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Voluntary Disclosure and Real Investment Distortions in IPOs

Praveen Kumar
University of Houston

Nisan Langberg
University of Houston

K. Sivaramakrishnan
Rice University

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Praveen Kumar  
University of Houston  
pkumar@uh.edu

Nisan Langberg  
University of Houston  
nlangberg@uh.edu

K. Sivaramakrishnan  
Rice University  
kshiva@rice.edu

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Abstract

We examine the effects of IPO underpricing on capital investment efficiency when informed insiders — concerned about their investment funding — strategically disclose value-relevant information to offset the informational advantage of informed traders. Intermediate levels of adverse selection are associated with the most severe underpricing and with excessive funding (relative to the complete information efficient levels) of IPO firms. High levels of adverse selection are associated with under-investment and low underpricing. Real investment is efficient only when adverse selection is very low. Consistent with the data, underpricing is higher and the quality of IPO firms is lower when the level of real investment is higher (“hot markets”). However, the relation of underpricing to private information is non-monotonic, which also appears supported by the evidence.

JEL classification: G14, G23, G32

Keywords: IPO markets; Real investment; Underpricing; Private information; Public information

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1 Introduction

The underpricing of IPOs is one of the most widely studied topics in finance (see, e.g., Ljungqvist, 2007). Because IPO prices determine the amount of funds raised at the time of the offering, they have a direct bearing on the efficiency of capital allocation in the market for IPOs. In particular, underpricing can lead to investment distortions if it deters private firms with positive NPV projects from going public (Lowry, 2003), or results in inefficient allocation of funds — under- or over-investment relative to the complete information levels. In this paper, we analyze strategic disclosure decisions of firms going public and derive implications for underpricing and capital investment efficiency in the IPO market.

By and large, the literature views underpricing as an outcome of asymmetric information with respect to the intrinsic value of IPO firms (Benveniste and Spindt, 1989; Rock, 1986). These firms can potentially limit underpricing by voluntarily disclosing value relevant information ahead of their IPOs. But, it is not clear that full disclosure of value-relevant information is always in an IPO firm’s best interest because strategic non-disclosure can result in a higher expected price in equilibrium (e.g., Dye, 1985; Verrecchia, 1983). This key insight from the voluntary disclosure literature points to an interesting trade off that IPO firms face between limiting underpricing (by disclosing), and securing a higher issue price by strategically withholding disclosure. But, the level of underpricing absent disclosure in turn reflects investors’ beliefs regarding the strategic behavior of the informed managers. We examine how this trade-off shapes a private firm manager’s (i.e., the informed insider’s) equilibrium disclosure strategies ahead of an IPO.

Beyond its importance as financing milestone, an IPO is indeed a major disclosure event. During the IPO process, firms publicly disclose detailed information about their operations, financial performance, business plans, competitors, risks and so forth for the first time (e.g., Ellis et al., 1999), via the prospectus and/or the book building process that involves meetings with potential investors to generate a demand for the IPO. The empirical literature suggests such disclosures prior to the IPO reduce information asymmetry and lead to more accurate pricing (Hanley and Hoberg, 2010; Benveniste and Wilhelm, 1990; Busaba and Chang, 2002; Cornelli and Goldreich, 2002).

\[\text{1}\] Brau and Fawcett (2006) and Aslan and Kumar (2011) present evidence that a major motivation for IPOs is to relax the financing constraints for capital investment of fast growing firms.
\[\text{2}\] For example, in Benveniste and Spindt (1989), underpricing is compensation for institutional investors to generate and provide information (on IPO firm value) to underwriters, while Rock (1986) argues that underpricing is needed to induce uninformed investors — who face adverse selection risk (or ‘allocation risk’) — to participate in IPOs.
\[\text{3}\] Hanley and Hoberg (2010) find that greater informative content of the IPO prospectus results in more accurate offer prices and less underpricing. They find the strongest association when examining the Management’s Discussion and Analysis section of the prospectus.
There has lately been a push by government to relax mandated disclosure requirements on firms going public in order to *jump-start-our-business-startups* (JOBS act, 2012),\(^4\) which makes voluntary disclosures by these firms all the more important to the IPO market. However, the current literature offers little insight into how voluntary disclosure ahead of the IPO might affect the issue price and investment.\(^5\)

We show that the informed insider’s equilibrium disclosure strategy, the level of investment, and the extent of underpricing, depend in an important way on the *intensity* of private information—that is, the fraction of informed investors in the IPO process. We find that the manager strategically responds to a higher intensity of private information by disclosing more often, i.e., setting a lower disclosure cutoff. Moreover, for sufficiently high intensity of private information, full disclosure emerges in equilibrium. Intuitively, with no informed investors, the uninformed outside participants are exposed only to the adverse selection of the informed insider (Dye, 1985; Myers and Majluf, 1984). However, in the presence of informed investors, the uninformed investors that participate in the IPO face in addition an allocation risk or the *winners’ curse* (Rock, 1986). Consequently, to induce these uninformed investors to participate, the IPO offer price of non-disclosing firms must include an additional discount to compensate for their expected loss from trading against the informed investors, i.e., it must be underpriced. Note that because the informed insiders can always choose to alleviate information asymmetries via disclosure, such underpricing will arise in equilibrium only if some informed insiders still choose to not disclose.

This intuition underlies the two types of disclosure equilibria that emerge depending on the intensity of private information—a partial disclosure equilibrium with high success rate of IPOs, *high-volume equilibrium*, and a full disclosure equilibrium with less investment in IPOs, *low-volume equilibrium*. If the intensity or private information is low, then there is a *high* volume of IPOs because even relatively *opaque* firms—who *choose* to not disclose—still succeed in going public even though they suffer from underpricing. When the intensity of private information is high, IPOs

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\(^4\)Some institutional background is useful in understanding the nature of disclosures that firms typically engage ahead of IPOs. The process of IPO begins with the issuance of an initial prospectus and a letter of intent from the investment bank (or the underwriter). This is followed by a “quiet period” during which the issuer and the investment bank analysts are restricted from public dissemination of information. Once the IPO is registered with the SEC (S-1), the issuer is permitted to go on road shows and marketing campaigns to promote the IPO. These events offer a way for the issuer to choose whether and what to disclose to generate investor interest and, therefore, are an integral part of the firms’ voluntary disclosure strategies. Some issuers with favorable value-relevant information may be more forthcoming than others. Some may even choose not to go on road shows/marketing campaigns.

\(^5\)Managers have substantial discretion in choosing what information to reveal to the public prior to the IPO. In particular, Schrand and Verrecchia (2005), Hanley and Hoberg (2010), and Spindler (2010) analyze the relation between the news that firms voluntarily release to the press prior to the IPO or the information content of the IPO prospectus and the level of IPO underpricing.
fail for opaque firms because underpricing is too severe, and there is a low volume of IPOs.

These disclosure equilibria are associated with important real investment and capital allocation effects. First, because the release of public information is strategically chosen by informed managers, the average quality of successful IPO firms—in NPV terms—is lower when there is partial disclosure (the high-volume equilibrium) relative to full disclosure (the low-volume equilibrium). This implication is consistent with the empirical finding that IPOs issued during “hot” IPO periods are of lower quality in terms of post-IPO return performance compared with IPOs in “cold” markets (Loughran and Ritter, 1995).\(^6\)

Second, somewhat paradoxically, periods of extensive disclosure and relatively low average underpricing can be indicative of real investment distortions—non-disclosing firms fail to go public despite having unfunded strictly positive NPV projects, on average. In other words, high levels of disclosure need not be indicative of investment efficiency. The reason is that, with high private information intensity, while some firms can address the underpricing problem by increasing their information disclosure, others are compelled to forego (e.g., postpone) their IPO. On the other hand, periods of relatively high average underpricing and less disclosure can be indicative of over-investment because some non-disclosing firms with negative NPV projects succeed in going public.

Third, our analysis also provides a novel perspective on the interaction between the strategic disclosure of information by insiders and the intensity of private information in the IPO market.\(^7\) While prior literature (e.g., Dye (1985)) suggests that informed managers will voluntarily disclose more information when the ex-ante likelihood of an information event is higher, we show that the propensity to disclose information increases with the intensity of informed trading. Indeed, a full disclosure equilibrium outcome is obtained once the intensity of private information is sufficiently high. However, in the partial disclosure equilibrium, the market reaction to disclosure might be negative. The IPO market is unique in that funds raised at the time of the IPO are determined by the IPO issue price, not the market price following the beginning of trade—both potentially affected by what is disclosed. Since managers wish to maximize the issue price and not the market price following the beginning of trade.

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\(^6\)This prediction distinguishes our work from others that have emphasized the role of underpricing as a signal of firm quality—implying that during hot periods, when underpricing is elevated, the average quality of the firm going public is higher.

\(^7\)By examining a the time-series of IPO prospectuses, Hanley and Hoberg (2012) find evidence that managers tradeoff information release and underpricing to potentially hedge against litigation risk. Enhanced disclosure reduces the probability that investors will be able to establish successfully that there was “material omission” prior to the IPO. In this way, issuers reduce the costs from suffering underpricing as a hedge against litigation risk (e.g., Tinic, 1986; Lowry and Shu, 2002). We, however, focus on the investment distortions introduced by underpricing of IPOs.
price, the marginal IPO firm that is indifferent between disclosure and non-disclosure realizes the same IPO issue price whether it chooses disclosure or not. But, due to underpricing, the expected market price of the non-disclosing firm will be strictly higher than its issue price. Consequently, firms disclose information that reduces their market price relative to that of non-disclosing IPO firms.\(^8\)

Finally, we contribute to an emerging literature that explores the real effects of voluntary disclosure on decisions of investors and corporations. For example, it has been argued that transparency and voluntary disclosures may lead to information production by markets (e.g., Fishman and Hagerty, 1989; Diamond and Verrecchia (1991), Langberg and Sivaramakrishnan, 2008) and that feedback from financial markets triggered by voluntary disclosures can guide managers’ real actions (e.g., Dye and Sridhar, 2002; Langberg and Sivaramakrishnan, 2010). In a related vein, investment efficiency can be improved by voluntary disclosure when manager need to secure equity financing (Beyer and Guttman, 2012) or when managers are disciplined by the market for corporate control (Kumar et al., 2011). We extend this literature by analyzing the role of (credible) voluntary disclosures in allocating capital to IPO firms and mitigating both investment and pricing distortions.

The paper proceeds as follows. We present our model in Section 2. In Section 3, we present the benchmark case in which all investors are equally uninformed and then address the more general model with informed investors and present our main results. In Section 4, we discuss empirical implications of our results. We provide a conclusion in Section 5.

## 2 The Model

Consider an investment opportunity or project available to an owner/manager of a firm. The project requires capital of \(I\). Whether investment \(I\) takes place is observable. The project generates expected net cash flows of \(\pi\), and the appropriate cost of capital is \(r \geq 1\). The expected cash flow \(\pi\) follows a continuous distribution with positive support \(\Pi \equiv [\pi_{\min}, \pi_{\max}] \subset [0, 1]\). By construction, the NPV of the project of type \(\pi\) is \(\frac{\pi}{r} - I\). Investment is therefore first-best-efficient if the project has a positive NPV or \(\pi > Ir\).

\(^8\) Alternatively, it has been suggested that managers may disclose bad news for strategic reasons when bargaining with labor unions (Liberty and Zimmerman, 1986), deterring competition (Darrough and Stoughton, 1990), reducing the exercise price of the options they are given (Aboody and Kasznik, 2000), or as a signal of quality (Teoh and Hwang, 1991).
2.1 Manager’s Preferences

The project owner or manager $M$ has no funds and must sell a fraction of firm-ownership in capital markets to raise the required funds for investment. Specifically, $M$ can initiate an IPO to sell equity to raise $I$ at offer price $P_{ipo}$. The implied fraction of equity $\beta$ offered to investors at the IPO (while the manager is left with equity stake $(1 - \beta)$) is $\beta = \frac{I}{P_{ipo}}$. Consequently, the manager of type $(\pi)$ receives a payoff with present value of $\left(1 - \frac{I}{P_{ipo}}\right) \frac{\pi}{r}$. Therefore, the manager’s payoff is increasing in the IPO offer price $P_{ipo}$ (i.e., decreasing in the fraction of equity sold $\beta$). The IPO need not be successful: the IPO fails if it is initiated but not enough capital can be raised to cover the required investment amount $I$. In particular, if the issue price is less than the capital required i.e., $P_{ipo} < I$, then selling even 100% equity share will not suffice to cover the initial investment and the IPO fails. For simplicity, we assume that all firms initiate an IPO while in equilibrium the IPO might fail according to the above discussion.

Let $A = 1$ represent the event in which the IPO succeeds (i.e., $P_{ipo} > I$) and investment takes place, and $A = 0$ the event in which the IPO fails and investment does not occur. Formally, the payoff to the manager $M$ of type $(\pi)$ denoted by $U^M(\pi|P_{ipo}, A)$ is given by,

$$U^M(\pi|P_{ipo}, A) = \begin{cases} \left(\frac{P_{ipo} - I}{P_{ipo}}\right) \frac{\pi}{r}, & \text{for } A = 1 \\ 0, & \text{for } A = 0 \end{cases}. \quad (1)$$

2.2 Information and the IPO process

Early information about the firm’s expected future cash flows $\pi$ is potentially available with probability $\lambda \in (0, 1)$. When information becomes available to the manager, i.e., there is an informational event (ala Dye and Sridhar (1995)), she can voluntarily and credibly disclose this information to the market (Dye, 1985; Verrecchia, 1983).\(^9\)

The market for the firm’s shares in the IPO consists of two types of heterogeneously informed investors (Grossman and Stiglitz, 1980; Benveniste and Spindt, 1989). In particular, a fraction $\eta \in (0, \frac{1}{2})$ of investors are classified as informed investors and to these investors (like the manager) the information $\pi$ is available. That is, the manager and the group of informed investors share the same information.\(^10\) The remaining fraction of investors $(1 - \eta)$ are uninformed. Formally, we let

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\(^9\)The assumption of ex post verifiability is common in the disclosure literature (Grossman, 1981; Diamond and Verrecchia, 1991), and is particularly applicable to the situation at hand because financial information available to managers ahead of the IPO becomes public after the IPO.

\(^10\)The informed investors in our model are similar to the “regular” investors in Benveniste and Spindt (1989). Our arguments generalize to the setting where the manager is at times more informed than the informed investors and
\( \omega \in \Omega = \{ \Pi \cup \phi \} \) denote the manager’s (and informed investors’) information so that for example \( \omega = \pi \) denotes information \( \pi \), and \( \omega = \phi \) denotes the state when there is no informational event.

For simplicity, we assume that there is a total measure 1 of potential investors each with wealth \( K dt \), such that there is enough funds in the hands of potential uninformed investors to satisfy the required issue size, i.e. \( (1 - \eta)K > I \), but, not enough in the hands of potential informed investors, i.e., \( \eta K < I \). When the IPO is over-subscribed (in our case this means that more than fraction \( I/K \) investors subscribe to the IPO) then all investors are granted the same allocation that falls short of their total purchasing power \( K dt \). These assumptions imply that raising sufficient funds is possible only when uninformed investors participate in the IPO (Rock, 1986). All investors are rational.

The fractional allocation of the IPO to the uninformed investors is of particular interest and is denoted by \( \pi \in [0, 1] \). Thus, the payoff to the uninformed investor from demanding \$K dt \) worth of shares of the IPO is \( K \pi [\pi - P_{ipo}] dt \).

Till now we have focused on the IPO offer price, \( P_{ipo} \), but this price is potentially different than the market price once trade beings following a successful IPO; we denote this price by \( P_{mkt} \). Namely, the uninformed investors participating in the IPO face both allocation risk, due to the uncertain allocation level \( \pi \), and valuation risks, due to the uncertainty regarding firm value \( \pi \). However, once trade begins investors face only valuation risk. A common result in the finance literature is that in equilibrium market prices are an unbiased and possibly noisy estimate of fundamental value conditional on the aggregate information in the market (e.g., Grossman and Stiglitz, 1980).\(^{11}\) The aggregate information in our model includes the information signal of the informed investors and the manager when there is an information event. Here we assume that the market price reflects the expected firm value conditional on the information in the market but without a noise term - a common simplifying assumption in the IPO literature (Rock, 1986; Benveniste and Spindt, 1989).\(^{12}\) Formally, the market price following the IPO efficiently incorporates or aggregates all information in market when \( P_{mkt}(\omega) = E(\pi|\omega) \). The market price following a successful IPO (i.e., \( A = 1 \)) is given by

\[
P_{mkt} = \begin{cases} 
\frac{\pi}{r} & \text{if } \omega = \pi \text{ and } A = 1 \\
E(\pi)/r & \text{if } \omega = \phi \text{ and } A = 1 
\end{cases}
\]

(2)

\(^{11}\)The precision of prices in Grossman and Stiglitz (1980) is shown to increase in the fraction of informed investors.

\(^{12}\)Since our focus is on the expected market price following the IPO and the consequent expected level of underpricing conditional on the disclosure action of the manager, whether market prices include a noise term or not does not qualitatively alter our results.
Consistent with the literature, we define the level of underpricing for successful IPOs, i.e., $\mathcal{A} = 1$, as the percentage difference between the offer price and the market price following the IPO. Formally, let $\gamma$ denote the realized level of underpricing of a successful IPO as follows:

\[
\text{[Realized Underpricing]} \quad \gamma \equiv \frac{P_{\text{mkt}} - P_{\text{ipo}}}{P_{\text{ipo}}} \quad \text{for } \mathcal{A} = 1
\] (3)

The sequence of events is as follows:

1. With probability $\lambda$ the manager and informed investors observe $\pi$ (i.e., informational event).
2. Manager potentially discloses information $\pi$ or not and IPO is initiated.
3. IPO is successful and $I$ is invested if $P_{\text{ipo}} > I$. Otherwise, the IPO fails.
4. Shares are traded at market price $P_{\text{mkt}}$ (provided that $P_{\text{ipo}} > I$).

3 Equilibrium

We will examine the Perfect Bayesian equilibrium (PBE) of the game set up by the timeline above. To define a PBE concisely, we establish some notation. The PBE consists of:

Manager’s Disclosure Strategy: The manager’s disclosure strategy is denoted by $s : \omega \rightarrow \{D, ND\}$, with $D$ denoting a voluntary disclosure of information $\pi$ by the manager, and $ND$ denoting non-disclosure. Of course, only the informed manager can choose strategy $D$.

IPO Participation Strategy: Given IPO issue price $P_{\text{ipo}}$ the uninformed investors decide whether to participate in the IPO or not based on the information disclosed by the manager, and their Bayes-consistent beliefs on the manager’s disclosure strategy and the participation strategy of the informed investors. Namely, the participation strategy of the uninformed investors is contingent on the public information $\Phi$, where $\Phi = \pi$ if disclosure takes place and $\Phi = ND$ if otherwise. The informed investors, however, directly observe $\omega$ and decide whether to participate or not.

IPO issue price: The IPO issue price $P_{\text{ipo}}$ is competitively set such that the uninformed investors are willing to participate - i.e., break even on their investment/participation in the IPO.

A PBE then is the profile $S^* = (s, P_{\text{ipo}})$ where the manager’s disclosure strategy is optimal given the consequent competitive IPO issue price, and investors participation in the IPO is optimal given the manager’s disclosure strategy and their information. For expositional ease, we will adopt
the usual tie-breaking convention that if the manager is indifferent between disclosure and non-disclosure (i.e., the two choices have the same expected payoffs along the equilibrium path), then the manager chooses non-disclosure.

### 3.1 Basic Properties of the Equilibrium

We begin by analyzing the equilibrium participation strategy of investors. In a successful IPO we need to consider only two cases: (1) all investors demand shares, (2) only uninformed investors demand shares. Remember that a successful IPO requires participation of the uninformed investors, since informed capital alone cannot fully finance the IPO \( \eta K < I \). Thus, for a successful IPO we can restrict attention to \( \zeta \in \{ \frac{I}{K}, \frac{I}{(1-\eta)K} \} \) to reflect the possibility of aggregate demand \( K \), i.e., \( \zeta = \frac{I}{K} \) (all investors participate), and aggregate demand \( (1-\eta)K \), i.e., \( \zeta = \frac{I}{(1-\eta)K} \) (only uninformed investors participate). In an unsuccessful IPO we will say that \( \zeta = 0 \). Formally,

**IPO Allocation**

\[
\zeta|_{A=1} = \begin{cases} \frac{I}{K}, & \text{all investors participate (measure 1)} \\ \frac{I}{(1-\eta)K}, & \text{only uninformed participate (measure 1-\eta)} \end{cases}, \quad \zeta|_{A=0} = 0 \quad (4)
\]

Now we can state the participation decision of both investor types:\(^{13}\)

**Lemma 1 [IPO Participation]** In any equilibrium, given private information \( \omega \in \Omega = \{ \Pi \cup \phi \} \) and public information following the disclosure decision \( \Phi \in \{ \pi, ND \} \):

1. The informed investors will participate if and only if \( P_{ipo} \leq E(\frac{\zeta}{P}|\omega); \)
2. The uninformed investors will participate if and only if \( P_{ipo} \) is such that \( E \left[ \zeta \left( \frac{\zeta}{P} - P_{ipo} \right) |\Phi \right] \geq 0; \)

The equilibrium participation of uninformed investors reflects their Bayes-consistent beliefs regarding the present value of the project \( \frac{\zeta}{P} \), their allocation in the IPO \( \zeta \), the disclosure behavior of the manager and the participation behavior of the informed investors. The above lemma states that the uninformed investors will participate in an IPO as long as it yields a positive expected payoff, \( E \left[ \zeta \left( \frac{\zeta}{P} - P_{ipo} \right) |\Phi \right] \geq 0. \) In competitive financial markets, however, the issuer will set the highest price such that the uninformed investors still find it optimal to participate - i.e., break even.

**Lemma 2 [IPO Issue price]** In any equilibrium \( S^* \), given disclosure outcome \( \Phi \in \{ \pi, ND \} \), the

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\(^{13}\)Formal proofs of Lemmas 1-3 are omitted as they follow directly from the definition of the PBE.
IPO offer price $P_{ipo}(\Phi) = P_{ipo}^*$ is implicitly given by:

$$0 = E \left[ \frac{\pi}{T} - P_{ipo}^* | \Phi \right] .$$

(5)

And, investment takes place, $A(\Phi) = 1$, (i.e., the IPO is successful) if $P_{ipo}(\Phi) \geq I$.

Note that both the adverse selection risk (Myers and Majluf, 1984) and the allocation risk (Rock, 1986) are reflected in the equilibrium IPO offer price. That is, uninformed investors take into account the possibility that the manager is strategically withholding information (following non-disclosure, $\Phi = ND$) and the possibility that the informed investors, are strategically participating in the IPO, potentially leaving the uninformed investors with a higher share of the over-priced IPOs.

In equilibrium, the manager takes into account the implications of her disclosure action on the competitive IPO issue price and investors’ participation:

Lemma 3 [Disclosure strategy] In any equilibrium $S^*$, the manager of type $\omega \in \Omega$ will choose between disclosure, i.e., $\Phi = \pi$, or non disclosure, i.e., $\Phi = ND$, to maximize her expected payoff $E \left[ U^M(\pi|P_{ipo}(\Phi), A(\Phi)) \right]$ as in (1).

Next, before further analysis of the equilibrium in the IPO market, we establish the benchmark outcome when investors all have the same information.

3.2 Homogeneous Investors Benchmark

When only the manager is potentially informed (i.e., there are no informed traders in the market or formally $\eta = 0$), the IPO participants are exposed to the adverse selection introduced by the informed manager only. In this case, the disclosure equilibrium that emerges is along the lines of Dye (1985). Since all investors are endowed with the same information, they share the same participation preferences in equilibrium (cf. Lemma 1). That is, when investors decide to participate they would expect an equilibrium allocation of the IPO $\pi|_A=1 = \frac{I}{T}$ (see (4)). Consequently, the market IPO offer price satisfies $P_{ipo} = E \left[ \frac{\pi}{T} | \Phi \right]$ (cf. Lemma 2) and the manager will disclose her private information whenever $\frac{\pi}{T} > P_{ipo}$ (cf. Lemma 3). Since, the IPO issue price equals the expected present value of cash flows $\frac{\pi}{T}$ conditional on the information disclosed by the manager, there is no underpricing. We can now define the equilibrium IPO issue price following non-disclosure
P_{ipo}(ND) = P^{bm}$ and disclosure cutoff $\pi^{bm} = rP^{bm}$ appropriate for our benchmark case as the solution to:

\[
rP^{bm} = E(\pi) - \lambda \left( \frac{E(\pi) - E(\pi | \pi \leq rP^{bm})}{\lambda Pr(\pi \leq rP^{bm}) + 1 - \lambda} \right) \\
\text{where, } \lambda \equiv \frac{\lambda Pr(\pi \leq rP^{bm})}{\lambda Pr(\pi \leq rP^{bm}) + 1 - \lambda}
\]  

(6)

Notice that $\lambda$ is the conditional probability that the manager is informed conditional on the observation of non-disclosure, while taking into account the manager’s cutoff disclosure strategy. As in Dye (1985), the price following non-disclosure is lower, the higher the probability that the manager is informed $\lambda$. This implies that the IPO issue price might be lower than the required level of investment following non-disclosure if $\lambda$ is sufficiently high. Thus, to focus our analysis on the more interesting case, we restrict attention to the parameter space in which the IPO succeeds following non-disclosure in the benchmark.\(^{14}\) Formally,

**Assumption A1:** \hspace{1cm} $P^{bm} > I$ (IPO successful following non-disclosure in benchmark)

We assume that A1 holds throughout the paper.\(^{15}\)

**Proposition 1 [Homogeneous Investors Benchmark]** Assume A1. The IPO issue price following non-disclosure is $P_{ipo}(ND) = P^{bm}$ (as given by (6)) and following disclosure is $P_{ipo}(\pi) = \frac{\pi}{r}$. The manager of type $\pi$ will disclose her private information when $\pi \geq rP^{bm}$. Finally, the IPO is successful and expected underpricing is zero for all $\Phi$, i.e., $P_{ipo}(\Phi) = E\left(\frac{\pi}{r} | \Phi\right) = E(P^{mkt} | \Phi)$, for $\Phi \in \{\pi, ND\}$.

When part of the investors are informed, the manager faces competition in exploiting, so to speak, the uninformed investors. Consequently, as we show next, the manager’s disclosure strategy, the expected level of IPO underpricing, and IPO investment efficiency all change according to the fraction of informed investors in the market.

\(^{14}\)While assumption A1 implies that the IPO is successful following non-disclosure in the *benchmark* case, this is no longer true in the more general model. We show that it is possible that the IPO fails in equilibrium once informed investors participate in the IPO.

\(^{15}\)Assumption A1 can be replaced by the requirement that $\lambda \leq \hat{\lambda}$ where $\hat{\lambda} \in (0, 1)$ is such that the solution to $P^{bm}$ as defined by (6) satisfies $P^{bm} = I$ for the value $\lambda = \hat{\lambda}$. For further discussion on this assumption see Section 4 and Figure 4. Alternatively, the assumption is satisfied for a sufficiently productive distribution of output $\pi$, a sufficiently low cost of capital $r$ or investment requirement $I$. 

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3.3 Equilibrium with Informed Investors

We start by analyzing the manager’s best response disclosure strategy to a given non-disclosure IPO offer price $P_{ipo}(ND)$. Suppose first that the non-disclosure issue price is sufficiently low such that the IPO would fail following non-disclosure, i.e., $P_{ipo}(ND) < I$. It follows that the manager deploys a cutoff disclosure strategy in equilibrium: the informed manager with a positive NPV project, i.e., $\pi > rI$, prefers disclosure (and consequently investment) over non-disclosure (leading to the failure of the IPO and no investment). Second, suppose that the non-disclosure issue price exceeds the investment requirement, i.e., $P_{ipo}(ND) > I$, i.e., the IPO would succeed following non-disclosure. Now, consider the informed manager of type $\frac{\pi}{r} > P_{ipo}(ND)$. If she discloses her type, then the IPO will succeed at issue price $\frac{\pi}{r}$, while if she withholds her information the IPO still succeeds yet at lower issue price $P_{ipo}(ND)$. The manager deploys a cutoff disclosure strategy in this case as well: managers of type $\frac{\pi}{r} > P_{ipo}(ND)$ find it optimal to disclose while managers of type $\frac{\pi}{r} \leq P_{ipo}(ND)$ will choose non-disclosure.

Proposition 2 [Cutoff Disclosure Strategy] In equilibrium, for any given non-disclosure offer price $P_{ipo}(ND) > I$, the manager’s best response is to disclose $\pi$ when it exceeds a threshold, $\pi > \hat{\pi} = rP_{ipo}(ND)$. Moreover, for any given non-disclosure offer price $P_{ipo}(ND) \leq I$, the manager’s best response is to disclose $\pi$ for all positive NPV projects, i.e., when $\pi > \hat{\pi} = rI$.

According to Lemma 2, the IPO issue price depends on the uninformed investors’ expectations conditional on the information disclosed by the manager. In particular, following non-disclosure the uninformed investors consider the possibility that the manager is strategically withholding information from the market. Therefore, the informed investors are at an information advantage over the uninformed following non-disclosure - this is true whether there was an information event or not. In particular, informed investors know the reason behind non-disclosure.

In deriving the equilibrium, it is useful to first consider the case that the IPO is successful following non-disclosure, $P_{ipo}(ND) \equiv \hat{P} > I$. Following non-disclosure by the manager the uninformed investors base their expectations on their beliefs whether the manager is informed given the manager’s strategy of disclosing whenever $\pi > \hat{\pi} = r\hat{P}$. We denote the conditional probability that

\[^{16}\text{One can concisely write } \hat{\pi} \equiv \max(rI, rP_{ipo}(ND)). \text{ In the case } P_{ipo}(ND) < I \text{ if the manager discloses information about a negative NPV project, then this will result in a failing IPO, i.e., a payoff of zero to the manager.}\]
the manager is informed following non-disclosure by $\lambda'(\hat{P})$, given by:

$$\lambda'(\hat{P}) = \frac{\lambda \Pr(\pi \leq r\hat{P})}{\lambda \Pr(\pi \leq r\hat{P}) + 1 - \lambda}. \quad (7)$$

The competitive issue price of a successful IPO is set such that the uninformed investors are willing to participate. However, when the manager is informed and strategically chooses not to disclose information, the informed investors will not participate in the IPO. Consequently, following non-disclosure by an informed manager, the participating uninformed investors receive allocation $\frac{I}{K(1-\eta)}$ and gain payoff $\left[ \frac{E(\pi|\pi \leq r\hat{P})}{r} - \hat{P} \right] \frac{I}{K(1-\eta)}$, which is negative. That is, the uninformed investors realize a loss in the cases that the informed investors choose not to participate.

When the manager is not informed, with conditional probability $(1 - \lambda'(\hat{P}))$, both the uninformed and the informed investors participate and the allocation received by the uninformed investors is reduced to $\frac{I}{K}$. In this case, the payoff to participants in the IPO is $\left[ \frac{E(\pi)}{r} - \hat{P} \right] \frac{I}{K}$, which is positive in equilibrium. On average, the expected payoff to the uninformed investors from participating in the IPO with price $\hat{P}$ is:

$$\lambda'(\hat{P}) \frac{I}{K(1-\eta)} \left[ \frac{E(\pi|\pi \leq r\hat{P})}{r} - \hat{P} \right] + (1 - \lambda'(\hat{P})) \frac{I}{K} \left[ \frac{E(\pi)}{r} - \hat{P} \right].$$

Accordingly, for the case that the IPO is successful following non-disclosure in equilibrium, we can define the appropriate equilibrium IPO issue price $P_{ipo}(ND) = \hat{P}$ (where the consequent disclosure cutoff is $\hat{\pi} = r\hat{P}$) as the solution to:

$$0 = \rho \lambda'(\hat{P}) \left[ \frac{E(\pi|\pi \leq r\hat{P})}{r} - \hat{P} \right] + (1 - \lambda'(\hat{P})) \left[ \frac{E(\pi)}{r} - \hat{P} \right], \text{ where } \rho \equiv \frac{1}{1 - \eta}. \quad (8)$$

Note that the difference relative to the benchmark case lies in the introduction of allocation risk, as summarized in (4) and is captured by $\rho$ in (8). When the measure of privately informed investors is zero (i.e., $\eta = 0$), the IPO issue price following non-disclosure $\hat{P}$ equals the benchmark price $P_{bm}$ that also equals the conditional expected value of the firm following non-disclosure (as in Dye, 1985). That is, in the presence of informed investors (i.e., $\eta > 0$), not only does the cutoff $\hat{\pi}$ change relative to the benchmark (i.e., $\hat{\pi}$ is a function of $\eta$) but also the IPO issue price following non-disclosure $\hat{P}$ need not equal the expected market value of the firm following non-disclosure, $\hat{P} \neq E \left( \frac{\pi}{r} \right| ND)$. Namely, the uninformed investors put additional weight on the possibility that
the manager is strategically withholding information, i.e., low valuation $E(\pi | \pi \leq r\hat{P})$.

It follows from Proposition 2 that the manager’s disclosure strategy depends on whether the non-disclosure price is sufficiently high for the IPO to succeed. In the benchmark case without private information (see (6)) the IPO is successful following non-disclosure, i.e., $P^{bm} > I$ - as required by assumption A1. However, once informed traders are incorporated into the model the cutoff disclosure strategy of the manager changes, and it is no longer the case that the IPO always succeeds following non-disclosure. In particular, when the fraction of informed investors is sufficiently high, it is no longer possible to finance the investment with their participation. Both aforementioned possibilities are reflected in the equilibrium outcomes listed below.

**Theorem 1 [Voluntary Disclosure Equilibrium]** In equilibrium, the manager voluntarily discloses favorable information, $\pi > \hat{\pi}$, toward a successful IPO issued at price $P_{ipo}(\pi) = \frac{r}{\hat{\pi}}$. The disclosure cutoff $\hat{\pi}$ and the success of the IPO following non-disclosure depend on the fraction of informed investors relative to the critical value $\hat{\eta} \in (0, \frac{1}{2})$ in the following manner:

**High IPO Volume** $[\eta \in (0, \hat{\eta})]$ Following non-disclosure the IPO is successfully issued at price $P_{ipo}(ND) = \hat{P} > I$ (see (8)) and the disclosure cutoff is given by $\hat{\pi} = r\hat{P}$ (partial disclosure equilibrium).

**Low IPO Volume** $[\eta \in (\hat{\eta}, \frac{1}{2})]$ Following non-disclosure the IPO fails and the manager discloses all positive NPV projects, i.e., $\hat{\pi} = Ir$ (full disclosure equilibrium).

In the equilibrium described in Theorem 1 the informed investors and the manager compete to exploit the uninformed investors. In particular, the informed manager withholds information to sell over-valued shares to the market while the informed investors strategically participate in under-valued IPOs. In equilibrium, the informed manager strategically sets her disclosure cutoff $\hat{\pi}$ sufficiently low such that the participants in the IPO over-pay while the informed investors choose not to participate. Of course, when the informed manager discloses information to level-the-playing-field the informed investors no longer have an information advantage and cannot gain from trade. But, when there is no information event (i.e., both the manager and the group of informed investors receive no signal on output $\pi$) the informed investors gain from participating in the under-valued IPO.

**Corollary 1 [Participation by Informed Investors]** Informed investors do not participate in the IPO following non-disclosure by an informed manager; otherwise, informed investors participate.
in the IPO. Moreover, informed investors profit from participating in the IPO when there is no information event.

(Insert Figure 1 here)

This strategic participation of the informed investors following nondisclosure leads to more disclosure relative to the benchmark and lowers the required issue price in order for the uninformed investors to break-even (ala Lemma 2). Eventually, the fraction of informed investors is sufficiently high to push the non-disclosure issue price below the required investment level leading to the failure of the IPO following non-disclosure, i.e., the low-volume equilibrium.

In Figure 1, we present the equilibrium non-disclosure IPO issue price as a function of the level of informed investors $\eta$ for an example where the distribution of firm value $\pi$ is uniformly distributed over the unit interval.\footnote{For the uniform distribution case $\pi \sim U(0,1)$ and when the cost of capital is normalized to $r = 1$ the IPO issue price following non-disclosure in the high-volume equilibrium is given by (according to (8)):}

$$\hat{P} = \frac{-(1-\lambda) + \sqrt{(1-\lambda)^2 + (1-\lambda)\lambda \hat{\rho}}}{\lambda \hat{\rho}}$$

provided that the above solution $\hat{P}$ is sufficiently high such that the IPO is successful following non-disclosure, i.e., $\hat{P} > I$. Thus, the cutoff $\hat{\eta}$ is set such that $\hat{P}(\hat{\eta}) = I$, i.e., $\hat{\eta}$ is implicitly given by (where $\hat{\rho} \equiv \frac{1}{1-\eta}$):

$$\lambda \hat{\rho} I = -(1-\lambda) + \sqrt{(1-\lambda)^2 + (1-\lambda)\lambda \hat{\rho}}$$

In Figure 1 the investment size is $I = 0.38$, and the probability of an information event is $\lambda = 0.5$.\footnote{Since the cost of capital is normalized to $r = 1$ in this example, the disclosure cutoff above which the manager discloses her private information equals the non-disclosure issue price, $\hat{x} = 1 \times \hat{P}$.}

However, when the fraction of informed investors is above the critical value $\hat{\eta} = 0.39$, the IPO fails following non-disclosure forcing the informed manager to disclose whenever her project has a positive NPV. This implies that managers without information and managers with unfavorable information that do not disclose cannot invest since their IPO fails in equilibrium. The expected level of investment (or IPO volume) in the high-volume equilibrium is about 45% higher compared to the low-volume equilibrium.\footnote{The probability that the IPO fails is $1 - \lambda + \lambda P(\pi \leq rI)$. We compare the investment efficiency in the high and low-volume equilibrium outcomes in detail in the subsequent section.}
raised fluctuate over time. There are “hot markets” and “cold markets” (Ibbotson and Jaffe, 1975; Ritter, 1984). Hot IPO markets have been characterized by an unusually high volume of offerings and severe underpricing, while cold IPO markets have much lower issuance and less underpricing. Theorem 1 suggests that the disclosure behavior of the managers of issuing firms varies with IPO volume (or fluctuates between hot and cold IPO markets): in the high-volume equilibrium there is less voluntary disclosure by managers of IPO firms relative to the low-volume equilibrium. This prediction of the model has not been tested empirically to the best of our knowledge, but could be potentially an interesting avenue for future empirical research. Subsequently, after we explore the level of underpricing in equilibrium and the efficiency of investment in IPO firms, we further relate our results to the empirical literature on IPO waves.

Now that we have established the equilibrium issue price, to calculate the level of under pricing, we turn to the market price that realizes once trade takes place (sometimes referred to as the after-market price). As specified earlier in (2) the market price represents the aggregate information in the market as captured by \( \omega \). From the perspective of the uninformed investors, given the information disclosed (or not disclosed) by the manager \( \Phi \in \{\pi, ND\} \), the expected market price conditional on information \( \Phi \) satisfies \( E(P_{mkt} | \Phi) = E(\pi | \Phi) \). It follows from (2) that once the uncertainty is removed by the manager via disclosure, \( \Phi = \pi \), the IPO issue price and the market price both equal \( P_{ipo} = P_{mkt} = \frac{\pi}{r} \).

Of course, following non-disclosure the uninformed investors do not know whether the manager is informed but is strategically withholding information or the manager is not informed since there was no information even. To calculate the expected market price conditional on the information disclosed (or not) by the manager, from the perspective of the uninformed investors, it is useful to consider the two aforementioned possibilities. First, in the case of non-disclosure following an information event, i.e., \( \omega = \pi' \leq \hat{\pi} \), the full-information-revealing market price will be \( P_{mkt} = \pi' / r \); Second, in the case of non-disclosure following no information event, i.e., \( \omega = \phi \), the market price will be \( P_{mkt} = E(\pi) / r \). The former possibility occurs with conditional probability \( \frac{\lambda \Pr(\pi \leq r \hat{P})}{\lambda \Pr(\pi \leq r \hat{P}) + 1 - \lambda} \) (i.e., conditional on the event \( ND \)). The expected market price following a successful IPO conditional on the information disclosed (or not disclosed) is given in the following proposition:

**Proposition 3** [Market Price] In the high-volume equilibrium, \( \eta \in (0, \hat{\eta}) \), the expected market price following non disclosure by the manager, from the perspective of the uninformed investors, is
(where \( \hat{P} \) is given by (8)),

\[
E(P^{mkt}|ND) = \frac{E(\pi)}{r} - \frac{\lambda'}{r} \left( E(\pi) - E(\pi|\pi \leq r\hat{P}) \right)
\]

where, \( \lambda' = \frac{\lambda \Pr(\pi \leq r\hat{P})}{\lambda \Pr(\pi \leq r\hat{P}) + 1 - \lambda} \). (11)

In the low-volume equilibrium, \( \eta \in (\hat{\eta}, \frac{1}{2}) \), the market price following non-disclosure is irrelevant since the IPO fails following non-disclosure. Finally, following disclosure the market price equals the IPO issue price, \( P^{mkt} = \frac{\pi}{r} = P_{ipo} \), for all \( \eta \in (0, \frac{1}{2}) \).

Figure 2 plots the IPO issue price against the true value \( \pi \) as observed by the informed manager. As suggested by the figure, the manager strategically discloses information to maximize the issue price, but there is underpricing following non-disclosure. In particular, the expected market price following non-disclosure (across all non-disclosing successful IPOs) exceeds the price at which the IPO is issued.\(^{20} \) Indeed, it follows from examination of (8) and (11) that \( P_{ipo}(ND) < E(P^{mkt}|ND) \) in the high-volume equilibrium. Of course, the IPO is perfectly priced following disclosure.

(Insert Figure 2 here)

Intuitively, the uninformed traders that participate in the IPO face competition from the informed investors that selectively participate in under-valued IPOs. Consequently, the uninformed investors will participate only if the IPO is underpriced - i.e., the offer price is sufficiently low to compensate them (Rock, 1986). But, the manager here can avoid the cost of underpricing by voluntarily disclosing information: following disclosure both the IPO offer price and the market price incorporate the same information, \( P^{mkt} - P_{ipo} = 0 \). If underpricing persists in equilibrium it is since the informed manager prefers it over the alternatively perfectly priced IPO (following disclosure).

The average level of underpricing observed in the data corresponds to the expected level of underpricing conditional on the IPO being successful, \( E(\gamma|A = 1) \). It follows from the above that the expected level of underpricing is strictly positive in the high-volume equilibrium and is zero in the low-volume equilibrium. This is formally stated in the following theorem.

\(^{20}\)For the uniform distribution example at hand the expected market price following non-disclosure is given by the discounted expected level of output following non-disclosure \( E(\pi|ND)/r \) and therefore (where \( \hat{\pi} \) was given earlier)

\[
E(P^{mkt}|ND) = \frac{1}{r} \left[ \frac{1}{2} - \frac{\lambda \hat{\pi}}{\lambda \hat{\pi} + 1 - \lambda} \left( \frac{1}{2} - \frac{\hat{\pi}}{2} \right) \right].
\] (12)
Theorem 2 [Underpricing] In the low-volume equilibrium, where the informed manager discloses all positive NPV projects, IPOs are not underpriced, i.e., \( E(\gamma|A = 1) = 0 \) for \( \eta \in (\hat{\eta}, \frac{1}{2}) \). However, in the high-volume equilibrium, where the manager selectively discloses information, the expected level of underpricing is strictly positive, i.e., \( E(\gamma|A = 1) > 0 \) for \( \eta \in (0, \hat{\eta}) \).

The expected level of underpricing, given the equilibrium issue price \( \hat{P} \) in (8), is calculated as \( E(\gamma|A = 1) = [1 - \lambda \Pr(\pi > \hat{\pi})] \frac{E(P_{\text{mkt}}|ND) - \hat{P}}{\hat{P}} \), for \( \eta < \hat{\eta} \) (where the cutoff is given by \( \hat{\pi} = r\hat{P} \)). Namely, with probability \( \lambda \Pr(\pi > \hat{\pi}) \) the manager is informed with favorable information and there is no underpricing due to disclosure. With probability, \( 1 - \lambda \Pr(\pi > \hat{\pi}) \) however, the manager is either not informed or is informed but does not disclose her information, i.e., there is no disclosure. In the latter case, the IPO succeeds (provided that \( \eta < \hat{\eta} \)) yet is underpriced.

(Insert Figure 3 here)

Returning to our example with uniformly distributed output, we plot the expected level of underpricing as a function of the fraction of informed investors in Figure 3. Notice that the level of expected underpricing is positive in the high-volume equilibrium (\( \eta \leq \hat{\eta} \)), but it equals zero for \( \eta > \hat{\eta} \). As the fraction of informed traders increases (i.e., the more severe the adverse selection problem between the two types of investors), the higher is the level of underpricing that follows non-disclosure. But, since it is more costly for the manager to withhold information she responds in equilibrium by reducing the disclosure cutoff (i.e., the likelihood of non-disclosure is lowered). For the uniform distribution example at hand, the expected level of underpricing increases in the fraction of informed investors till it exceeds the threshold \( \hat{\eta} \) after which there is no underpricing.

A substantial difference between the high and low volume equilibrium outcomes has to do with the propensity to disclose and the failure of IPOs following non-disclosure. In a complete-information (or first-best) economy investment takes place if and only if profitable. In the high-volume equilibrium, however, IPOs are successful regardless of the manager’s disclosure strategy and consequently there is over investment relative to the first-best. Namely, informed managers with negative NPV projects secure sufficient funds in the IPO. On the other hand, in the low-volume equilibrium, IPOs fail following non-disclosure. That is, positive NPV projects of the uninformed managers are not financed, i.e., there is under-investment relative to the first-best. Moreover, the average failing IPO in the low-volume equilibrium is endowed with a strictly positive NPV project. To see this, note that the probability that the IPO fails in the low-volume equilibrium is given by \( (1 - \lambda + \lambda \Pr(\pi \leq Ir)) \), i.e., it fails when there is no information event, \( \omega = \phi \), or there is
an information event but the project has a negative NPV, $\pi \leq Ir$. The lack of investment or the failure of the IPO following non-disclosure prevents the informed manager from investing in a negative NPV project. However, at the same time, it prevents the uninformed manager from investing in an average project that has a strictly positive NPV, since $E(\pi) > Ir$ (assumption A1). Taking into account these two conflicting forces, the overall implication for investment efficiency is unambiguous: the average failing IPO firm is endowed with a positive NPV project.

**Theorem 3 [Investment Efficiency]** There is under (over) investment in IPOs in the low (high) volume equilibrium relative to the complete-information investment level. Moreover, the average failing IPO in the low volume equilibrium is endowed with a positive NPV project, i.e., $\frac{E(\pi|ND)}{r} > I$ for $\eta \in (\hat{\eta}, 1)$.

It is surprising that full disclosure of information and the elimination of underpricing of IPOs is consistent with under-investment or excessive failing of IPOs. To understand this result, it is instructive to focus attention on the firms that fail to go public. When IPOs fail in the model it is because a sufficiently high IPO issue price to support investment is not obtained in equilibrium. Now, since the issue price is depressed (or there is underpricing), IPOs might suffer under-investment if underpricing leads to the failure of the IPO. Thus, it is when we do not observe underpricing that investment opportunities are foregone in equilibrium. Namely, an IPO of a non-disclosing firm succeeds as long as the proceeds from the IPO cover the initial investment, i.e., $P_{ipo}(ND) > I$. But, this is the case for $\eta \in (0, \hat{\eta})$ since the IPO price is decreasing in the fraction of informed investors $\eta$ and the boundary $\hat{\eta}$ is defined such that $P_{ipo}(ND) = I$. Since underpricing is strictly positive at the boundary we obtain that $P_{ipo}(ND) = I < \frac{E(\pi|ND)}{r}$, which implies a positive NPV on average for IPO firms that fail.

### 4 Empirical Implications

As discussed above the fraction of informed investors is directly linked to the level of underpricing required by the uninformed investors (see (8)). In the high-volume equilibrium, the IPO is successful even following non-disclosure as the manager trades off disclosing information to eliminate underpricing with withholding information and proceeding with the IPO while suffering underpricing. As long as the level of underpricing is smaller than the informational gap between the manager’s private information and investors’ beliefs, the manager will withhold information
and choose non-disclosure. This trade-off is directly affected by the level of underpricing which increases with the fraction of informed investors. Therefore, we would expect that as the fraction of informed investor goes up, the manager will be more willing to disclose to avoid underpricing i.e. the disclosure cutoff level will be lower. Moreover, the manager will be also more inclined to disclose information when the likelihood of an information event is higher, which is consistent with the traditional voluntary disclosure literature (Dye, 1985). The following proposition formalizes these arguments.

**Proposition 4 [Propensity to Disclose]** In the high-volume equilibrium, \( \eta \in (0, \hat{\eta}) \), the manager is more likely to disclose information when the fraction of informed traders increases (i.e., \( \frac{\partial x}{\partial \eta} < 0 \)) or when the probability of an information event is higher (i.e., \( \frac{\partial x}{\partial \lambda} < 0 \)). In the low-volume equilibrium, \( \eta \in (\hat{\eta}, \frac{1}{2}) \), all positive NPV projects are disclosed and the disclosure cutoff is fixed.

Proposition 4 points to some novel empirical implications. It implies that in periods of high IPO volume, we would expect managers’ efforts’ to inform the market (via prospectuses and road shows) to increase in the fraction of informed traders. We should therefore expect to find a positive association between informed investor interest in IPOs and the informativeness of prospectuses and/or the extent of marketing campaigns undertaken by these firms ahead of their IPOs. In periods of low IPO volume, however, we should not expect to find such a relation.

While Proposition 4 also establishes that the disclosure cut-off decreases in \( \lambda \), a higher probability \( \lambda \) can push the equilibrium into the low-volume (and full-disclosure) region. To see why, note that the relation of the fraction of informed investors \( \eta \) relative to the critical value \( \hat{\eta} \) determines whether the equilibrium is of high or low volume (Theorem 1) - affecting the level of underpricing, volume and investment efficiency. The critical value is endogenously determined in equilibrium as the value that sets the expected value of the IPO firm in the eyes of the uninformed investors (following non-disclosure by the manager) equal to the required level of investment by the IPO firm. As such, it depends on the size of the investment \( I \), the discount rate \( r \), and the manager’s propensity to disclose according to the the ex-ante likelihood that the manager is informed \( \lambda \).

**Proposition 5 [IPO Volume]** For any given fraction of informed investors \( \eta \), the equilibrium is one of low-volume (cf. Theorem 1) if the probability of an information event \( \lambda \), the cost of capital \( r \), or the required investment level \( I \), are sufficiently high.

This proposition suggests that the high-volume equilibrium is more likely when the probability of an information event is lower, as is likely the case in emerging industries and new technologies.
In such instances, firms undertake considerable investments based more on promise and the desire to garner first-mover competitive advantage, than on informed expectation. A good example is the Internet dotcom boom era when many firms went public at a time when there was great uncertainty about the potential of internet usage, and the prospects. Consequently, the adverse selection problem that informed managers face is not as severe (because uninformed investors attach a greater probability to IPO firms being uninformed given a low $\lambda$), and it is preferable for them to withhold information and suffer some underpricing in equilibrium. As $\lambda$ increases, the adverse selection problem becomes increasingly acute to the point where the equilibrium shifts to a low volume equilibrium in which IPO firms are more forthcoming with disclosures ahead of the IPO.

An immediate empirical implication here is that we should expect less pre-IPO disclosures and less informative IPO prospectuses and higher levels of underpricing for young growth firms and firms pursuing nascent technologies. In other words, “hot” IPO or high-volume eras should witness less pre-IPO disclosures and higher levels of underpricing relative to “cold” IPO eras in which IPO managers would be willing to fully disclose information.

While propositions 4 and 5 mention empirical implications with respect to the probability of an information event, $\lambda$, recall that the assumption required by Theorem 1, i.e., $\mathbf{A1}$, practically puts an upper bound on the probability of an information event. In particular, it requires that $\lambda \leq \hat{\lambda}$ for some $\hat{\lambda} \in (0, 1)$ and ensures that the critical level is interior, $\tilde{\eta} \in (0, \frac{1}{2})$. Note that if $\lambda$ increases above $\hat{\lambda}$, i.e., assumption $\mathbf{A1}$ does not hold, then the low-volume equilibrium prevails for any fraction of informed investors. Thus, we have focused our analysis on the region where changes in the fraction of informed investors influence the manager’s disclosure strategy, the expected level of underpricing and the volume of IPOs. The equilibrium type as a function of the probability of the information event $\lambda \in (0, 1)$ and the fraction of informed traders $\eta$ is depicted in Figure 4. One can see from the figure that the more likely an information event, the lower is the critical level $\tilde{\eta}$, above which the low-volume equilibrium with full disclosure by the informed manager holds.

(Insert Figure 4 here)

Proposition 5 also suggests that firms that are required to finance larger investments are more likely to engage in sufficient pre-IPO disclosures before successfully going public.

**Proposition 6 [IPO Profitability]** The average profitability of IPO firms in the high-volume equilibrium is lower than that in the low-volume equilibrium. Moreover, average profitability of disclosing firms is higher relative to non-disclosing firms.
Interestingly, this prediction of the model that the profitability of IPO firms in the low-volume equilibrium is on average higher than that in high-volume markets obtains despite there being under-investment in IPO firms in this equilibrium (cf. Theorem 3). The reason is that only firms with positive NPV projects engage in IPOs and succeed in the low-volume equilibrium, and, therefore, the average successful IPO has positive NPV above the NPV of the population average. In particular, investment only takes place following disclosure and the average profitability (of the successful IPOs) is $ \frac{E(\pi | \pi > Ir)}{r} - I $. In contrast, all IPOs are successful in the high-volume equilibrium and the average profitability of the IPO firms is given by the population average $ \frac{E(\pi)}{r} - I $. This “self-selection” on the part of IPO firms with positive NPV projects in the low-volume equilibrium leads to the prediction that IPO firms would appear profitable \textit{ex post} in the low-volume equilibrium (i.e., in “cold” IPO periods) relative to the high-volume equilibrium (i.e., in “hot” IPO eras).

Finally, we address the question of whether disclosure of information by the manager results in higher expected market price. In other words, whether firms that release more information in the pre-IPO period are more valuable. Recall, the manager discloses information to maximize the IPO issue price and not the market price. Since the market price aggregates all information in the market (i.e., incorporates $ \omega $) and since the IPO offer price exhibits underpricing it is possible that the market values of non-disclosing firms are higher than that of disclosing firms.

**Proposition 7** [Market Reaction to Disclosure] In the high-volume equilibrium, the market price of disclosing firms $ P_{mkt} $ need not be higher than that of non-disclosing firms $ E(P_{mkt} | ND) $, as in (11). Formally, the market price is higher (lower) following disclosure relative to non-disclosure for $ \frac{E}{r} > E(P_{mkt} | ND) \ (\frac{\bar{E}}{r} \in (P_{ipo}(ND), E(P_{mkt} | ND))) $, $ \eta \in (0, \bar{\eta}) $.

Empirically, this proposition implies that firms that do not appear to engage in extensive pre-IPO disclosure campaigns and do not appear to put out particularly informative prospectuses may actually be priced higher by the market than disclosing firms in the high-volume or “hot” IPO periods.

5 Conclusion

It is well known that considerable information asymmetry and uncertainty surrounds young growth firms as they approach the capital market for the first time to raise needed capital, and that these initial public offerings (IPOs) take place at considerable discount. While many theories
have been put forth to rationalize this IPO underpricing phenomenon, there is general consensus it is attributable to adverse selection that arises primarily from the aforementioned information asymmetries between issues/informed investors and uninformed investors.

Clearly, one way in which to mitigate IPO underpricing is to reduce information asymmetries via voluntary disclosures of value relevant information. However, the voluntary disclosure literature has established that strategic non-disclosure of unfavorable value relevant information can have positive market valuation effects in equilibrium. Thus, firms contemplating IPOs face an interesting trade off: Whether to disclose information and reduce
e\im\eliminate underpricing or withhold information and proceed with the IPO while suffering some underpricing and leaving money on the table in order to be valued higher.

In this paper, we model this trade off that has hitherto not been examined in this literature. We bring together two strands of literature – the role of adverse selection in IPO underpricing and the role of adverse selection in strategic voluntary disclosure— to provide insight into equilibrium disclosure strategies of IPO firms and the consequent implications for underpricing and investment efficiency. In our model, uninformed capital providers, whose participation is key to IPO success, face two types of risk—an adverse selection risk arising from the IPO issuer being privately informed about firm value (Dye 1985, Myers and Majluf 1984), and an allocation risk to the extent there exist a set of informed investors (Rock, 1986). We show that the equilibrium disclosure strategies are determined in an important way by the presence and the magnitude of these two types of risks.

In particular, we show that the manager of the IPO firm strategically takes into account the presence of informed traders when disclosing information: more disclosure takes place (i.e., lower disclosure cutoff) when the fraction of informed traders increases, and full disclosure is the equilibrium outcome when this fraction is above a threshold Moreover, while the IPO issue price is higher for disclosing firms relative to non-disclosing firms, the IPO market price need not be higher, relative to that of non-disclosing firms.

We distinguish between two equilibrium outcomes: when the fraction of informed investors is low, firms going public disclose less information, there is underpricing, and the volume of firms going public is high (the high volume equilibrium), and when the fraction of informed investors is sufficiently high, there is full disclosure of information by firms, no underpricing, and less investment by IPO firms (the low volume equilibrium). In other words, “hot” IPO or high-volume eras should witness less pre-IPO disclosures and higher levels of underpricing relative to “cold” IPO eras in which IPO managers would be willing to fully disclose information. In addition, we also show that
in the low volume equilibrium, there is underinvestment as the average failing IPO has a positive NPV project, while in the high volume equilibrium there is overinvestment since firms with negative NPV projects that strategically withhold information from investors succeed to go public. Thus, full disclosure need not be indicative of investment efficiency.

Finally, we find that while more disclosure reduces underpricing, the average level of underpricing is nonmonotonic in the fraction of informed investors. Thus, our results provide a rationale for the extant empirical evidence on the relation between underpricing and value uncertainty in “hot” and “cold” IPO markets (which conform to the high- and low-volume equilibria, respectively) and provide directions for future research. As the intensity of private information increases up to a certain level, managers disclose more information (for the reasons indicated above), but the expected level of underpricing (across all successful IPOs) increases. This positive relation between underpricing and private information intensity is consistent with extant IPO literature (Rock, 1986; Benveniste and Spindt, 1989; Ellul and Pagano, 2006). However, if the information asymmetry problem becomes sufficiently severe, then, in equilibrium, insiders make public all value-relevant information to avoid foregoing positive NPV projects. The relatively lower levels of information disclosure in the high-volume equilibrium as compared to the low-volume equilibrium, is consistent with the observed higher volatility of initial returns in hot IPO periods (Lowry, Officer, and Schwert, 2010).

6 Appendix

Proof. [Proposition 1] The proof follows directly from Dye (1985) and is not repeated here.

Proof. [Proposition 2] Consider first the price $P_{ipo}(ND) \equiv P_{ipo} > I$. If the informed discloses information $\pi$, then the issue price will reflect this information, i.e., $P_{ipo}(D) = \frac{\pi}{I}$. Therefore, the informed manager will disclose her information if it results in a higher payoff $\frac{\pi}{I} - I$ relative to non-disclosure $\left(\frac{P_{ipo}-I}{P_{ipo}}\right) \frac{\pi}{I}$. Or equivalently, if $\frac{\pi}{I} - I > \left(\frac{P_{ipo}-I}{P_{ipo}}\right) \frac{\pi}{I}$ and this implies that the manager will prefer disclosure for $\pi > P_{ipo}r$. Alternatively, if $P_{ipo}(ND) < I$ then the IPO fails following non-disclosure. Since the manager’s payoff is zero if the IPO fails, the manager of type $\pi$ is better off disclosing her information when ever her project has a positive NPV, i.e., for all values $\pi > Ir$. In this case, that $P_{ipo}(ND) < I$, the manager can also disclose information about negative NPV projects but this will not result in a successful IPO, thus with out loss of generality we can assume here that the manager will disclose information as long as $\pi > rI$. ■
Proof. [Theorem 1] First suppose that the IPO is successful following non-disclosure, \( P_{ipo}(ND) = \hat{P} > I \), i.e., the high-volume equilibrium. Following non-disclosure the uninformed investors base their expectations on their beliefs whether the manager is informed or not. With conditional probability \( \lambda'(\hat{P}) \) (as defined in (8)) the manager is informed but chooses not to disclose. In this case, the informed investors will not participate in the IPO and the participating uninformed investors receive allocation \( I K (1 - \eta) \) and gain payoff \( \frac{E(\pi \mid \pi \leq rz) - \hat{P}}{r} = \frac{I K (1 - \eta)}{r} \) which is negative in equilibrium. Otherwise, if the manager is not informed, with probability \( (1 - \lambda'(\hat{P})) \), then the informed investors participate and the allocation received by the uninformed investors is \( I K \). In this case, the payoff to participants in the IPO is \( \frac{E(\pi)}{r} \) which is positive in equilibrium.

Finally, the weights \( \lambda'(\hat{P}) \) take into account the manager’s disclosure strategy, i.e., that disclosure occurs for \( \pi > r \hat{P} \).

Thus, the equilibrium non-disclosure IPO price \( P_{ipo}(ND) \) is set such that the uninformed investors break even on average and is the solution to \( F(z) = 0 \) where \( \rho = \frac{1}{1-\eta} \):

\[
F(z) = \lambda'(z) \rho \left[ \frac{E(\pi \mid \pi \leq rz)}{r} - z \right] + (1 - \lambda'(z)) \left[ \frac{E(\pi)}{r} - z \right].
\]

A solution exists since for \( z = 0 \) we have \( F(0) = \frac{E(\pi)}{r} > 0 \) but on the other extreme for \( z = \frac{E(\pi)}{r} \) we have \( F \left( \frac{E(\pi)}{r} \right) = \lambda \rho [E(\pi \mid \pi \leq E(\pi)) - E(\pi)] < 0 \) (\( F(\cdot) \) is continuous). Thus, there exists a price such that \( \hat{P} \in (0, \frac{E(\pi)}{r}) \). Now, this will be a disclosure equilibrium as long as the IPO is successful following non-disclosure, i.e., \( \hat{P} > I \). As we see next, this condition requires that \( \eta < \hat{\eta} \).

Notice from the above that the IPO offer price (assuming that investment takes place following non-disclosure) is the solution to

\[
F(z, \rho) = \lambda'(z) \rho \left[ \frac{E(\pi \mid \pi \leq rz)}{r} - z \right] + (1 - \lambda'(z)) \left[ \frac{E(\pi)}{r} - z \right] = 0.
\]

For \( z = I \) we define \( \hat{\eta} \equiv 1 - \frac{1}{\rho} \) implicitly by

\[
F(I, \hat{\rho}) = 0.
\]

That is, we define \( \hat{\eta} \) to be the highest fraction of informed traders such that the IPO is successful following non-disclosure. It remains to show that such a solution \( \hat{\rho} \in (1, \infty) \) exists. This follows since \( F(I, \infty) < 0 \), and \( F(I, 1) > 0 \) (we require assumption A1 here). The uniqueness of \( \hat{\eta} \) follows since \( \frac{\partial F}{\partial \rho} = \lambda'(z) \left[ \frac{E(\pi \mid \pi \leq rz)}{r} - z \right] < 0. \)
Finally, for \( \eta \in (\bar{\eta}, 1) \), i.e., the *low-volume equilibrium*, the valuation following non disclosure (assuming that the IPO succeeds following non-disclosure) is not sufficiently high to grant a successful IPO following non-disclosure. Thus, in this region, the IPO fails following non-disclosure and the manager’s disclosure strategy is to disclose all positive NPV projects, or, \( \pi > Ir \). ■

**Proof. [Corollary 1]** Note that following non-disclosure the IPO is over-priced when there is no information event \( (\omega = \phi) \) and is under-priced otherwise \( (\eta \in (0, \bar{\eta})) \), as \( \hat{P} \in \left( \frac{E(\pi|\pi < r\hat{P})}{r}, \frac{E(\pi)}{r} \right) \). ■

**Proof. [Proposition 3]** The expected value of the firm following non-disclosure follows directly from the manager’s disclosure strategy as specified in Theorem 1. ■

**Proof. [Theorem 2]** In the high-volume equilibrium \( (\eta \in (0, \bar{\eta})) \), it follows from (11) that \( \frac{E(\pi|ND)}{r} > \hat{P} \) for any equilibrium non-disclosure issue price \( P_{ipo}(ND) = \hat{P} \). In particular, we note that the average value of the firm that chooses non-disclosure given \( \hat{P} \) is

\[
\frac{rE(P^{mk}|ND)}{r} = E(\pi|ND) = \lambda'(\hat{P})E(\pi|\pi \leq r\hat{P})+(1-\lambda'(\hat{P}))E(\pi), \text{ where } \lambda'(\hat{P}) = \frac{\lambda Pr(\pi \leq r\hat{P})}{\lambda Pr(\pi \leq r\hat{P}) + 1 - \lambda} \tag{16}
\]

But, the equilibrium offer price \( P_{ipo}(ND) = \hat{P} \) is given by (see (8))

\[
r\hat{P} = \frac{\lambda'(\hat{P})\rho E(\pi|\pi \leq r\hat{P})+(1-\lambda'(\hat{P}))E(\pi)}{\lambda'(\hat{P})\rho + (1-\lambda'(\hat{P}))} \tag{17}
\]

let \( \lambda'(\hat{P}, \rho) = \frac{\lambda'(\hat{P})\rho}{\lambda'(\hat{P})\rho + (1-\lambda'(\hat{P}))} \) thus,

\[
r\hat{P} = \lambda'(\hat{P}, \rho)E(\pi|\pi \leq r\hat{P}) + (1 - \lambda'(\hat{P}, \rho))E(\pi). \tag{18}
\]

This implies that,

\[
\lambda'(\hat{P}, \rho) = \frac{\lambda Pr(\pi \leq r\hat{P})}{\lambda Pr(\pi \leq r\hat{P}) + \left( \frac{1-\lambda}{\rho} \right)} > \frac{\lambda Pr(\pi \leq r\hat{P})}{\lambda Pr(\pi \leq r\hat{P}) + 1 - \lambda} = \lambda'(\hat{P}). \tag{19}
\]

And consequently \( E(P^{mk}|ND) > \hat{P} \) in equilibrium. ■

**Proof. [Theorem 3]** In the complete information benchmark only IPOs with positive NPV projects are successful, i.e., \( \pi > rI \). In the high volume equilibrium all IPOs are successful, i.e., there is over investment since IPOs with negative NPV projects are financed following non-disclosure. On the other hand, in the low volume equilibrium only IPOs of disclosing firms are successful, i.e., there is under investment since positive NPV projects are not financed. Moreover,
the average failing IPO has a positive NPV project. To see this, note that the probability of non-
disclosure is \(\Pr(c) + (1 - \lambda)\) and the expected value of the investment following non-disclosure
is \(E(\pi|ND)\). Thus, the loss due to non-investment following non-disclosure is

\[
(\lambda \Pr(\pi \leq \pi^c) + 1 - \lambda) \left[ \frac{E(\pi|ND)}{r} - I \right]
\]

Since the cutoff \(\hat{\pi}\) is defined such that \(\frac{\hat{\pi}}{r} = I = \hat{P}\), and expected under-pricing is strictly positive, i.e., \(E(P_{mk}|ND) > \hat{P}\) (see Theorem 2) we conclude that the investment efficiency loss conditional on IPO failure is strictly positive:

\[
\frac{E(\pi|ND)}{r} - I > 0.
\]

Moreover, the expected efficiency loss due to the possibility of IPO failure is:

\[
\frac{(1 - \lambda)E(\pi) + \lambda \int_0^I \pi f(\pi)d\pi}{r} - I(1 - \lambda + \lambda \Pr(\pi \leq rI))
\]

Proof. [Proposition 4] Let,

\[
F(z) = \lambda' \rho [E(\pi|\pi \leq z) - z] + (1 - \lambda' \rho) [E(\pi) - z].
\]

It is required to show that

\[
\frac{\partial z}{\partial \rho} = - \frac{\partial F}{\partial \rho} \left/ \frac{\partial F}{\partial z} \right. < 0
\]

Note,

\[
\frac{\partial F}{\partial \rho} = \lambda' \rho [E(\pi|\pi \leq z) - z] < 0, \frac{\partial F}{\partial z} < 0.
\]

The latter requires that \(\frac{\partial [E(\pi|\pi \leq z) - z]}{\partial z} < 1\) a common assumption in this literature that is satisfied
by a wide class of distributions (see Dye, 1985, Langberg and Sivaramakrishnan, 2009).

Proof. [Proposition 5] Follows since \(\frac{\partial P}{\partial \lambda} < 0\) (see ((8))), i.e., that the disclosure cutoff is decreasing in the likelihood that the manager is informed.

Proof. [Proposition 6] Follows from the equilibrium defined in Theorem 1 and since \(E(\pi|\pi > Ir) > E(\pi)\).

Proof. [Proposition 7] Follows since \(\frac{E(\pi|ND)}{r} > P_{ipo}(ND)\).
The graph is plotted based on the example of uniformly distributed output $\pi \sim U(0,1)$ and for the parameter values $(\lambda = 0.5, r = 1, I = 0.38)$. The critical fraction of informed traders above which the equilibrium is a low-volume equilibrium is $\hat{\eta} = 0.392$. 
The graph is plotted based on the example of uniformly distributed output $\pi \sim U(0,1)$ and for the parameter values $(\lambda = 0.5, r = 1, I = 0.38)$. The specific fraction of informed investors assumed here is $\eta = 0.35$ which is lower than the critical value $\hat{\eta} = 0.392$. and consequently the equilibrium is of high-volume where the disclosure cutoff is $\hat{\pi} = 0.386$.
The graph is plotted based on the example of uniformly distributed output $\pi \sim U(0,1)$ and for the parameter values $(\lambda = 0.5, r = 1, I = 0.38)$. The critical fraction of informed traders above which the equilibrium is a low-volume equilibrium is $\eta = 0.392$. 
Voluntary Disclosure Equilibrium

Figure 4

- Critical value $\hat{\eta}$
- Low IPO volume & full-disclosure
- High IPO volume & partial-disclosure

Fraction of informed investors $\eta$

Probability of information event $\lambda$
Figure 5

The graph presents annual data on underpricing and aggregate liquidity using the Sadka (2006) liquidity factor and IPO data from the website of Jay Ritter, years 1983-2010. A quadratic fit is represented by the solid line.