} \tag{17}$$

Effectively, the informed investor accepts a loss in the low state if the expected present value of all future rents from continuing to participate in IPOs offered by the bank exceeds the costs. Assume that (17) is satisfied as an equality.[29] Then substituting back into (16) gives:

$$V_I = (1 - \delta) \frac{c}{2} \left(1 - \eta^*\right)^2 \tag{18}$$

[28] This requires effectively that the bank can always find another investor who can perform the same information collection role.

[29] This is always true and proved in the proof of Proposition 12 in the appendix.

Hence, if the bank has some leverage over the informed investors by virtue of a repeated relationship, she can reduce the informational rent extracted by informed investors. If the bank is certain not to make any future public offerings, then the rent of the informed investor is given by (18) with $\delta = 0$. This is the case analyzed before (see Proposition 4 above). The ability to reduce the informational rent of informed investors makes it less costly for $E$ to employ the information collection ability of outside investors. This has an impact on her optimal strategy:

**Proposition 12** *: If E can use an intermediary that can credibly commit not to offer any shares to an informed investor in the future whenever the investor has not taken up his allocation in the offering, then informed investors are willing to acquire overpriced shares. Then E is more likely to go public relative to a situation where she has no leverage over outside investors. This improves the allocation in terms of social welfare.*

Note that Proposition 12 has some important normative implications. Since $E$ has to give up rents to outside investors, she will be more likely to go public and rely more on the outside market if she can reduce these rents, other things being equal. However, from the point of view of social welfare, these rents are transfers. From an efficiency point of view, only the informed investor's costs of information acquisition are important. Hence, to the extent that $E$ can reduce these informational rents, she can also reduce the deadweight loss from delays in the decision to go public. For $\delta = 1$, we would have the socially efficient outcome.

Proposition 12 also has some empirical implications if we investigate the main determinants of $\delta$. Suppose the bank does one IPO this period with probability $p$ conditional on having done one IPO in the previous period. Then $\delta = \frac{p}{1+r}$ where $r$ is the informed investor's discount rate. The parameter $\delta$ is the relevant factor of the informed investor for discounting the rents between two IPOs offered by the bank. Hence, if the bank conducts public offerings with a higher frequency, and can commit to offer them to the same informed investor with a higher credibility, then $\delta$ will increase. This shows that:

**Result 3** : *Banks will tend to take companies public earlier if they have more companies in their portfolio, and offer shares to the same group of investors in these IPOs; then they will also tend to haver lower IPO discounts.*

If an entrepreneur goes public, then this is typically a one-off transaction. Then the reputation of an intermediary like an investment bank, who deals with the same group of investors repeatedly, can improve the allocation and may make it feasible for an entrepreneur to go public in the first place. Hence, Result 3 is an alternative interpretation of the certification effect. Beatty and Ritter (1986) report supporting empirical evidence for such a reputation equilibrium for underwriters of initial public offerings. They find that those underwriters who underprice IPOs too much or too little lose market share. Weiss and Wilhelm (1995) report more direct evidence, since they find that informed investors sometimes purchase shares in overpriced offerings, which is consistent with the analysis in this section. Carter and Manaster (1990) also find that more reputable underwriters have lower IPO discounts, and the theory developed here presents an alternative explanation of their findings. Note that the analysis leading to Result 4 does not depend on any signaling or other asymmetric information argument. To the contrary, $E$ is less informed than some of the investors in the model.

# 8 Conclusion

This paper has analyzed a model where the owner of a privately owned company considers to take the company public. She benefits from the IPO, since the offering process gives new investors incentives to acquire and reveal information that can be used to evaluate the investment projects of the company. The blockholder can reduce her monitoring costs, since she can learn the information acquired by prospective investors. Monitoring through the stock market is indirectly costly since investors need to be compensated through underpricing. The main contributions of the paper are:

- A comprehensive analysis of the decision to go public. The main point here is that being privately held provides a temporary advantage for the entrepreneur and possibly other insiders who have firm-specific knowledge. Once the company moves on to a different stage in its life cycle, the relative advantage no longer exists and going public becomes optimal. This links a theory of IPO underpricing with a theory of the decision to go public.

- If the decision by one or a few firms in an industry to go public leads to learning by the market about this new industry, then the first public offerings may trigger a wave of subsequent IPOs of companies in the same industry (hot issue markets).

- The process of going public creates frictions in the form of informational rents. Intermediaries and the design of the offering mechanism can help to reduce these frictions and remove socially inefficient delays in the decision to go public. Allowing issuers to discriminate between investors can be socially beneficial.

Hence, the theory presented here can explain some puzzles about initial public offerings. In particular, it helps to understand why underpricing of IPOs can persist even though mechanisms exist, such as public competitive auctions that could help to reduce underpricing. Also, investors as well as entrepreneurs who hold a large part of their wealth in the equity of a company where they also provide management services have to choose the optimal point in time where they receive a return on their investment. The theory of the decision to go public developed here centers on the resolution of this timing problem.

One limitation of the model presented here is its static character. Companies make repeated decisions and probably benefit from information aggregated in the stock price more than once. This could be adequately reflected only in a dynamic model which is beyond the scope of this paper. Another aspect linked to this concerns the question of long-term performance, which cannot be explained by this model. These questions are left for future research.

# 9 Notation

| | |
|---|---|
| $G$ | Payoff of the project if the outcome is good |
| $B$ | Payoff of the project if the outcome is bad |
| $P^H$ / $P^L$ | Prices in the secondary market if the informed investor has reported the high($H$)/low($L$) signal |
| $P_0$ | Offering price |
| $x$ | Ex ante probability of the good project outcome $G$ |
| $q,\ q^H,\ q^L$ | Number of shares allocated to the informed investor (if he has reported the high/low signal) |
| $Q_I$ / $Q_U$ | Maximum number of shares applied for by the informed / uninformed investor |
| $1-\beta^S$ | Number of shares held by $E$ after the IPO ($S \in \{H, L\}$) |
| $\beta^S$ | Number of shares offered in the IPO ($S \in \{H, L\}$) |
| $\Sigma$ | Signal of the informed investor |
| $\eta,\ c$ | Error and cost parameter of signal of the informed investor |
| $\sigma$ | Signal of $E$ (the entrepreneur) |
| $\epsilon,\ d$ | Error and cost parameter of $E$'s signal |

# 10 Appendix

**Proof of Proposition 1:**

If the investor becomes informed, he maximizes (4), and (6) follows directly from the first order condition. Then his net payoff from becoming informed is (substitute (6) into (4)):

$$V_I^* = \frac{(qx)^2}{2c}\left(P^H - P_0\right)^2 \tag{19}$$

If he remains uninformed he applies for shares without having any information if the payoff is positive. In this case he obtains:

$$V_{NI}^* = Max\left\{q\left(x\left(P^H - P_0\right) + (1-x)\left(P^L - P_0\right)\right),\ 0\right\} \tag{20}$$

The investor becomes informed only if $V_I^* \geq V_{NI}^*$, which gives:

$$\frac{qx^2}{2c}\left(P^H - P_0\right)^2 \geq Max\left\{0,\ x\left(P^H - P_0\right) + (1-x)\left(P^L - P_0\right)\right\} \tag{21}$$

If $P_0 \leq P^L$, then the investor always buys the shares irrespective of her information, hence she never becomes informed if $P_0 \leq P^L$. If $V_{NI}^* = 0$ and $P_0 > P^L$, then the investor always becomes informed since $V_I^* > 0$. If $V_{NI}^* > 0$, then the investor becomes informed only if $P_0 > \underline{P}$, where $\underline{P} = P_0$ solves (21) as an equality. If (21) is satisfied for $\underline{P}$, then it is also satisfied for any $P_0 > \underline{P}$, but not for any $P_0 < \underline{P}$. If $V_{NI}^* > 0$, then (21) is only satisfied if $q > 0$, hence a lower bound $\underline{q}$ must exist. ■

**Proof of Proposition 2**:

$E$ updates her priors about the probability of the good state from $x$ to $b(\sigma, \Sigma)$, where $b$ denotes the posterior probability she assigns to the good state. We have $b(\overline{\sigma}, \overline{\Sigma}) = b(\overline{\sigma}, \underline{\Sigma}) = b(\underline{\sigma}, \overline{\Sigma}) = 1$ from equations (2) and (3) above. Similarly, it also follows that

$$b\left(\underline{\sigma}, \underline{\Sigma}\right) = \frac{x\eta\epsilon}{x\eta\epsilon + 1 - x} \leq x\ . \tag{22}$$

Since $E$ has the right to stop the project, she will exercise this right whenever the payoff from continuing is less than the payoff from stopping the project:

$$\begin{aligned} & b(\sigma, \Sigma) G + (1 - b(\sigma, \Sigma)) B \leq 0 \\ \Rightarrow \quad & 0 < b(\sigma, \Sigma) \leq \hat{b} \equiv \frac{-B}{G - B} < x \ . \end{aligned} \tag{23}$$

Since $B < 0$, $\frac{-B}{G-B}$ is a strictly positive number. $E$ will never stop the project if the informed investor reveals a high signal. Therefore $P^H = G$. From (23) $E$ ignores all information she has and lets the project continue irrespective of the information she observes if $b(\underline{\sigma}, \underline{\Sigma}) > \hat{b}$. She stops the project whenever both signals are unfavorable if $b(\underline{\sigma}, \underline{\Sigma}) \leq \hat{b}$. Then she stops the project in the good state with probability $\epsilon\eta$, whereas the project is stopped in the low state with probability 1. Equations (23) and (22) together imply that $E$ stops the project if and only if all her information is sufficiently precise:

$$\epsilon\eta \leq \frac{-B(1-x)}{xG} \ . \tag{24}$$

Hence, condition (24) defines an upper limit on the compound error $\epsilon\eta$ of both signals.

The following table summarizes all events and parameters, assuming that (23) is satisfied in equilibrium:

**Table 1**

| Prob | $\tilde{N}$ | $\Sigma$ | $\sigma$ | $b$ | $\beta^S$ | Price $P^S$ | Intrinsic Value |
|---|---|---|---|---|---|---|---|
| $x(1-\eta)(1-\varepsilon)$ | $G$ | $H$ | $\bar{\sigma}$ | 1 | $\beta^H$ | $P^H$ | $G$ |
| $x(1-\eta)\varepsilon$ | $G$ | $H$ | $\underline{\sigma}$ | 1 | $\beta^H$ | $P^H$ | $G$ |
| $x\eta(1-\varepsilon)$ | $G$ | $L$ | $\bar{\sigma}$ | 1 | $\beta^L$ | $P^L$ | $G$ |
| $x\eta\varepsilon$ | $G$ | $L$ | $\underline{\sigma}$ | $\leq \hat{b}$ | $\beta^L$ | $P^L$ | 0 |
| $1-x$ | $B$ | $L$ | $\underline{\sigma}$ | $\leq \hat{b}$ | $\beta^L$ | $P^L$ | 0 |

The last two lines of the table express the fact that the intrinsic value of the shares is zero because the project was terminated. Note that this implies immediately:

$$P^H = G \tag{25}$$

$$P^L = \frac{(1-\varepsilon)\, x\eta G}{(1 - x(1-\eta))} \tag{26}$$

If (23) were not satisfied, then the last two lines of this table would become:

**Table 2**

| Prob | $\tilde{N}$ | $\Sigma$ | $\sigma$ | $b$ | $\beta^S$ | Price $P^S$ | Intrinsic Value |
|---|---|---|---|---|---|---|---|
| $x\eta\varepsilon$ | $G$ | $\underline{\Sigma}$ | $\underline{\sigma}$ | $> \hat{b}$ | $\beta^L$ | $P^L$ | $G$ |
| $1-x$ | $B$ | $\underline{\Sigma}$ | $\underline{\sigma}$ | $> \hat{b}$ | $\beta^L$ | $P^L$ | $B$ |

We can use these tables to rewrite *E's* objective from (7) as (recall $\pi = x(1-\eta)$):

$$\begin{aligned} V &= \pi\left(\beta^H P_0 + \left(1-\beta^H\right)G\right) + (1-\pi)\,\beta^L P_0 + x\eta\varepsilon\left(1-\beta^L\right)\tilde{R}_1 \\ &\quad + x\eta(1-\varepsilon)\left(1-\beta^L\right)G + (1-x)\left(1-\beta^L\right)\tilde{R}_2 - \frac{d}{2}(1-\epsilon)^2 \\ &\quad \textit{where} \quad \begin{array}{l} \left(\tilde{R}_1, \tilde{R}_2\right) = (0,0) \quad if \quad b(\underline{\sigma}, \underline{\Sigma}) \leq \hat{b} \\ \left(\tilde{R}_1, \tilde{R}_2\right) = (G,B) \quad if \quad b(\underline{\sigma}, \underline{\Sigma}) > \hat{b} \end{array}. \end{aligned} \tag{27}$$

The objective of $E$ (27) is a concave function in $\epsilon$. The first order condition from (27) gives the expression inside the maximum in (8). Since $\epsilon$ is a probability, the constraint $\epsilon \geq 0$ needs to be imposed, which is accomplished through the *Max* in (8).

However, $E$ acquires costly information only if this gives a higher expected payoff than acquiring no information and never stopping the project. Hence, we require that (27) evaluated at (8) is at least as large as (27) evaluated at $\varepsilon = 1$. This gives the condition:

$$x\eta\varepsilon^*\left(1-\beta^L\right)G + (1-x)\left(1-\beta^L\right)B + \frac{d}{2}(1-\epsilon^*)^2 \leq 0 \tag{28}$$

Substituting the expression for $\epsilon^*$ from (8), assuming $\varepsilon^* > 0$ (otherwise the conclusion would already be assumed to hold) and rearranging we can rewrite this condition as:

$$\eta\left(1-\frac{\left(1-\beta^L\right)x\eta G}{2d}\right)\leq\frac{-\left(1-x\right)B}{xG} \tag{29}$$

Define $\hat{\eta}$ as that value of $\eta$ where (29) holds as an equality. Since the right hand side of (29) is strictly positive, (29) is always true for $\eta = 0$, and, by continuity of the left hand side of (29) in $\eta$, also in a neighborhood of $\eta = 0$. Note that the first derivative of the left hand side of (29) is equal to $\epsilon^* > 0$, so (29) holds on a compact interval $0 < \eta \leq \hat{\eta}$, some $\hat{\eta} > 0$. Defining $\overline{\eta} \equiv Min\{1, \hat{\eta}\}$ satisfies the claim for $\overline{\eta}$ of the proposition. ■

**Proof of Proposition 4:**

The entrepreneur's objective is given in (11). The problem is to maximize (11) subject to four constraints:

1. The participation constraints of uninformed investors, (9),
2. The first order condition of the informed investor to acquire information of precision $\eta$, (6),
3. The first order condition for $E$ to collect information of precision $\epsilon$, (8),
4. The constraints on $q$ and $P_0$ from the participation constraint of the informed investor, (21).

To show the result of the proposition we demonstrate first that the participation constraint (9) of uninformed investors is always binding as an equality. (step 1) Then we rewrite (6) to substitute for $\Delta$. (step 2) Finally, we substitute these two constraints in order to derive (12). (step 3)

**Step 1**: Uninformed investors will only participate in the IPO if:

$$K \equiv \pi\beta^H\left(P^H-P_0\right)-q\pi\left(P^H-P_0\right)+\left(1-\pi\right)\beta^L\left(P^L-P_0\right) \tag{30}$$

$$= \Delta-q\pi\left(P^H-P_0\right)\geq 0 \tag{31}$$

which defines $K$ as the rent appropriated by uninformed investors. The last inequality follows from (9) and the definition of the IPO-discount $\Delta$ in (10). Now rewrite the expected price in the secondary market as:

$$\begin{aligned} \pi P^H + (1-\pi) P^L &= \underbrace{x(1-\eta)}_{=\pi} \underbrace{G}_{=P^H} + \underbrace{(1-x(1-\eta))}_{=1-\pi} \underbrace{\frac{(1-\varepsilon) x\eta G}{(1-x(1-\eta))}}_{=P^L} \\ &= xG(1-\varepsilon\eta) \end{aligned} \tag{32}$$

where the substitutions follow immediately from (25) and (26).

Now rewrite the objective (11), using the definition of $K$ from (30) and (32):

$$V = xG(1-\varepsilon\eta) - K - qx(1-\eta)(G-P_0) - \frac{d}{2}(1-\varepsilon)^2 \tag{33}$$

The claim is that we can improve on any candidate solution with $K > 0$. Clearly, $\beta^H = q$ cannot be a solution, since then the left hand side of (9) would become negative, hence $\beta^H > q$. Also, $P_0 = P^H$ is not a solution, since then the left hand side of (9) would be negative as well, hence $P_0 < P^H$. Now we demonstrate the claim by contradiction. Hence, suppose that (9) is slack so that $K > 0$. Then we can reduce $\beta^H$. This will not affect $\eta$ ($\eta$ only depends on $q$). It will also not affect $\varepsilon$ ($\varepsilon$ only depends on $\beta^L$). Then all variables in (33) and (30) are unaffected except $K$, which is reduced. Then $V$ increases unambiguously, contradicting the assumption that a solution could have $K > 0$.

**Step 2**: The first order conditions for the informed investor gives (6) from (4), the first order condition for the entrepreneur gives (8) from (7). Both conditions must be satisfied as equalities for any interior optimum. Since both optimization problems are concave, these conditions are also sufficient.

**Step 3:** From $K = 0$ (step 1) and (30) we can conclude immediately that:

$$\Delta = q\pi(P_H - P_0) \tag{34}$$

From (6) we can derive:

$$qx\left(P^H - P_0\right) = c(1-\eta^*) \tag{35}$$

Substituting (35) into (34) gives:

$$\Delta = c\left(1-\eta^{*}\right)^{2} \tag{36}$$

Then substitute (36) and (32) into (11) to obtain (12). The rent for the informed investor follows directly from substituting the first order condition (6) into his objective (4). ■

**Proof of Proposition 5:**

From equation (35) we obtain immediately the first expression for $P_0$ in (13). Using $P^H = G$ (see (32) above) and multiplying the fraction through by $1-\eta$ gives the second expression. (Use $V_I = c\left(1-\eta\right)^2$ from Proposition 4.)

From (6) we have immediately that $\eta = 1$ implies $q\left(P^H - P_0\right) = 0$, so the company does not go public in this case. If $\varepsilon = 0$, then (12) can only be maximized for $\eta = 1$. ■

**Proof of Proposition 6:**

The proof proceeds in three steps. Step 1 shows that staying private is optimal for $d$ sufficiently small. Step 2 shows that going public is optimal for $d$ sufficiently large if $c$ is not too large. Step 3 shows that there is one unique value $\hat{d}$ with the property stated in the proposition.

**Step 1.** We show that staying private is optimal for $d$ sufficiently small. The value of the company if the entrepreneur does not take it public and gathers some information herself is:

$$V_{\mathrm{Pr}} = xG\left(1-\varepsilon\right) - \frac{d}{2}\left(1-\varepsilon\right)^2 \tag{37}$$

The first order conditions imply that

$$\varepsilon_{\mathrm{Pr}} = Max\left\{0, 1-\frac{xG}{d}\right\} \tag{38}$$

Substituting back gives:

$$V_{\mathrm{Pr}} = \begin{cases} xG - \frac{d}{2} & if \quad d < xG \\ \frac{(xG)^2}{2d} & if \quad d \geq xG \end{cases} \tag{39}$$

For $d = 0$ we have $V_{\text{Pr}} = xG \geq V_{Pu}$ from (12) and (39).

**Step 2.** For $d \geq \frac{(xG)^2}{xG+(1-x)B}$, the entrepreneur does not gather any information to be able to make a decision. (to see this, note that then $\varepsilon \geq \frac{-(1-x)B}{xG}$ and therefore $b(\underline{\sigma}) \geq \hat{b}$, see (23).) Then:

$$V_{\text{Pr}} = xG + (1-x)B \tag{40}$$

This reduces the value from taking the firm public (if $c$ is not too large and $d = \infty$):

$$V_{Pu} = xG(1-\eta^*) - c(1-\eta^*)^2 \tag{41}$$

First order conditions give then:

$$\eta^{**} = Max\left\{0, 1 - \frac{xG}{2c}\right\} \tag{42}$$

Substituting back gives:

$$V_{Pu} = \begin{cases} xG - c & if \quad c < xG/2 \\ \frac{(xG)^2}{4c} & if \quad c \geq xG/2 \end{cases} \tag{43}$$

Hence, for $d$=$\infty$ going public is optimal if:

$$\frac{(xG)^2}{4c} \geq xG + (1-x)B \tag{44}$$

$$\Leftrightarrow \quad c \leq \frac{(xG)^2}{4(xG + (1-x)B)} \equiv \overline{c} \ . \tag{45}$$

**Step 3.** In order to show that there is a unique cutoff point $\hat{d}$ with the property stated in the proposition we must show that for any given $c$ the expression $V_{Pu} - V_{\text{Pr}}$ is a function of $d$ that changes signs only once. For the private firm we can use the envelope theorem to obtain:

$$\frac{dV_{\text{Pr}}}{d(d)} = -\frac{1}{2}(1-\varepsilon_{\text{Pr}})^2 \tag{46}$$

For the public firm we cannot use the envelope theorem and solve directly:

$$\frac{dV_{Pu}}{d(d)} = -\frac{1}{2}(1-\varepsilon_{Pu})^2 + \frac{\partial V_{Pu}}{\partial \varepsilon_{Pu}} \frac{\partial \varepsilon_{Pu}}{\partial d} \tag{47}$$

From (12) and (6) we obtain:

$$\frac{\partial V_{Pu}}{\partial \varepsilon} = -x\eta G + d\left(1-\varepsilon_{Pu}\right) \tag{48}$$

$$\frac{\partial \varepsilon_{Pu}}{\partial d} = \frac{\left(1-\beta^{L}\right)x\eta G}{d^{2}} \tag{49}$$

Substituting for $\varepsilon_{\mathrm{Pr}}$, $\varepsilon_{Pu}$ we evaluate:

$$\begin{aligned}
\frac{d\left(V_{\mathrm{Pr}}-V_{Pu}\right)}{d\left(d\right)} &= -\frac{1}{2}\left(1-\varepsilon_{\mathrm{Pr}}\right)^{2}+\frac{1}{2}\left(1-\varepsilon_{Pu}\right)^{2} \qquad (50)\\
&\quad -\left(-x\eta G+d\left(1-\varepsilon_{Pu}\right)\right)\frac{\left(1-\beta^{L}\right)x\eta G}{d^{2}}\\
&= -\frac{1}{2}\left(\frac{xG}{d}\right)^{2}+\frac{1}{2}\left(\frac{xG\left(1-\beta^{L}\right)\eta}{d}\right)^{2}\\
&\quad +\left(1-\beta^{L}\right)\left(\frac{x\eta G}{d}\right)^{2}-\left(\frac{xG\left(1-\beta^{L}\right)\eta}{d}\right)^{2}\\
&= \frac{1}{2}\left(\frac{xG}{d}\right)^{2}\left[-1+\eta^{2}\left\{-\left(1-\beta^{L}\right)^{2}+2\left(1-\beta^{L}\right)\right\}\right]\\
&= -\frac{1}{2}\left(\frac{xG}{d}\right)^{2}\left[1-\eta^{2}\left(1-\left(\beta^{L}\right)^{2}\right)\right]<0 \qquad (51)
\end{aligned}$$

where the strict inequality holds whenever $\beta^{L}>0$ or $\eta<1$. Hence, as $d$ increases, $V_{\mathrm{Pr}}$ decreases faster than $V_{Pu}$.

Since we have $V_{\mathrm{Pr}} \geq V_{Pu}$ for small $d$ from step 1, and $V_{\mathrm{Pr}} \leq V_{Pu}$ for large $d$ from step 2, and since $V_{\mathrm{Pr}}-V_{Pu}$ is monotonic from step 3, there is a unique value $\hat{d}$ such that:

$$V_{\mathrm{Pr}}\left(\hat{d}\right)-V_{Pu}\left(\hat{d}\right)=0\ . \tag{52}$$

Clearly, $V_{\mathrm{Pr}}$ is independent of $c$, whereas $V_{Pu}$ is decreasing in $c$. Hence, $V_{\mathrm{Pr}}-V_{Pu}$ is increasing in $c$: going public becomes less attractive as $c$ increases, so the critical value of $\hat{d}$ above which going public is the preferred alternative also increases in $c$ from the implicit function theorem applied to (52). ■

**Proof of Proposition 7:**

When the entrepreneur goes public she chooses $P_0$ optimally so as to maximize (12) subject to the conditions that (i) the entrepreneur chooses $\varepsilon$ subsequently to satisfy (8), (ii) the informed investor becomes informed, so (21) is satisfied. Recall that the other two conditions (the participation constraint of uninformed investors (9) and the first order condition for the precision of information collected by the informed investor (6) have been substituted in the derivation of (12) above.) The claim in the proposition compares the solution to this program to the unconstrained maximum of (12) that does not take into account the constraints of the investor and the entrepreneur. Unconstrained maximization of (12) gives:

$$\frac{\partial V}{\partial \varepsilon} = d\left(1-\varepsilon\right) - x\eta G \tag{53}$$

Evaluating this at the optimal level for $\varepsilon$ from (8) gives:

$$\frac{\partial V}{\partial \varepsilon} = \underbrace{d\frac{\left(1-\beta^{L}\right)x\eta G}{d}}_{=1-\varepsilon^{*}} - x\eta G = -\beta^{L} x\eta G < 0 \tag{54}$$

Hence, the equilibrium level of $\varepsilon^{*}$ is higher than the optimum as a direct consequence of (8).

For the choice of $\eta$ we have already substituted the equilibrium level of $\eta^{*}$ for the investor. However, the entrepreneur cannot choose $\eta$ directly and can influence it only through the choice of $P_0$. The choice of $P_0$ must satisfy:

$$\frac{dV}{dP_0} = \frac{\partial V}{\partial \eta}\frac{\partial \eta}{\partial P_0} \leq 0 \tag{55}$$

with the equality holding if the constraint (21) is not binding. If the constraint is binding, then $\frac{\partial V}{\partial \eta} \leq 0$ since $\frac{\partial \eta}{\partial P_0} > 0$ from (6) and the result holds immediately. If the constraint is not binding we have $\frac{\partial V}{\partial \eta} = 0$. Compare this to the unconstrained program where the entrepreneur maximizes the objective:

$$VB = xG\left(1-\eta^{*}\epsilon^{*}\right) - \frac{c}{2}\left(1-\eta^{*}\right)^{2} - \frac{d}{2}\left(1-\epsilon^{*}\right)^{2} \tag{56}$$

Direct comparison with (12) gives:

$$VB = V + \frac{c}{2}\left(1-\eta^{*}\right)^{2} \tag{57}$$

so that:

$$\frac{\partial VB}{\partial \eta^*} = -c\left(1-\eta^*\right) < 0 \tag{58}$$

Hence, the same result holds also for $\eta$. ■

**Proof of Proposition 8:**

If the entrepreneur could avoid paying an informational rent to investors she would only have to pay the informed investor for the costs incurred for acquiring information. Then the objective would be given by (56). Hence, $c/2$ takes the place of $c$ in (12) which is equivalent to assuming a reduction of $c$. Then the conclusion follows immediately from Proposition 6. Proposition 6 implies that a lowering of $c$ implies a lower cutoff point $\bar{d} < \hat{d}$, where $\bar{d}$ pertains to the case where the entrepreneur does not pay rents to investors. Hence, there is an interval of length $\hat{d} - \bar{d}$ where the entrepreneur goes public in case she does not pay rents, but does not go public in case she does. ■

**Proof of Proposition 9:**

If the signal acquired by the informed investor is only revealed with probability $\lambda$, then the entrepreneur has now three signal realizations from the informed investor, so that $\Sigma \in \{L, \phi, H\}$, where $\phi$ denotes the state where she receives no signal from the informed investor. Then she has to make a decision on the project exclusively on the basis of her own signal $\sigma$. Whenever $\sigma = \overline{\sigma}$, the entrepreneur concludes that the state is high and accepts the project. Whenever $\sigma = \underline{\sigma}$, she may either reject or accept. We investigate both cases in turn.

**Case 1:** $(\phi, \underline{\sigma})$ implies rejection. Assume she always rejects the project if she does not observe the investor's signal. Then she obtains the payoff $xG$ whenever she observes a high signal herself, or if she observes the high signal of the investor. Then the objective (12) becomes:

$$xG\left(1-\varepsilon+\varepsilon\lambda\left(1-\eta\right)\right) - \frac{d}{2}\left(1-\varepsilon\right)^2 - c\left(1-\eta\right)^2 \tag{59}$$

Now define $\tilde{\eta}$ and $\tilde{c}$ by the relationships:

$$1-\tilde{\eta} = \lambda\left(1-\eta^*\right) \quad (60)$$

$$\tilde{c} = c/\lambda^2 \quad (61)$$

Then (59) becomes:

$$xG\left(1-\varepsilon\tilde{\eta}\right)-\frac{d}{2}\left(1-\varepsilon\right)^2-\tilde{c}\left(1-\tilde{\eta}\right)^2 \quad (62)$$

Note that (62) is identical to (12) except that the costs of the informed investor are now $\tilde{c} > c$. Moreover, $\varepsilon^*$ is now given by:

$$\varepsilon^* = Max\left\{0,\ 1-\frac{\left(1-\beta^L\right)x\tilde{\eta}G}{d}\right\} \quad (63)$$

Then the logic of the proof of Proposition 6 implies that the critical cutoff point $\hat{d}$ has increased.

**Case 2:** Assume she always accepts the project if she does not observe the investor's signal. Then the objective (59) becomes:

$$xG\left(1-\varepsilon\eta\right)+\left(1-\lambda\right)\left\{x\varepsilon\eta G+\left(1-x\right)B\right\}-\frac{d}{2}\left(1-\varepsilon\right)^2-c\left(1-\eta\right)^2 \quad (64)$$

where the expression in curly brackets is always non-positive from substituting condition (29). Hence, the firm is worth strictly less when public for any $\lambda < 1$. Then going public is less advantageous, and the conclusion follows directly. ■

**Proof of Proposition 10:**

Proposition 6 shows that for sufficiently large values of $c$ it is always optimal to stay private, see (45). Hence, there exists a cutoff point $\widetilde{c} \leq \overline{c}$ such that the company goes public whenever $c \leq \widetilde{c}$, and stays private otherwise. Denote the cumulative distribution function of $\tilde{c}$ by $K\left(\tilde{c}\right)$ and index $\tilde{c}$ by $j$, indicating that this cut-off point is different across companies, depending on $d_j$. Since $F\left(\tilde{d}\right)$ has a density, so has $K\left(\tilde{c}_j\right)$. Since $F\left(\tilde{d}\right) < 1$ for every $d < \infty$, $K\left(\tilde{c}_j\right) < 1$ for every $c < \overline{c}$. Recall from (14) that the actual costs $c$ are deterministic. Hence, after the $r-th$ private company went public going public is optimal for any company $j$ where $\tilde{c}_j \geq g(I-r-1)$, or with probability $1-K(g(I-(r-1)))$. Now, define the cumulative distribution function for the maximum by $H$:

$$H_k(c) \equiv \Pr\left(Max_{j=1,\ldots,k}\, \tilde{c}_j \leq c\right) = K(c)^k \tag{65}$$

where the parameter $k$ indicates that $k$ of the remaining private companies have a cutoff parameter lower than or equal to $c$. Hence, the probability of observing at least one IPO subsequent to the IPO of the r-th company is $1-H_k(g(I-r+1))$. Analogously, the probability for observing a second IPO is $1-H_{k-1}(g(I-r+2))$, where $H_{k-1}$ is defined analogously to (65). Since the probability $K(\tilde{c}) < 1$, $H_k(c) < 1$ as well. The probability that *all r-1* companies go public is therefore:

$$\prod_{i=1}^{i=r-1}\left(1-H_{r-i}(g(I-r+i))\right) > 0 \tag{66}$$

and the conclusion of the proposition follows. ■

**Proof of proposition 11:**

We have already demonstrated above (equation (36)) that

$$\Delta = c(1-\eta^*)^2 \tag{67}$$

which gives the result for $\Delta$ immediately. ■

**Proof of Result 1:**

Note from the proof of Proposition 4 we have 4 constraints on the original maximization. In (12) we have already substituted 2. We use the objective (12) and substitute the optimal value of $\varepsilon$ from (8) to yield:

$$V = xG(1-\eta^*) + \frac{(xG\eta^*)^2}{2d}\left(1-\beta^L\right)^2 - c(1-\eta^*)^2 \tag{68}$$

Assume that (21) is not binding, so that (68) is unconstrained. Solving the first order conditions for $\eta^{**}$ gives:

$$\eta^{**} = \frac{2c - xG}{2c - \frac{(xG)^2}{d}\left(1-\beta^L\right)^2} \tag{69}$$

The denominator of this equation needs to be negative, otherwise $\eta^{**}$ would be at a corner. In this case no comparative static results could be derived. Then we have:

$$\frac{\partial \eta^{**}}{\partial d} = -\eta^{**} \frac{\left(\frac{xG}{d}\right)^2 \left(1-\beta^L\right)^2}{2c - \frac{(xG)^2}{d} \left(1-\beta^L\right)^2} < 0 \tag{70}$$

Then the result follows immediately from Proposition 11. Note that this analysis is valid only if (21) is not binding. ■

**Proof of Result 2:**

Observe that:

$$\epsilon\eta = \eta - \eta^2 \frac{\left(1-\beta^L\right) xG}{d} \tag{71}$$

Therefore,

$$\frac{\partial \epsilon\eta}{\partial \beta^L} = \eta^2 \frac{xG}{d} > 0 \tag{72}$$

which demonstrates the result. ■

**Proof of proposition 12:**

To facilitate the notation of this proof, denote:

$$h = q^H \left(P^H - P_0\right) \tag{73}$$

$$l = q^L \left(P_0 - P^L\right) \tag{74}$$

Then the objective of the informed investor can be written as:

$$V_I = x\left(1-\eta\right) h - \left(1 - x\left(1-\eta\right)\right) l - \frac{c}{2} \left(1-\eta\right)^2 \tag{75}$$

Then the optimal $\eta$ is given by:

$$\eta^* = 1 - \frac{x}{c}\left(h + l\right) \tag{76}$$

Substituting $c\left(1-\eta^*\right)$ for $x\left(h+l\right)$ (just rewriting (76)) in (75) gives:

$$V_I = -l + \frac{c}{2}\left(1-\eta\right)^2 \tag{77}$$

which gives (16). For any interior $\eta^*$, this must hold as an equality. Condition (17) can be rewritten as:

$$l \leq \frac{c\delta}{2}\left(1-\eta^*\right)^2 \tag{78}$$

In addition to (17) $P_0$ is constrained by the participation constraint for the uninformed:

$$(1-\pi)\left(\beta^L - q^L\right)\left(P_0 - P^L\right) \leq \pi\left(\beta^H - q^H\right)\left(P^H - P_0\right) \tag{79}$$

$$\pi\beta^H\left(P^H - P_0\right) + (1-\pi)\beta^L\left(P^L - P_0\right) \geq \pi(h+l) - l \tag{80}$$

Now, we need to establish which of the constraints (17) and (80) is binding. We show by contradiction that both must be binding in equilibrium. Suppose (80) were not binding in a candidate equilibrium. Then we can always reduce $\beta^H/\beta^L$ without affecting either $h$ or $l$, hence (76) and (77) remain unaffected, thus eliminating the rent of the uninformed investor and increasing $V$. Conversely, assume (17) is not binding. Then we can always increase $l$ and reduce $h$ without affecting $\eta^*$, hence $\eta^*$ can remain the same. Using definitions (73), (74), we can rewrite the IPO-discount from (**??**) as:

$$\begin{aligned}\Delta &= \underbrace{\pi\left(\beta^H - q^H\right)\left(P^H - P_0\right) + (1-\pi)\left(\beta^L - q^L\right)\left(P^L - P_0\right)}_{\text{Rent of uninformed Investors}} \\ &\quad +\pi h - (1-\pi)l\end{aligned} \tag{81}$$

From the proof of Proposition 4 above we know that the rent of uninformed investors (line 1 in (81) is zero. Using (75), the second line of (81) can be rewritten as:

$$\begin{aligned}\Delta = \pi(h+l) - l &= V_I + \frac{c}{2}(1-\eta^*)^2 \\ &= \frac{c}{2}(1-\eta^*)^2 + (1-\delta)\frac{c}{2}(1-\eta^*)^2\end{aligned}$$

where the last equality uses (18). Then (81) becomes:

$$\Delta = c\left(1 - \frac{\delta}{2}\right)(1-\eta^*)^2$$

Then we can rewrite $V$ as (use (11) and (12)):

$$V = xG(1-\eta^*\epsilon^*) - (2-\delta)\frac{c}{2}(1-\eta^*)^2 - \frac{d}{2}(1-\varepsilon^*)^2 \tag{82}$$

Adapting the argument from the proof of Proposition 6, we can now conclude that the cutoff point $\hat{d}$ above which the company goes public has dropped, since $c$ has been replaced by $c\,(1-\delta/2)$. Then the company is more likely to go public if $\delta$ is larger. ■

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