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Voluntary Disclosure with Informed Trading in the IPO Market

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ABSTRACT

We examine voluntary disclosure and capital investment by an informed manager in an initial public offering (IPO) in the presence of informed and uninformed investors. We find that in equilibrium, disclosure is *more* forthcoming—and investment efficiency is *lower*—when a greater fraction of the investment community is *already* informed. Moreover, managers disclose more information when the likelihood of an information event is higher, more equity is issued, or the cost of information acquisition is lower. Investment efficiency and the expected level of underpricing are non-monotonic in the likelihood that the manager is privately informed.

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1. Introduction

Corporate insiders have a natural information advantage with respect to their firms' economic prospects but financial markets also provide incentives for outside investors to generate and potentially profit from value-relevant information. Indeed, aggregation of dispersed information in security prices and its attendant effects on real investment are topics of long-standing interest in the accounting and finance literatures. Theory suggests that informed managers sometimes secure higher valuations from direct disclosures to markets, but the presence of informed investors can potentially affect such benefits significantly. This issue is of substantial interest because there is considerable evidence of informed trading ahead of several corporate disclosure events—such as announcements of earnings forecasts, mergers and acquisitions, and initial public offerings (IPOs).

Prima facie, informed investors can affect incentives for disclosure in conflicting ways. On one hand, if a manager's private information is already present in financial markets (through a relatively high intensity of informed traders), then disclosure will have low impact on security prices, other things being equal—thereby reducing the manager's incentive to disclose. On the other hand, it is well known that the presence of informed traders raises adverse selection risk for uninformed traders, which can lead to higher risk premium and lower security prices—thereby increasing the incentive to disclose.[1] The resolution of these contending effects and the consequent implications for equilibrium disclosure levels of firms have not been addressed in the existing disclosure literature.

In this paper, we analyze managers' disclosure strategies in the presence of both *informed* and *uninformed* market participants. We focus on IPOs as the setting for our study because IPO firms have considerable discretion over what to disclose ahead of the IPO.[2] They also have a natural incentive to limit underpricing through such disclosures (see, e.g., Ljungqvist [2007]).[3] The literature shows that underpricing can arise because of

[1] See, for example, Garleanu and Pederson [2004] or even Akerlof [1970] and Milgrom and Stokey [1982] on market failure.

[2] Beyond their importance as a financing milestone, IPOs are major disclosure events. During the IPO, firms often go beyond mandated disclosure requirements to provide detailed information about their operations, financial performance, business plans, competitors, risks and so forth (e.g., Ellis, Michaely, and O'Hara [1999]) in IPO prospectuses and/or during "book building"—a process that involves meetings with potential investors to generate demand for their IPOs.

[3] In particular, evidence suggests that such disclosures reduce information asymmetry and lead to more accurate pricing. See, for example, Hanley and Hoberg [2010], Benveniste and

"allocation" risk that informed investors impose on the uninformed (Rock [1986]); IPO firms can reduce this risk by offsetting the advantage of informed investors via voluntary disclosures. On the other hand, strategic *non-disclosure* can help them secure higher expected prices in equilibrium (e.g., Verrecchia [1983], Dye [1985], Jung and Kwon [1988]). We model this tradeoff and show that it shapes disclosure strategies of informed firms in unique and important ways not hitherto identified in the literature.

Our analysis yields a striking and seemingly counterintuitive result on the relation between demand and supply (through disclosure) of information in equilibrium. Namely, disclosure is *most* forthcoming in equilibrium when it is *least* valuable—it is *precisely* when a greater fraction of investors is *already* informed that IPO issuers disclose more in equilibrium. We show that this result has important implications for investment efficiency when firms go public to fund capital investment requirements. In particular, investment efficiency *suffers* when the market is more informed: The equilibrium level of underinvestment rises as the fraction of informed investors increases in the IPO market.

In related literature, a number of papers show that informed trading induces an incentive to *withhold* information (Fishman and Hagerty [2003], Holmstrom, [2009], Pagano and Volpin [2012]). In our setting, higher disclosure ameliorates IPO underpricing by reducing the (information) advantage of informed traders over the uninformed.[4] Furthermore, the negative relation of market information and capital investment efficiency complements recent results in the literature (e.g., Axelson and Makarov [2014]).[5] In addition, our analysis reveals somewhat counter-intuitive pricing effects of heterogeneously informed market participants in the presence of strategic disclosure. Specifically, the extent of underpricing need not be monotonic in the intensity of informed trading, a result that adds to the literature on the effect of informed trading on the distortion in security prices (Glosten and Milgrom [1985]).

The novel equilibrium association between the demand for information and its supply through disclosure continues to hold even with costly information acquisition and endogenous determination of the fraction of informed investors. Namely, managers are more likely to withhold information from markets *precisely* when there is more demand for it, that is, when a lower fraction of investors choose to become informed. Thus, when the cost of information acquisition is high, disclosures are less forthcoming.

Wilhelm [1990], Busaba and Chang [2002], Cornelli and Goldreich [2003], Schrand and Verrecchia [2005], Spindler [2010], and Chaplinsky, Hanley, and Moon [2014].

[4] At a broader level, our result is consistent with the literature in the sense that informed trading can induce distortions in firms' incentives to disclose information.

[5] In an auction setting Axelson and Makarov [2014] show that a larger number of privately informed bidders who bid for the ownership of an investment project might lead to less rather than more efficient investment due to the winners' curse. In equilibrium, several bidder types pool and bid zero (or do not participate) and prevent efficient information aggregation or investment.

The existing literature finds that corporate disclosures may promote information acquisition by market participants and enhance liquidity (Fishman and Hagerty [1989], Diamond and Verrecchia [1991], Boot and Thakor [2001], Einhorn [2014]). Our results shed light on how managers respond to information acquisition that takes place *prior* to such disclosures.[6]

Our paper is also related to the growing literature that explores the interaction between voluntary disclosure and firms' access to financial markets (Bertomeu, Beyer, and Dye [2011], Beyer and Guttman [2012], Kumar, Langberg, and Sivaramakrishnan [2012], Cheynel [2013], Hughes and Pae [2014]). In Bertomeu, Beyer, and Dye [2011] firms issue securities to investors who might subsequently be forced to liquidate their holdings and trade against informed investors in the case that the manager does not disclose information. The optimal financial security to minimize the potential loss from informed trading and maximize the issue price is derived in light of strategic voluntary disclosure. While their focus is primarily on the impact of a firm's disclosure *following* the issue of financial securities on its capital structure and cost of capital, our interest lies in characterizing voluntary disclosure in a setting in which firms' securities are issued with a fraction of investors already informed. Hughes and Pae [2015], Cheynel [2013], Beyer and Guttman, [2012], and Kumar, Langberg, and Sivaramakrishnan [2012] shed light on the implications of discretional disclosure for the efficiency of real capital allocation. We add to these studies, in which all investors are homogeneously informed, by considering heterogeneously informed investors and exploring the joint determination of voluntary disclosure, investment, and extent of informed trading.

From a broader perspective, the impact of information asymmetry on a firm's ability to raise money from capital markets has been a subject of much research in the literature. It has been suggested that firms can *signal* their quality through the level of dividends, ownership structure, and financial securities they issue (Leland and Pyle [1977], Myers and Majluf [1984], Miller and Rock [1985], DeMarzo and Duffie [1999]). In related literature, Allen and Faulhaber [1989] provide a rationale for underpricing in an IPO market by showing that good firms with superior prospects can signal through low IPO price and quantity. However, when firms can communicate to markets information about the quality of their firms, for example, as reflected in the cross-sectional differences in the informativeness of IPO prospectuses (Hanley and Hoberg [2010]), then the strategic disclosure behavior of issuing firms must also be taken into account. Thus, our result that information endowment, disclosure behavior, and underpricing are intricately related adds to this literature.

The paper proceeds as follows. Section 2 lays out the model. We develop the disclosure equilibrium in section 3 by initially assuming an exogenously

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[6] It has also been argued that information production by markets that is triggered by disclosure allows managers to learn from the reaction of market prices through feedback (Dye and Sridhar [2002], Langberg and Sivaramakrishnan [2010]).

given mass of informed traders, and later allowing for endogenous information acquisition by investors. In section 4, we explicitly consider capital investment by the IPO firm. We provide a conclusion in section 5.

2. *The Model*

We model a private firm, controlled by an owner-manager M, that possesses a project with expected net future cash flows of π that have a continuous distribution with positive support $\Pi \equiv [\pi_{\min}, \pi_{\max}] \subset [0, 1]$. The firm has decided to go public through an IPO of $q \in (0, 1]$ shares out of a total of 1 share outstanding. The motivations for the IPO are outside the purview of our model,[7] and we take q as a given parameter throughout our analysis.

Subsequently, M receives information about the firm's expected future cash flows π with probability $\lambda \in (0, 1)$ via an *informational event* (a là Dye and Sridhar [1995]). When informed, M can voluntarily and credibly disclose this information to the market (Verrecchia [1983], Dye [1985]).[8] For example, she can choose to make the IPO prospectus more informative or disseminate information through the investment banks in the IPO process (Hanley and Hoberg [2010]). Let $\omega \in [\pi_{\min}, \pi_{\max}] \cup \phi$ denote the manager's information so that $\omega = \pi'$, where $\pi' \in [\pi_{\min}, \pi_{\max}]$ is the true realization of π when the manager is informed, and $\omega = \phi$ when the manager is uninformed.

The market for the firm's shares in the IPO consists of two types of differentially informed investors (Grossman and Stiglitz [1980], Benveniste and Spindt [1989]). In particular, we model a continuum of rational investors with *mass* or *number* $N = N_{UI} + N_I$.[9] The mass $N_{UI} \geq 0$ are *uninformed* investors, while the mass $N_I \geq 0$ are *informed* investors that receive early information about π with probability $\lambda \in (0, 1)$ via the same informational event that informs M.[10] Throughout the paper we take the total mass of traders (N) as fixed. We assume initially that the mass of informed investors N_I is also fixed (i.e., N_I is taken to be an exogenous parameter). Later in the analysis, as a robustness check on our results, we allow N_I to be endogenously determined (prior to the possible arrival of information) through costly information acquisition.

[7] A number of papers in the literature provide useful surveys of the theories or motivations for going public—for example, Pagano, Panetta, and Zingales [1998], Brau and Fawcett [2006], and Aslan and Kumar [2011]. In particular, relaxing project financing constraints is a major motivation for going public, and we examine this issue in section 4.

[8] The intuition of our results holds also when, as in Dye [2013], managers have the duty to disclose material information in their possession and may incur penalties when caught violating this requirement.

[9] We use the terms *mass* and *number* of investors interchangeably throughout the paper.

[10] A more general information structure would lead to qualitatively similar results as long as the manager, by disclosing information, reduces the information advantage of informed investors.

Each atomistic investor can purchase at most one share; thus, all investors can purchase at most N shares. If the number of investors subscribing to the IPO, denoted by N^D, turns out to be greater than the number of shares to be issued, then the IPO would be oversubscribed. In this case, all investors receive the same allocation that falls short of their total demand, that is, each investor would receive an allocation of $\frac{q}{N^D}$, if $N^D \geq q$. On the other hand, if $N^D < q$, the manager fails to sell the desired amount of shares, and the IPO fails. To ensure that successful IPO is feasible, we will assume that all q shares can be sold in the IPO to the uninformed investors (Rock [1986]), that is,

ASSUMPTION 1. $N_{UI} \geq q$.

The issue or IPO price P_{ipo} is determined endogenously conditional on the manager's disclosure decision. We will specify the process for the determination of P_{ipo} below and will henceforth refer to it as "issue price" or "offer price." Following the determination of P_{ipo}, M obtains a cash inflow of qP_{ipo} and retains ownership with value $(1-q)\pi$.[11] Thus, the payoff to M given expected cash flows π and the realized IPO offer price P_{ipo}, conditional on q, is

$$U^M(\pi, P_{ipo}) = qP_{ipo} + (1-q)\pi. \tag{1}$$

The realized payoff to investors from ownership of one share of the stock purchased is then $(\pi - P_{ipo})$.

Because the demand for the IPO is random, this process exposes uninformed investors to *allocation risk* (Rock [1986]), as we will see below. Note that uninformed investors receive a lower fraction of their demand when informed investors find it optimal to participate, that is, when N^D is high. For this reason, uninformed investors need to be compensated for this risk via low issue prices or underpricing.

Following the IPO, the true value of the firm becomes public and the firm is traded at price $P^{mkt} = \pi$. Consistent with the literature, we define the level of IPO underpricing as the percentage difference between the offer price P_{ipo} and the market value following the IPO:

$$[\text{Realized Underpricing}] \;\; \gamma \equiv \frac{P^{mkt} - P_{ipo}}{P_{ipo}}. \tag{2}$$

The sequence of events after an IPO, with q as common knowledge, is as follows:

1) The manager and informed investors observe the information event or not.
2) The informed manager potentially discloses information π or not.

[11] In a subsequent section, we explicitly consider the case in which M initiates the IPO to finance an investment opportunity.

3) The offer price P_{ipo} is determined.
4) Following the IPO, the market price P^{mkt} is realized.

3. *Voluntary Disclosure with Informed Investors*

We will examine the perfect Bayesian equilibrium (PBE) in pure strategies of the game set up by the time line above. The PBE consists of:[12]

Manager's Disclosure Strategy: Let s denote the manager's disclosure strategy: $\pi \rightarrow \{D, ND\}$, with D denoting a voluntary disclosure of information π by the informed manager, and ND denoting nondisclosure. The uninformed manager has nothing to disclose.

IPO Trading Strategy: Given the IPO issue price P_{ipo}, *uninformed* investors decide whether to participate in the IPO based on the information disclosed by the manager, their Bayes-consistent beliefs on the manager's disclosure strategy, and the participation strategy of informed investors. In particular, the participation strategy of uninformed investors is contingent on the public information Φ, where $\Phi = \pi$ if disclosure takes place and $\Phi = ND$ if otherwise. Informed investors, however, effectively observe ω and decide whether to participate.

IPO Issue Price: The IPO offer price P_{ipo} is such that the uninformed investors just break even in expectation—that is, the participation constraint of the uninformed investors is just binding (see equation (4) below).

3.1 PRELIMINARIES

As discussed earlier, in order for the manager to be able to fully finance the IPO from the capital provided by uninformed investors, it has been assumed that $N_{UI} \geq q$. But, at the same time, it must not be possible to cover the IPO with only the informed investors, $N_I < q$ —otherwise, as we explain below, the IPO price will always reflect their information.

Suppose instead that $N_I \geq q$, that is, there is sufficient demand for q shares of the stock at its fair price. There exists an equilibrium where only informed investors participate in the IPO, which is *perfectly* priced. Of course, this will not be an equilibrium in the extended game (introduced in section 3.5) in which this mass N_I of informed investors must *choose* to become informed because there are no gains here from informed trading.

Similarly, consider the case in which both types of investors are required to participate in the IPO for it to succeed; that is, $N_I < q$, $N_{UI} < q$, but $N_{UI} + N_I \geq q$. In this case, there exists an equilibrium in which the IPO is perfectly priced and the uninformed *always* participate knowing that the IPO will fail if the informed choose not to participate (because there would not be sufficient demand to cover the issue); once again, there are no gains from informed trading. Thus, informed investors can potentially gain from informed trading only when $N_I < q \leq N_{UI}$—in line with Rock [1986].

[12] We focus on pure strategies played by the manager and the traders.

It follows from the above that it suffices to restrict attention to equilibrium outcomes in which either *all* investors participate in the IPO or only uninformed investors participate, that is, equilibria in which all uninformed investors always participate in the IPO (without knowing if it is underpriced or overpriced) while informed investors participate only in the underpriced IPOs. Consider the IPO allocation per participant (for $N_{UI} \geq q$), denoted by $\varkappa$,

$$\varkappa = \begin{cases} \frac{q}{N_{UI}+N_I}, & \text{if all } N_{UI}+N_I \text{ investors participate} \\ \frac{q}{N_{UI}}, & \text{if only uninformed, } N_{UI}\text{, participate} \end{cases}, \text{ IPO Allocation.} \quad (3)$$

3.2 INVESTOR PARTICIPATION

Specifically, in any equilibrium, given private information ω and public information revealed by the disclosure decision $\Phi \in \{\pi, ND\}$,

- *Informed* investors will participate if and only if $P_{ipo} \leq E(\pi|\omega)$.
- *Uninformed* investors will participate if and only if $E[\varkappa(\pi - P_{ipo})|\Phi] \geq 0$.

The equilibrium participation of uninformed investors reflects their Bayes-consistent beliefs regarding the value of the project π, their allocation in the IPO $\varkappa$, the disclosure behavior of the manager, and the participation behavior of informed investors. In equilibrium, the uninformed investors just break even from participating in the IPO (i.e., equation (4), below). That is, the equilibrium IPO offer price $P_{ipo}(\Phi) = P^*_{ipo}$ satisfies:

$$0 = E\left[\varkappa\left(\pi - P^*_{ipo}\right)|\Phi\right]. \quad (4)$$

This equilibrium IPO offer price reflects both the adverse selection risk (Myers and Majluf [1984], Dye [1985]) and the allocation risk (Rock [1986]). That is, uninformed investors take into account the possibility that (1) the manager is strategically withholding information (following nondisclosure, $\Phi = ND$), and (2) informed investors are strategically participating in the IPO, potentially leaving them (uninformed investors) with higher shares of overpriced IPOs.

Because informed investors do not participate when an IPO is overvalued, and uninformed investors participate in all IPOs, we can define the expected payoffs to informed investors, V^I, and to uninformed investor, V^{UI}, as

$$V^I = \frac{q}{N_{UI}+N_I} E\left(\left[\pi - P^*_{ipo}\right] \mathbf{I}_{E(\pi|\omega)>P^*_{ipo}}\right), \text{ and } V^{UI} = E\left[\varkappa\left(\pi - P^*_{ipo}\right)\right], \quad (5)$$

where $\mathbf{I}_{E(\pi|\omega)\geq P^*_{ipo}}$ denotes the participation of informed investors, i.e., $\mathbf{I}_{E(\pi|\omega)\geq P^*_{ipo}} = 1$ for $E(\pi|\omega) \geq P^*_{ipo}$ and zero otherwise.

3.3 DISCLOSURE STRATEGY OF THE INFORMED MANAGER

In equilibrium, the informed manager takes into account implications of her disclosure action on the competitive IPO issue proceeds and on investor participation. In particular, the manager of type π will choose between disclosure, that is, $\Phi = \pi$, or nondisclosure, that is, $\Phi = ND$, to maximize her expected payoff $E[U^M|\pi]$ as in (1). If the informed manager discloses, then $P_{ipo} = \pi$ and her payoff is $U^M(\pi|\Phi = D) = \pi$. If, on the other hand, the informed manager does not disclose her information, then the IPO issue price following non-disclosure is $P_{ipo}(ND)$, and her payoff is $U^M(\pi|\Phi = ND) = qP_{ipo}(ND) + (1-q)\pi$. Thus, as in Dye [1985] and Jung and Kwon [1988], the manager discloses when her private information π exceeds this non-disclosure price:

$$\pi \geq P_{ipo}(ND)\,[\text{Manager Prefers Disclosure over Non-Disclosure}]. \quad (6)$$

3.4 PROPERTIES OF THE EQUILIBRIUM

It is worth noting that $N_I = 0$ is the benchmark of homogeneous investors (Dye [1985]). In this benchmark, all IPO participants are exposed only to the adverse selection introduced by the informed manager (there is no allocation risk). Because all investors N_{UI} are endowed with the same information, they share the same participation preferences in equilibrium. When they decide to participate, they expect an equilibrium allocation of the IPO $\varkappa = \frac{q}{N_{UI}}$ (see (3)). Consequently, in equilibrium, the IPO offer price satisfies $P_{ipo} = E[\pi|\Phi]$ and the marginal manager π^{HI} is indifferent between disclosing information and not disclosing information when $P^{HI} = E[\pi|\Phi = ND]$. Thus, when $N_I = 0$, the equilibrium IPO issue price following non-disclosure $P_{ipo}(ND) = P^{HI}$ equals the disclosure cutoff $\pi^{HI} = P^{HI}$ and is the solution to:

$$P^{HI} = \breve{\lambda} E\left(\pi|\pi \leq P^{HI}\right) + (1-\breve{\lambda})E(\pi),$$
$$\text{where } \breve{\lambda} \equiv \left[\frac{\lambda \Pr(\pi \leq P^{HI})}{\lambda \Pr(\pi \leq P^{HI}) + 1 - \lambda}\right]. \quad (7)$$

It follows from Dye [1985] and Jung and Kwon [1988] that in this benchmark there exists a cutoff $P^{HI} < E(\pi)$ (as given by (7)) such that the manager of type π will disclose her private information when $\pi \geq P^{HI}$, and the IPO issue price following nondisclosure is given by $P_{ipo}(ND) = P^{HI}$ and following disclosure is $P_{ipo}(\pi) = \pi$. It follows also that expected underpricing is zero for all Φ, that is, $P_{ipo}(\Phi) = E(\pi|\Phi) = E(P^{mkt}|\Phi)$, for $\Phi \in \{\pi, ND\}$.

When some investors are informed, the manager faces competition in exploiting uninformed investors, so to speak. Consequently, as we show next, the manager's disclosure strategy and the IPO issue price following nondisclosure depend on the fraction of informed investors in the market.

Recall that the IPO issue price depends on uninformed investors' expectations conditional on the information disclosed by the manager. Following nondisclosure, uninformed investors would weigh the possibility that the manager is informed but strategically withholding information given the manager's strategy of not disclosing whenever $\pi \leq \hat{P}$. And, as discussed earlier, the IPO issue price $P_{ipo} = \hat{P}$ is set to be the highest price at which uninformed investors are still willing to participate.

Participating in the IPO is beneficial from the perspective of informed investors when they *know* that the manager is *uninformed*; otherwise, the IPO is overvalued and informed investors do not participate. In particular, informed investors will not participate in the IPO following nondisclosure by the informed manager because $\pi < \hat{P}$, in which case participating uninformed investors receive allocation $\frac{q}{N_{UI}}$ and realize (negative) payoff $[E(\pi|\pi \leq \hat{P}) - \hat{P}]\frac{q}{N_{UI}}$.

However, when the manager is not informed (i.e., firm value is $E(\pi)$), both uninformed and informed investors will participate and receive allocation $\frac{q}{N_{UI}+N_I}$. The payoff to any participating investor would be $[E(\pi) - \hat{P}]\frac{q}{N_{UI}+N_I}$, which is positive in equilibrium. The following lemma summarizes participation of informed investors in equilibrium as follows from the above discussion.

LEMMA 1 (Trading by Informed Investors). *In any equilibrium, with mass of informed investors $N_I < q \leq N_{UI}$ and IPO issue price following nondisclosure of $\hat{P}$, informed investors do not participate in the IPO following nondisclosure by an informed manager (i.e., of type $\pi < \hat{P}$); otherwise, when informed investors know that the manager is not hiding information and firm value is $E(\pi)$ (since there was no information event), they participate in the IPO if $\hat{P} < E(\pi)$.*

Therefore, the expected payoff to an informed investor given N_I and $\hat{P} < E(\pi)$ is,

$$V^I(N_I, \hat{P}) = \frac{q}{N_I + N_{UI}}(1-\lambda)(E(\pi) - \hat{P}). \tag{8}$$

Similarly, the expected payoff to an uninformed investor is:

$$V^{UI}(N_I, \hat{P}) = \lambda' \frac{q}{N_{UI}}(E(\pi|\pi \leq \hat{P}) - \hat{P}) + \frac{q}{N_I + N_{UI}}(1-\lambda')(E(\pi) - \hat{P}),$$

where

$$\lambda' = \frac{\lambda \Pr(\pi \leq \hat{P})}{\lambda \Pr(\pi \leq \hat{P}) + 1 - \lambda}. \tag{9}$$

Accordingly, the equilibrium IPO issue price $P_{ipo}(ND) = \hat{P}$ is the solution to $V^{UI}(N_I, \hat{P}) = 0$ or:

$$\hat{P} = \left(\frac{\lambda'\rho}{\lambda'\rho + 1 - \lambda'}\right) E(\pi|\pi \leq \hat{P}) + \left(\frac{1-\lambda'}{\lambda'\rho + 1 - \lambda'}\right) E(\pi),$$
$$\text{where } \rho \equiv \frac{N_I + N_{UI}}{N_{UI}}. \tag{10}$$

The difference here relative to the homogeneous investor case lies in the introduction of allocation risk, as is summarized in (3) and captured by ρ in (10). When the measure of privately informed investors is zero (i.e.,

$N_I = 0$), the IPO issue price following nondisclosure $\hat{P}$ equals the benchmark price P^{HI}, which also equals the conditional expected value of the firm following nondisclosure. In the presence of informed investors (i.e., $N_I > 0$), not only does the cutoff $\hat{\pi}$ change relative to the benchmark, but the IPO issue price following nondisclosure $\hat{P}$ will also not equal the expected market value of the firm following nondisclosure, $\hat{P} \neq E(\pi|ND)$. The reason is that, following nondisclosure, uninformed investors put higher weight (notice $\rho > 1$) on the possibility that the manager is strategically withholding information and attribute low valuation, that is, on the net loss $E(\pi|\pi \leq \hat{P}) - \hat{P}$.

EQUILIBRIUM (Voluntary Disclosure). *There exists for any given mass of informed investors $N_I < q$, a unique cutoff $\hat{P} \in (0, P^{HI})$ (given by the solution to* (10)*) such that the informed manager voluntarily discloses favorable information, $\pi > \hat{P}$, with consequent IPO issue price of $P_{ipo}(\pi) = \pi$, and issue price following non-disclosure of $\hat{P}$.*

To show there exists such an equilibrium cutoff for which $V^{UI}(N_I, \hat{P}) = 0$, note that for $\hat{P} = \pi_{\min}$, the expected profit of the uninformed is strictly positive ($V^{UI} = \frac{q}{N_I + N_{UI}}(E(\pi) - \pi_{\min}) > 0$), while for $\hat{P} = E(\pi)$ we have, $V^{UI} = \lambda' \frac{q}{N_{UI}}(E(\pi|\pi \leq E(\pi)) - E(\pi)) < 0$. Consequently, we conclude from the Intermediate Value Theorem that there exists such an equilibrium IPO issue price. We show in the appendix that this issue price is unique and lower than that in the benchmark case with homogeneous investors, that is, $\hat{P} \in (0, P^{HI})$.

The informed manager's incentive in withholding information is to sell overvalued shares to the market while informed investors strategically participate in undervalued IPOs. In equilibrium, the informed manager strategically sets her disclosure cutoff $\hat{P}$ so that the participants in the IPO overpay even as informed investors choose not to participate. Of course, whenever the informed manager discloses, informed investors no longer have an information advantage and cannot gain from trade. This disclosure strategy of the manager (for a given mass of informed investors) is simulated in figure 1, assuming that firm value (π) is distributed uniformly.

When the manager is uninformed, that is, when both the manager and informed investors do not observe π, informed investors gain from participating in the undervalued IPO because they *know* the manager is also uninformed but uninformed investors do not.

This strategic behavior of informed investors following nondisclosure leads to more disclosure relative to when there are no informed investors. The reason is that it lowers the nondisclosure issue price so that uninformed investors break even. Indeed, as figure 1 illustrates, the equilibrium disclosure cutoff decreases as the fraction of informed investors $\frac{N_I}{N_I + N_{UI}}$ increases.

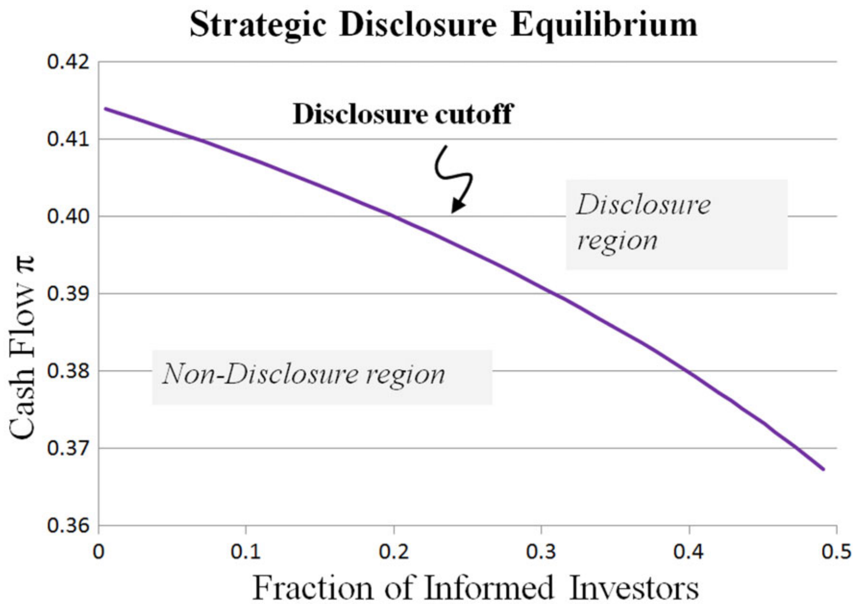

FIG. 1.—The graph is plotted based on the example of uniformly distributed firm value $\pi \sim U(0, 1)$ and for the parameter values ($\lambda = 0.5$, $q = 0.2$).

PROPOSITION 1 (Propensity to Disclose). *For any given mass of informed investors $N_I < q$, the disclosure cutoff above which the manager discloses information is decreasing in the fraction of informed investors $\frac{N_I}{N_I+N_{UI}}$, is decreasing in the likelihood of an information event λ, and is not affected by the level of equity sold in the IPO q in the interval $q \in (N_I, N_{UI})$.*

Strikingly, *it is when a greater fraction of investors is already informed that the informed manager would be more forthcoming with disclosure.* This result is attributable to the level of underpricing following non-disclosure. The greater the fraction of informed investors, the more severe is the allocation risk imposed on uninformed investors, and, consequently, the informed manager has a greater incentive to disclose, in order to level the playing field and avoid issuing equity at a deeper discount.

We also note that the higher the probability that the manager is informed (λ), the more severe is the adverse selection problem between the informed manager and the outside investors, and the lower is the disclosure cutoff in equilibrium. Finally, in the interval $q \in (N_I, N_{UI})$, the fraction of equity sold has no effect on the disclosure cutoff; rather, it is the relative mass of informed investors partaking in the IPO that is salient in determining the disclosure cutoff.

To calculate the level of underpricing, we turn next to the realized market price once trade takes place (sometimes referred to as the *after-market* price). As specified earlier, the market price reflects the true realization of firm value $P^{mkt} = \pi$. It is clear that once the uncertainty is removed by the manager via disclosure (that is, $\Phi = \pi$), the IPO issue price and the market price are both equal: $P_{ipo} = P^{mkt} = \pi$. Following nondisclosure, the expected market price (or expected firm value) $E(P^{mkt}|ND)$ reflects the conditional likelihood that the manager is informed and is strategically withholding information, $\lambda' \equiv \frac{\lambda \Pr(\pi \leq \hat{P})}{\lambda \Pr(\pi \leq \hat{P}) + 1 - \lambda}$, with corresponding expected value $E(\pi|\pi \leq \hat{P})$, and the likelihood that the manager is uninformed $(\omega = \phi)$, $1 - \lambda'$, in which case the expected value is $E(\pi)$. Therefore, the *expected* market price following nondisclosure by the manager is (where $\hat{P}$ is given by (10)),

$$E(P^{mkt}|ND) = \lambda' E(\pi|\pi \leq \hat{P}) + \left(1 - \lambda'\right) E(\pi),$$
$$\text{where } \lambda' \equiv \left[\frac{\lambda \Pr(\pi \leq \hat{P})}{\lambda \Pr(\pi \leq \hat{P}) + 1 - \lambda}\right]. \tag{11}$$

We note that $E(P^{mkt}|ND)$ exceeds the price at which the IPO is issued. Indeed, it follows from (10) and (11) that $P_{ipo}(ND) < E(P^{mkt}|ND)$ in equilibrium. Intuitively, uninformed traders face competition from informed investors that selectively participate in undervalued IPOs. Consequently, uninformed investors will participate only if the IPO is underpriced, that is, 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 and the market price incorporate the same information, $P^{mkt} - P_{ipo} = 0$. In equilibrium, the level of underpricing following nondisclosure therefore depends on the manager's disclosure strategy.

Figure 2 illustrates the difference between the IPO issue price and the market price following nondisclosure for the uniform distribution. Three disclosure cutoffs are depicted: for the benchmark case and for high and low fractions of informed investors. Note that the disclosure cutoff in the benchmark case of homogeneous investors, P^{HI}, is above the two disclosure cutoffs with informed investors $\hat{P}$ (consistent with Proposition 1). This observation is useful in understanding why the level of underpricing is increasing in the relative mass of informed investors. In particular, the expected value of the firm (following nondisclosure), for a given disclosure cutoff π', is minimum at the equilibrium disclosure cutoff, P^{HI}, in the benchmark case of homogenous investors—this property follows from condition (7). At the equilibrium cutoff with informed trading $\hat{P}$ (which is to the left of P^{HI}) the expected market value of the firm following nondisclosure is above the disclosure cutoff or IPO issue price, and is to the left of, and higher than, the expected value of the firm in equilibrium in the homogeneous investor case. These effects are more pronounced as we increase the fraction of informed traders (the purple line vs. the red line relative to the blue line). Thus, as the relative mass of informed investors increases and the IPO issue price following nondisclosure decreases, the corresponding market price

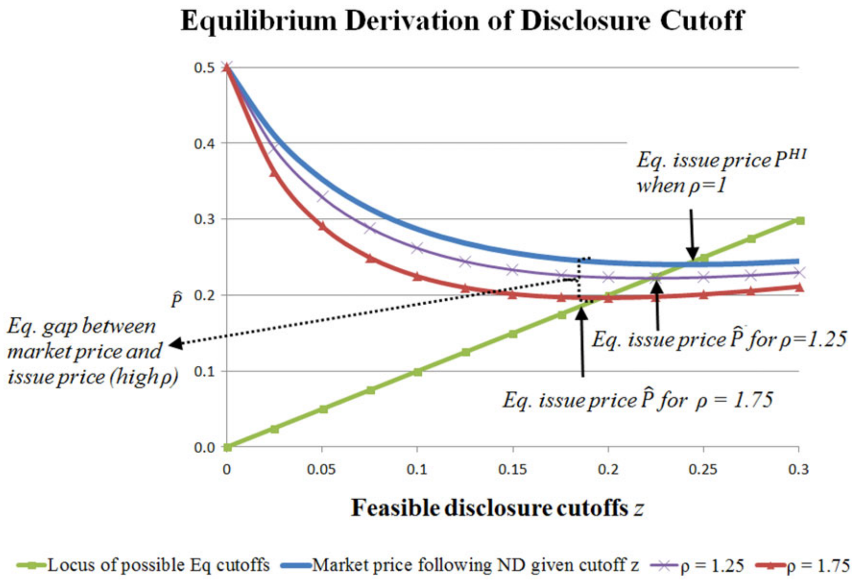

FIG. 2.—The graphs plotted are based on the example of uniformly distributed firm value $\pi \sim U(0, 1)$ and for the parameter values ($\lambda = 0.9$, $q = 0.2$). The three cases $\rho = 0$, $\rho = 1.25$, and $\rho = 1.75$ are plotted separately.

following nondisclosure (on the blue line) increases, and consequently the underpricing also increases.

COROLLARY 1 (Underpricing). *For any given mass of informed investors $N_I < q$, the expected level of underpricing following nondisclosure is strictly positive and is increasing in the fraction of informed investors, that is, $E(\gamma|ND) > 0$, and $\frac{\partial E(\gamma|ND)}{N_I} > 0$. The expected level of underpricing following disclosure is zero. The overall expected level of underpricing $E(\gamma)$ is nonmonotonic in the likelihood of an information event λ.*

The expected level of underpricing $E(\gamma)$ approaches zero as the likelihood of an information event approaches the extreme values of either 0 or 1. Intuitively, when $\lambda \to 0$ the uninformed investors do not face allocation risk and do not demand a discount in order to participate in the IPO, and on the other extreme when $\lambda \to 1$ the manager fully discloses her private information. Thus, the expected level of underpricing is zero at both extremes and is maximized for an interior value of the likelihood of an information event.

3.5 INFORMATION ACQUISITION BY MARKET PARTICIPANTS

We now consider endogenous costly information acquisition by a segment of investors or market participants. Specifically, from the total mass of investors $N \geq 2q$ we endogenously derive the mass of investors N_I that choose to become informed about the quality of the IPO when information acquisition is costly.[13] The mass of investors that remain uninformed is thus $N - N_I$.

To model information acquisition in a simple manner—and to obtain a unique equilibrium with pure strategies—we assume that all investors $x \in [0, N]$ are ordered such that the cost of information acquisition for x is monotonically increasing in x and is given by $\delta(x) = \delta x$, $\delta > 0$. As before, informed investors (like the manager) observe the valuation signal π when there is an information event (with probability λ). Let the set of investors who *choose* to become informed be given by the ordered set $[0, x'(N_I)]$, where N_I represents the conjectured mass of informed investors in equilibrium. Note that all informed investors realize the *same* expected gain from informed trading $V^I(N_I, \hat{P}(N_I))$ as defined in equation (8). The equilibrium conjectured mass of informed investors N_I defines the marginal investor of type $x'(N_I)$ who is exactly indifferent between becoming informed or not, that is, $x'(N_I)\delta = V^I(N_I, \hat{P}(N_I))$. In equilibrium, of course, the conjectured mass of informed investors exactly equals the mass of investors that *choose* to become informed, or $N_I = x'(N_I)$.

Specifically, let $\Upsilon(N_I)$ be the expected gains net of information acquisition costs for the marginal informed investor. Then, for sufficiently large cost of information acquisition δ, an interior solution exists to the following condition that defines the equilibrium mass of informed investors (where $\hat{P}(N_I)$ is the solution to (10)),

$$\Upsilon(N_I) = \frac{q}{N}(1 - \lambda)(E(\pi) - \hat{P}(N_I)) - \delta N_I = 0. \tag{12}$$

It is noteworthy that in any equilibrium in which N_I traders rationally choose to become informed, they must expect positive rents from informed trading. As discussed in the previous section, such positive rents accrue when $N_I < q$, which will indeed be the case in equilibrium provided the cost of acquiring information (δ) is sufficiently large. This is established in the following result.

EQUILIBRIUM (Endogenous Mass of Informed Investors). *There exists a lower bound cost of information acquisition $\hat{\delta} \geq 0$, such that, for any $\delta > \hat{\delta}$, there is a mass of informed investors N_I^* and a disclosure cutoff $\hat{P}(N_I^*)$ that satisfy the equilibrium conditions* (10), (12), *and $N_I^* < q$.*

Of particular interest is the equilibrium relation between the cost of information acquisition and the disclosure policy of the manager or the disclosure cutoff. As one might expect, a higher cost of information acquisition discourages investors from acquiring information, and it does so in two ways: first, directly since the cost of information acquisition is

[13] We require that $N \geq 2q$ so that there are always enough uninformed investors $N - N_I$ to participate in the IPO (in the spirit of assumption A1) for the equilibrium level of N_I derived shortly.

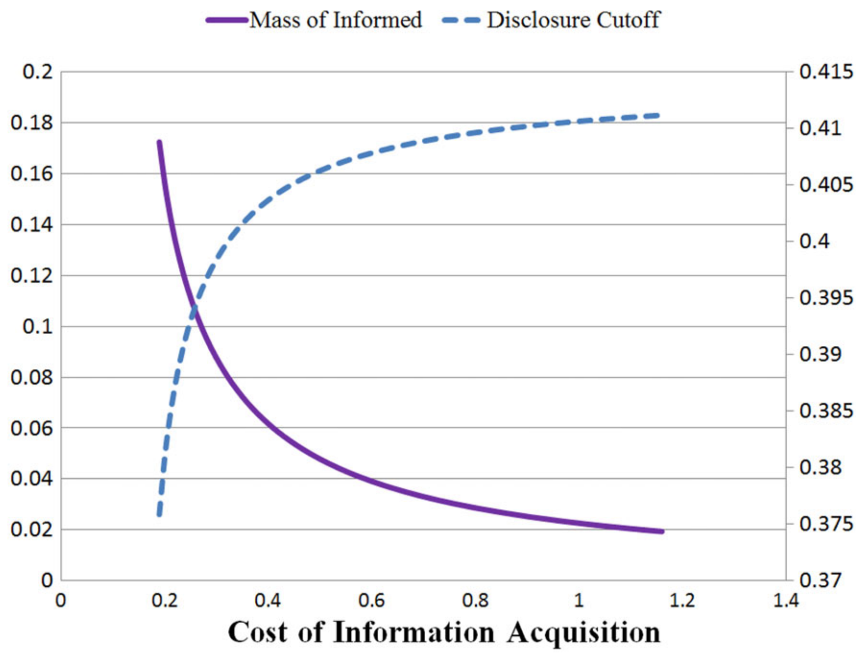

FIG. 3.—The graph is plotted based on the example of uniformly distributed firm value $\pi \sim U(0, 1)$ and for the parameter values ($\lambda = 0.5$, $q = 0.2$, $N = 0.4$). Disclosure cutoff values are on the right.

proportional to δ (referring to expression (12)) and second, indirectly *through* its negative effect on the potential profits from informed trading. In equilibrium, the mass of informed investors affects the IPO issue price through the disclosure policy of the manager, which, in turn, affects the benefits from becoming informed.[14] Moreover, as in our earlier analysis, with less informed investors, the disclosure threshold increases, leading to less disclosure in equilibrium. Overall, this implies that the disclosure cutoff is increasing in the cost of acquiring information.

Thus, the underlying tenor of a primary message of this paper remains the same—that disclosure is more forthcoming when it has less information value, that is, when the cost of information acquisition is low and the mass of informed investors is high. Figure 3 depicts the equilibrium mass of informed investors and the disclosure cutoff as a function of the cost of information acquisition.

On the other hand, the benefit of acquiring information or the expected gains from informed trading are influenced by the fraction of equity sold

[14] To see how, notice that the IPO issue price following nondisclosure $\hat{P}(N_I)$ decreases in the fraction of informed traders $\frac{N_I}{N}$. Consequently, looking at the expression (12), one can see that a decrease in N_I increases $\hat{P}(N_I)$, and therefore decreases the expected gain $(1 - \lambda)(E(\pi) - \hat{P}(N_I))$ from purchasing the stock when it is profitable to do so.

(q), and the total mass of investors (N). We next analyze the equilibrium disclosure behavior of the manager with respect to these parameters. Intuitively, the potential gains from trade for informed investors and, thus, the equilibrium mass of informed traders N_I, are increasing in the allocation of shares $\frac{q}{N}$ they receive in the IPO. Consequently, while the manager discloses information more aggressively when the fraction of informed investors $\frac{N_I}{N}$ is larger, our analysis suggests that there will be more disclosure when the fraction of equity sold q is higher or when the total mass of investors that plan to participate in the IPO N is smaller.

COROLLARY 2 (Propensity to Disclose). *The managers' disclosure cutoff is (1) increasing in the cost of becoming informed δ, (2) decreasing in the fraction of equity sold at the time of the IPO (q), and (3) increasing in the total mass of investors N.*

We end this section by highlighting implications of our disclosure equilibrium for underpricing. As discussed earlier, the IPO issue is underpriced to compensate the uninformed investors for allocation risk. Due to the effects of the aforementioned parameters on the endogenous mass of informed investors and since the expected level of underpricing is increasing in the mass of informed investors (Corollary 1), the following results immediately follow.

COROLLARY 3 (Underpricing). *The expected level of underpricing following non-disclosure is (1) decreasing in the cost of becoming informed δ, (2) increasing in the fraction of equity sold at the time of the IPO (q), and (3) decreasing in the total mass of investors N.*

4. *Capital Investment and Disclosure in IPOs*

In this section, we highlight some real implications of our model by considering the effects of the informed manager's disclosure strategy and the fraction of informed investors on the level and efficiency of capital investment by the IPO firms. These real effects of strategic disclosure and informed trading arise when the proceeds from a successful IPO are used to finance new investment opportunities, which is consistent with the stylized fact that external financing of capital investment is a major driver of the going public decision (Brau and Fawcett [2006], Aslan and Kumar [2011]). To fix ideas, note that an important insight from the previous analysis is that the fraction of informed investors together with strategic disclosure by the manager exacerbate adverse selection in the IPO market and reduce the IPO issue price. Hence, the intensity of informed trading in the IPO market can drive investment funding and, hence, have a major impact on investment efficiency.

More formally, we undertake a simple extension of our model by introducing an investment opportunity with a constant rate of return R, where

$R \in (1, \frac{1}{q})$.[15] If the firm invests $K \geq 0$, then the total value of the firm (with assets-in-place of π) is $\Pi(\pi, K) = \pi + RK$.[16] The investment, in turn, is determined by the proceeds of the IPO. Hence, if the IPO results in the sale of the fraction q of shares of the firm at the issue price P_{ipo}, then $K = qP_{ipo}$ and the firm realizes a gross return of RqP_{ipo}. The expected payoff to the manager is then

$$(1 - q)\left(\pi + RqP_{ipo}\right). \tag{13}$$

Clearly, the manager's payoff is increasing in the IPO issue price; hence, she will prefer to disclose π (and realize the issue price $P_{ipo}(\pi)$) rather than not disclose (and realize the issue price $P_{ipo}(ND)$) whenever $P_{ipo}(\pi) \geq P_{ipo}(ND)$. Note that, following a disclosure of π, there is no uncertainty and the issue price satisfies $P_{ipo}(\pi) = \pi + RqP_{ipo}(\pi)$, which simplifies to:

$$P_{ipo}(\pi) = \frac{\pi}{\varphi}, \text{ [Price Following Disclosure]}$$

where $\varphi \equiv 1 - Rq$.[17] Consequently, the manager will disclose information if $\pi \geq \varphi P_{ipo}(ND)$.

As before, the price following nondisclosure must induce participation by the uninformed investors. Following the earlier analysis, the payoff to the uninformed investor given IPO issue price $P_{ipo}(ND) = \widetilde{P}$ is:

$$\begin{aligned} V^{UI}(N_I, \widetilde{P}) = \lambda' \frac{q}{N_{UI}} & \left(E(\pi | \pi \leq \varphi\widetilde{P}) - \varphi\widetilde{P}\right) \\ & + \frac{q}{N_I + N_{UI}}(1 - \lambda')\left(E(\pi) - \varphi\widetilde{P}\right), \end{aligned} \tag{14}$$

where λ' is given by (9). Accordingly, the equilibrium IPO issue price $\widetilde{P}$ is the solution to $V^{UI}(N_I, \widetilde{P}) = 0$ or:

$$\begin{gathered} \varphi\widetilde{P} = \left(\frac{\lambda'\rho}{\lambda'\rho + 1 - \lambda'}\right) E(\pi | \pi \leq \varphi\widetilde{P}) + \left(\frac{1 - \lambda'}{\lambda'\rho + 1 - \lambda'}\right) E(\pi), \\ \text{where } \rho \equiv \frac{N_I + N_{UI}}{N_{UI}}, \text{ and } \varphi \equiv 1 - Rq > 0. \end{gathered} \tag{15}$$

In sum, when there is a constant returns to scale investment technology and the IPO proceeds are used for investment, then the issue price is $\varphi\widetilde{P} = \hat{P}$, where $\hat{P}$ is given by the equilibrium price derived in subsection 3.4 and the solution to equation (10). Thus, the disclosure cutoff is not affected by the introduction of the investment technology. In contrast, the level of

[15] It will become clear that, to ensure that prices are well defined, we require this upper bound on the return on investment.

[16] We thank an anonymous referee for suggesting this setting. Note that our previous analysis can be viewed as a special case when $R = 1$ and the proceeds from the IPO are not reinvested in the firm.

[17] The upper bound on the return on capital invested implies that $R < \frac{1}{q}$, so that $\varphi \equiv 1 - Rq > 0$.

investment is affected by the fraction of informed investors in the market, the return on investment, the fraction of shares issued at the IPO, and the likelihood of an information event. Intuitively, the higher the return on investment R and the higher the fraction of shares that are sold in the IPO, the higher is the expected level of investment. In particular, variations in the fraction of informed investors affect the equilibrium disclosure strategy of the manager and impact the level of investment.

Since the level of investment is given by qP_{IPO}, it is useful to specify the expected IPO issue price $E(P_{IPO})$ implied by the equilibrium disclosure cutoff $\hat{P}$ (where $F(\hat{P}) = \Pr(\pi \leq \hat{P})$),

$$E(P_{IPO}) = (1 - \lambda + \lambda F(\hat{P}))\frac{\hat{P}}{\varphi} + \lambda \int_{\hat{P}}^{\pi_{\max}} \frac{\pi}{\varphi} f(\pi)\, d\pi. \tag{16}$$

While the fraction of informed investors does not appear explicitly in (16), it affects the expected level of investment through the equilibrium disclosure strategy and level of underpricing (see Corollary 1). Because non-disclosure results in underpricing in equilibrium (i.e., $P_{IPO}(ND) < E(\Pi(\pi, P_{IPO}(ND))|ND))$, it follows that we can deduce the comparative statics for $E(P_{IPO})$ with respect to the fraction of informed traders and other salient parameters.

PROPOSITION 2 (Investment with Fixed Mass of Informed Investors). *When the manager can invest the proceeds from the IPO qP_{IPO} at gross rate of return R, the disclosure cutoff (as before) is given by a unique cutoff $\hat{P} \in (0, P^{HI})$ (the solution to (10)). The IPO issue price following disclosure is $P_{ipo}(\pi) = \frac{\pi}{\varphi}$ and following nondisclosure is $P_{ipo}(ND) = \widetilde{P} = \frac{\hat{P}}{\varphi}$. Consequently, expected investment $qE(P_{IPO})$ is decreasing in the fraction of informed investors $\frac{N_I}{N_I+N_{UI}}$, increasing in the return on capital R, and increasing in the fraction of equity sold at the IPO q.*

Proposition 2 indicates the real investment implications of voluntary disclosure in the presence of informed trading in IPOs. In particular, it is especially interesting to develop the real effects of higher intensity of informed trading. Because the disclosure cutoff $\hat{P}$ is decreasing in the fraction of informed traders, the price following nondisclosure $\widetilde{P} = \frac{\hat{P}}{\varphi}$ decreases with informed intensity of financial markets, and so does the capital investment of the *nondisclosing* firm (i.e., $K = q\frac{\hat{P}}{\varphi}$). Thus, there is lower investment when there is no information event or when an information event occurs but the manager strategically withholds information. Moreover, the informed managers that now disclose under the lower disclosure cutoff (due to higher informed intensity) also realize a lower issue price and, hence, investment. Overall, the expected capital investment—which is determined by the IPO issue price—is decreasing in the fraction of informed investors. Formally,

$$\frac{dE(P_{IPO})}{dN_I} = \frac{dE(P_{IPO})}{d\hat{P}}\frac{d\hat{P}}{dN_I} = \left(\frac{1 - \lambda + \lambda F(\hat{P})}{\varphi}\right)\frac{d\hat{P}}{dN_I} < 0. \tag{17}$$

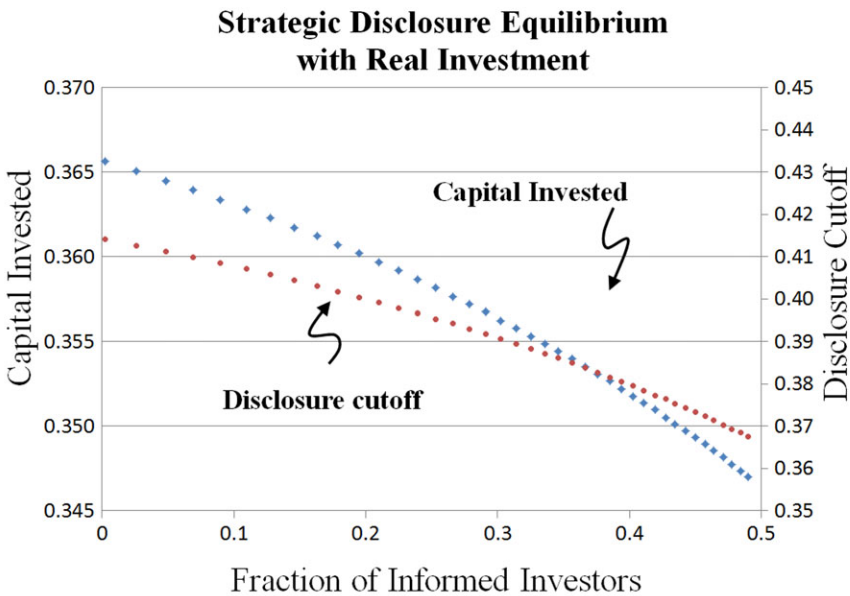

FIG. 4.—The graph is plotted based on the example of uniformly distributed firm value $\pi \sim U(0, 1)$ and for the parameter values ($q = 0.4$, $R = 1.25$, $\lambda = 0.5$, $N_{UI} = 0.4$).

In figure 4, we graphically show this negative relation of expected investment and $\hat{P}$. We plot the disclosure cutoff and the level of expected investment as a function of the fraction of informed investors for the uniform distribution. Thus, the higher the fraction of informed investors, the lower the disclosure cutoff and the lower the level of investment.

Meanwhile, the likelihood of an information event is also an important determinant of the manager's disclosure strategy (Dye [1985]). As we have shown in Proposition 1, the manager discloses more information when she is ex ante more likely to be informed. However, the expected level of investment is nonmonotonic in the likelihood of an information event and therefore is also not monotonic in the disclosure cutoff. We demonstrate this nonmonotonicity in figure 5, which plots the disclosure cutoff and the expected level of investment as a function of the likelihood of an information event. When the adverse selection problem is least severe, or λ is near zero or one, then there is lower expected underpricing and expected investment is maximized.

5. *Discussion and Empirical Implications*

Our analysis presents novel empirical predictions for both the literatures on voluntary disclosure and IPOs. The foregoing results suggest a link between the level of informed trading at the time of the IPO and the disclosure behavior of the manager. Namely, IPO firms with a higher fraction

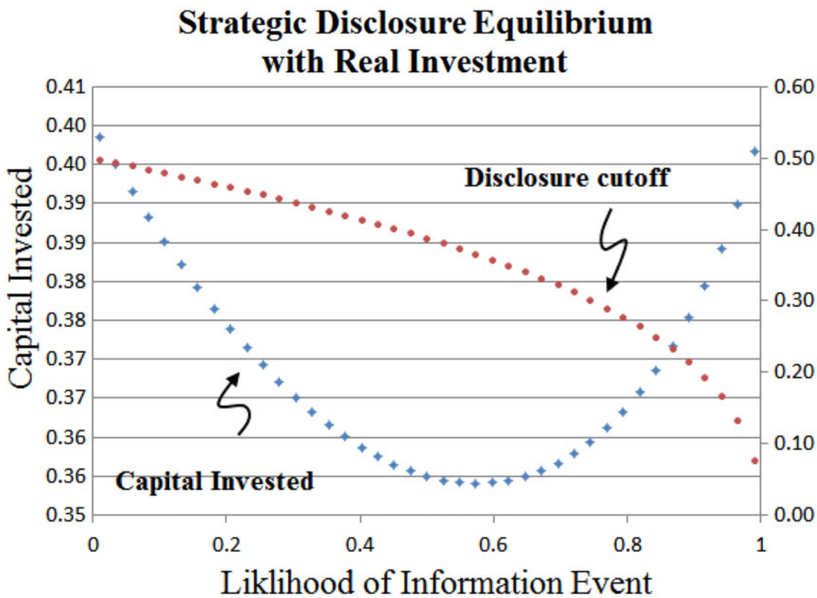

FIG. 5.—The graph is plotted based on the example of uniformly distributed firm value $\pi \sim U(0, 1)$ and for the parameter values ($q = 0.4$, $R = 1.25$, $N_I = 0.2$, $N_{UI} = 0.4$).

of informed traders are predicted to be more forthcoming with their disclosures at the time of the IPO (i.e., a lower disclosure cutoff) and are predicted to invest less efficiently. The market microstructure literature uses a variety of measures of informed trading. These include bid-ask spread levels (e.g., Stoll [1989]), the probability of informed trading (PIN) measure of Easley and O'Hara [1987], and stock trading liquidity based measures (e.g., Hasbrouck [1991], Sadka [2006]). Our analysis therefore predicts that empirical measures of informed trading following the IPO should be positively related to the level of pre-IPO disclosure—as reflected in a more informative IPO prospectus, news releases ahead of the IPO, and issue price revisions—and negatively related to the level of capital investment by the IPO firm. To our knowledge, such an empirical test has not been undertaken in the literature.

Next, our analysis lends itself to further exploration of voluntary disclosure behavior of IPO firms in the cross section and in the time series. We expect investors' costs and benefits from acquiring private information to vary across firms and industries, as well as intertemporally with changing macroeconomic business conditions. Consistent with the aforementioned prediction of our model, our analysis suggests that pre-IPO disclosure by firms should be positively related to the expected net benefit to investors from information acquisition. Thus, the level of disclosure will be high when the fraction of firm equity sold in the IPO is high. However, the level of disclosure will be low when the cost of acquiring information is high and when there are more investors that are likely to participate in the IPO. These predictions suggest less disclosure by IPO firms in industries where it is costly to acquire information—for example, in emerging industries due to the lack of established business models that facilitate valuation. Moreover, we should observe higher disclosure by IPO firms when they are *not* part of an IPO wave because the opportunity cost of information acquisition is arguably lower for investors in such cases. Again, many of these predictions remain to be tested empirically.

Finally, as a consequence of strategic disclosure, our model generates the novel prediction that the expected level of underpricing and the likelihood of an information event (i.e., the likelihood that some investors have private information) are related in a nonmonotonic fashion. Ellul and Pagano [2006] provide preliminary evidence of such a nonmonotonic relationship, but a more direct analysis would be of substantial empirical interest. In a related vein, our model also predicts a negative relation of IPO underpricing and the cost of acquiring information and a positive relation with the fraction of equity issued at the IPO. These predictions are consistent with the observation that underpricing increases with informed trading intensity of financial markets (Rock [1986]).

6. *Conclusion*

In this paper we characterize equilibrium voluntary disclosure strategies and investment of informed managers when the capital market consists of informed and uninformed investors. We focus on the IPO setting because the presence of informed investors imposes an allocation risk on uninformed investors (Rock [1986]) and therefore firms must underprice their IPO securities to alleviate this risk and attract the uninformed investors. Credible voluntary disclosures potentially fully eliminate this allocation risk by offsetting the advantage of informed investors. However, as the vast literature on voluntary disclosure has established, strategic nondisclosure can fetch a higher issue price. Consequently, managers of issuing firms face an important tradeoff in choosing whether or not to disclose.

Our main contribution is to show that, in equilibrium, managers of issuing firms disclose more information and invest less efficiently precisely when a greater fraction of IPO participants are informed—that is, the higher the fraction of informed investors, the more aggressive is a manager in her disclosure strategy and the lower is the expected level of capital raised (and also investment efficiency) in the IPO. However, such aggressive disclosures reduce the gains from informed trading, that is, from acquiring costly information. In equilibrium, the extent of information acquisition by potential investors affects the issuer's disclosure strategy. But the disclosure strategy, in turn, affects the incentives for costly information acquisition since the expected gains from informed trading depend on the fraction of informed traders in the market.

Some interesting and novel insights emerge from this equilibrium. First, disclosures are less forthcoming and investment is more efficient when the cost of information acquisition is high, suggesting that managers are more likely to withhold information from markets precisely when there is more demand for it. Second, larger IPOs (which imply higher expected allocations) lead to a higher fraction of informed investors, and, consequently, managers of issuing firms are more forthcoming with disclosures when selling a higher fraction of equity. Third, the level of investment (and also investment efficiency) is nonmonotonic in the likelihood of an information event. These results suggest that the extent of voluntary disclosure need not be monotonically associated with investment efficiency. Finally, the equilibrium association between underpricing and the likelihood of an information event is nonmonotonic.

In sum, we show that the fraction of informed investors and managers' disclosure strategies are jointly determined in equilibrium and have real implications for capital investment.

APPENDIX A

Proof (Equilibrium Voluntary Disclosure). Following nondisclosure the uninformed investors base their expectations on their beliefs whether the manager is informed or not. With conditional probability $\lambda'(\hat{P}) = \frac{\lambda \Pr(\pi \leq \hat{P})}{\lambda \Pr(\pi \leq \hat{P}) + 1 - \lambda}$ (as defined in (10)) 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 $\frac{q}{N_{UI}}$ and realize expected (negative) payoff $[E(\pi | \pi \leq \hat{P}) - \hat{P}]\frac{q}{N_{UI}}$. 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 $\frac{q}{N_{UI} + N_I}$. In this case, the expected (positive) payoff to participants in the IPO is $[E(\pi) - \hat{P}]\frac{q}{N_{UI} + N_I}$. Of course, the weights $\lambda'(\hat{P})$ take into account the manager's disclosure strategy, that is, that disclosure occurs for $\pi > \hat{P}$.

Thus, as in equation (10), the nondisclosure IPO price $P_{ipo}(ND)$ is set such that the uninformed investors break even on average and is the solution to $\Delta(z) = 0$ ($\rho = \frac{N_{UI} + N_I}{N_{UI}}$), where $\Delta(z)$ is given by:

$$\Delta(z) \equiv \lambda(z) E(\pi | \pi \leq z) + (1 - \lambda(z)) E(\pi) - z,$$
$$\text{where } \lambda(z) \equiv \frac{\lambda \rho \Pr(\pi \leq z)}{1 - \lambda + \lambda \rho \Pr(\pi \leq z)}. \tag{A1}$$

A solution exists since for $z = \pi_{\min}$ we have $\Delta(\pi_{\min}) = E(\pi) - \pi_{\min} > 0$, but on the other extreme for $z = E(\pi)$ we have $\Delta(E(\pi)) = (\frac{\lambda \Pr(\pi \leq E(\pi))\rho}{\lambda \Pr(\pi \leq E(\pi))\rho + 1 - \lambda})[E(\pi | \pi \leq E(\pi)) - E(\pi)] < 0$ ($\Delta(\cdot)$ is continuous). Thus, there exists an interior solution for the IPO issue price following nondisclosure such that $\hat{P} \in (0, E(\pi))$.

We show next that the solution is unique by establishing that at any solution z^*, that is, $\Delta(z^*) = 0$, the function Δ is decreasing and therefore there can be only one such solution. It is useful to note that (where we denote $F(z) \equiv P(\pi \le z)$ and $\overline{F}(z) = 1 - F(z)$),[18]

$$E(\pi|\pi \le z) = \frac{1}{F(z)}\left[E(\pi) - \int_z^{\pi_{\max}} \overline{F}(x)\,dx - z\overline{F}(z)\right]. \tag{A2}$$

It is useful to define $\Psi(z)$ using expression (A1) to yield the right hand side of equation (10):

$$\Psi(z) \equiv \Delta(z) + z = \lambda(z)E(\pi|\pi \le z) + (1 - \lambda(z))E(\pi). \tag{A3}$$

Thus, the solution z^* satisfies $\Delta(z^*) = 0 \Leftrightarrow \Psi(z^*) = z^*$. To establish uniqueness, we show that at any solution z^* the function $\Psi(z)$ satisfies $\frac{\partial\Psi}{\partial z}|_{z=z^*} = 0$ and as a result $\frac{\partial\Delta}{\partial z}|_{z=z^*} = -1 < 0$. That is, at any solution z^* that satisfies $\Delta(z^*) = 0$ the derivative of this function is negative and therefore there can only exist one such solution.

To show that indeed $\frac{\partial\Psi}{\partial z}|_{z=z^*} = 0$, we use the above expression in (A2) for the conditional expectation $E(\pi|\pi \le z)$ to rewrite (A3),

$$\begin{aligned}\Psi(z) &= \frac{\lambda\rho F(z)}{1-\lambda+\lambda\rho F(z)}E(\pi|\pi \le z) + \frac{1-\lambda}{1-\lambda+\lambda\rho F(z)}E(\pi)\\ &= \frac{(1-\lambda+\lambda\rho)E(\pi) - \lambda\rho\left[\int_z^{\pi_{\max}} \overline{F}(x)\,dx + z\overline{F}(z)\right]}{1-\lambda+\lambda\rho F(z)}.\end{aligned}$$

The derivative can now be explicitly derived as (where the density function is $f(z) = F'(z)$),

$$\frac{\partial\Psi(z)}{\partial z} = -\frac{\lambda\rho f(z)}{1-\lambda+\lambda\rho F(z)}[\Psi(z) - z].$$

This implies that

$$\Psi(z^*) = z^* \Leftrightarrow \left.\frac{\partial\Psi(z)}{\partial z}\right|_{z=z^*} = 0. \tag{A4}$$

Now that we have established uniqueness of the solution for the equilibrium IPO issue price following nondisclosure, z^*, we show that this price is decreasing in the mass of informed investors, or that $\frac{\partial z^*}{\partial\rho} < 0$ (where $\rho = \frac{N_{UI}+N_I}{N_{UI}}$). It follows from (A4) that $\frac{\partial\Delta}{\partial z}|_{z=z^*} < 0$ and from the definition of $\Delta(z)$ that $\frac{\partial\Delta}{\partial\rho} = \frac{\partial\lambda(z)}{\partial\rho}[E(\pi|\pi \le z) - z] < 0$, where $\lambda(z) \equiv \frac{\lambda\rho\,\Pr(\pi\le z)}{1-\lambda+\lambda\rho\,\Pr(\pi\le z)}$. Thus, it follows from the Implicit Function Theorem that

$$\frac{\partial z^*}{\partial\rho} = -\left.\frac{\partial\Delta}{\partial\rho}\Big/\frac{\partial\Delta}{\partial z}\right|_{z=z^*} < 0. \tag{A5}$$

[18] This follows from $E(\pi) = \int_0^\infty \overline{F}(x)\,dx$, and since $E(\pi|\pi \le z) = \int_0^\infty \Pr(\pi \ge x|\pi \le z)\,dx = \frac{1}{F(z)}\int_0^z(\overline{F}(x) - \overline{F}(z))\,dx$.

Recall, P^{HI} is the solution for the case $\rho = 1$, thus, any local increase in $\rho \in (1, 2)$ leads to a lower IPO issue price. □

Proof. Proposition 1 (Propensity to Disclose). While still considering the function $\Psi(\cdot)$ from above, this follows from $\frac{\partial \Psi}{\partial \rho} < 0$, $\frac{\partial \Psi}{\partial z} < 0$, $\frac{\partial \Psi}{\partial \lambda} = \frac{\partial \lambda'(z)}{\partial \lambda}[\rho(E(\pi|\pi \le z) - z) - (E(\pi) - z)] < 0$ (since $\frac{\partial \lambda'(z)}{\partial \lambda} > 0$ and $E(\pi) > z$ in equilibrium), and $\frac{\partial \Psi}{\partial q} = 0$. □

Proof. Corollary 1 (Underpricing). This follows from Proposition 1 and the property that is stated in Lemma A.1 given below. In particular, the expected level of underpricing following nondisclosure $\frac{E(P^{mkt}(ND))}{\hat{P}}$ is increasing in the mass of informed investors N_I or equivalently in ρ since the expected price following nondisclosure $E(P^{mkt}(ND))$ is decreasing in the disclosure cutoff $\hat{P}$ for $\hat{P} \le P^{HI}$ (Lemma A.1), while the disclosure cutoff $\hat{P}$ is decreasing in ρ (Proposition 1). That is, an increase in ρ leads to an increase in the ratio $\frac{E(P^{mkt}(ND))}{\hat{P}}$, that is, a higher expected level of underpricing. Finally, the unconditional expected level of underpricing is given by: $E(\gamma) = (1 - \lambda + \lambda \Pr(\pi \le \hat{P}))E(\gamma|ND)$. Thus, as $\lambda \to 0$ the solution $\hat{P} \to E(\pi)$ and $E(\gamma|ND) = 0$; and as $\lambda \to 1$ the solution $\hat{P} \to \pi_{\min}$ and $(1 - \lambda + \lambda \Pr(\pi \le \hat{P})) \to 0$. □

LEMMA A.1. *The expected market price following nondisclosure for a given disclosure cutoff z, that is given by* $E(\pi|ND, z) = \lambda'(z)E(\pi|\pi \le z) + (1 - \lambda'(z))E(\pi)$, *where* $\lambda'(z) = \frac{\lambda P(\pi \le z)}{\lambda P(\pi \le z) + 1 - \lambda}$ *(see equation (11)), is minimized at the solution of the benchmark case* $z = P^{HI}$ *that satisfies* $z = E(\pi|ND, z)$ *(cf. (7)).*

Proof of Lemma. The right hand side of equation (11) for a given disclosure cutoff z can be written as in (A6)

$$E(\pi|ND, z) = \frac{E(\pi) - \lambda\left[\int_z^{\pi_{\max}} \overline{F}(z)\,dz + z\overline{F}(z)\right]}{1 - \lambda\overline{F}(z)}. \tag{A6}$$

The above follows from (A2), that is, that $E(\pi|\pi \le z) = \frac{1}{F(z)}[E(\pi) - \int_z^{\pi_{\max}} \overline{F}(z)\,dz - z\overline{F}(z)]$, and since $\lambda'(z) = \frac{\lambda F(z)}{1 - \lambda\overline{F}(z)}$. It follows from (A6) that $E(\pi|ND, z)$ is minimized (i.e., $\frac{\partial}{\partial z}E(\pi|ND, z) = 0$) at the point that equation (7) is satisfied. In particular, expanding the first order condition implies that

$$\frac{\partial}{\partial z}E(\pi|ND, z) = 0 \Leftrightarrow z = \frac{E(\pi) - \lambda\left[\int_z^{\pi_{\max}} \overline{F}(z)\,dz + z\overline{F}(z)\right]}{1 - \lambda\overline{F}(z)}.$$

Thus, we conclude that the expected market price following nondisclosure for a given disclosure cutoff z is decreasing at first to obtain a minimum at the point of optimum P^{HI}. □

Proof (Equilibrium Endogenous Mass of Informed Investors). To show that there exists such a cutoff, consider the function Υ defined in equation (12). First note that, for $N_I = 0$ (or cutoff $\hat{P}(0) = P^{HI}$), $N_{UI} = N$, and hence the potential profits from informed trading upon entry of an informed trader are positive:

$$\Upsilon(N_I = 0) = \frac{q}{N}(1-\lambda)\left(E(\pi) - P^{HI}\right) > 0.$$

On the other extreme, at the limit $N_I \to q$, the potential profits from informed trading upon entry of an informed trader are given by

$$\Upsilon(N_I = q) = \frac{q}{N}(1-\lambda)(E(\pi) - \hat{P}(q)) - \delta q.$$

It is useful to express Υ slightly differently by taking into account the fact that the price $\hat{P}(N_I)$ is set such that the uninformed investors break even on their investment in equilibrium, that is,

$$\frac{q}{N}(1-\lambda)(E(\pi) - \hat{P}(N_I)) = \frac{q}{N-N_I}\lambda \Pr(\pi \le \hat{P}(N_I))(\hat{P}(N_I) - E(\pi|\pi \le \hat{P}(N_I))).$$

We can write Υ as

$$\Upsilon(N_I) = \frac{q}{N-N_I}\lambda \Pr(\pi \le \hat{P}(N_I))(\hat{P}(N_I) - E(\pi|\pi \le \hat{P}(N_I))) - \delta N_I. \quad \text{(A7)}$$

It follows that, at the limit $N_I \to q$,

$$\Upsilon(N_I = q) = \frac{q}{N-q}\lambda \Pr(\pi \le \hat{P}(q))(\hat{P}(q) - E(\pi|\pi \le \hat{P}(q))) - \delta q.$$

To establish the lower bound on the cost of acquiring information parameter δ for which $\Upsilon(N_I = q) < 0$, we show that the expression $\Pr(\pi \le z)(z - E(\pi|\pi \le z))$ is increasing in $z \in (\pi_{\min}, \pi_{\max})$ or that the following derivative is positive:

$$\frac{\partial(F(z)(z - E(\pi|\pi \le z)))}{\partial z} = f(z)(z - E(\pi|\pi \le z)) + F(z)\left[1 - \frac{\partial E(\pi|\pi \le z)}{\partial z}\right]. \quad \text{(A8)}$$

This is shown by substituting the equality $\frac{\partial E(\pi|\pi \le z)}{\partial z} = \frac{f(z)}{F(z)}(z - E(\pi|\pi \le z))$ in (A8) to conclude that

$$\frac{\partial(\Pr(\pi \le \hat{P})(\hat{P} - E(\pi|\pi \le \hat{P})))}{\partial \hat{P}} = F(\hat{P}) > 0. \quad \text{(A9)}$$

Due to this monotonicity (and that $\hat{P} \le E(\pi)$), a sufficient condition for $\Upsilon(N_I = q) < 0$ is that the value of δ exceeds the following lower bound:

$$\delta > \hat{\delta} \equiv \frac{1}{q}\lambda \Pr(\pi \le E(\pi))\ (E(\pi) - E(\pi|\pi \le E(\pi))). \quad \text{(A10)}$$

Thus, it follows from the Intermediate Value Theorem that there exists a solution N_I^* to the equation $\Upsilon(N_I) = 0$. Notice, in our definition of the lower bound $\hat{\delta}$ we have divided by q and not by $N - q$. This stricter requirement on the value of δ (as $N - q \geq q$) is required to establish uniqueness of the solution N_I^* or, in particular, that $\frac{\partial}{\partial N_I}\Upsilon(N_I) < 0$ at the optimum.

Using (A7), we obtain

$$\frac{\partial \Upsilon}{\partial N_I} = \frac{q}{N - N_I}\lambda \frac{\partial(\Pr(\pi \leq \hat{P})(\hat{P} - E(\pi|\pi \leq \hat{P})))}{\partial \hat{P}} \frac{\partial \hat{P}}{\partial N_I} + \frac{q}{(N - N_I)^2}[\lambda \Pr(\pi \leq \hat{P})(\hat{P} - E(\pi|\pi \leq \hat{P}))] - \delta. \tag{A11}$$

By using the result in (A9), we can simplify (A11)

$$\frac{\partial \Upsilon}{\partial N_I} = \frac{q}{N - N_I}\lambda F(\hat{P}) \frac{\partial \hat{P}}{\partial N_I} + \frac{q}{(N - N_I)^2}[\lambda \Pr(\pi \leq \hat{P})(\hat{P} - E(\pi|\pi \leq \hat{P}))] - \delta. \tag{A12}$$

As the IPO issue price $\hat{P}(N_I)$ is decreasing in the relative mass of informed investors or $\frac{\partial \hat{P}}{\partial N_I} < 0$ (see Proposition 1), a sufficient condition for the derivative in (A11) to be negative at the optimum, that is, for $\left.\frac{\partial \Upsilon}{\partial N_I}\right|_{N_I = N_I^*} < 0$, is that $\frac{q}{(N-N_I)^2}[\lambda \Pr(\pi \leq \hat{P})(\hat{P} - E(\pi|\pi \leq \hat{P}))] - \delta < 0$ for the optimal N_I. Using again the monotonicity shown in (A9), it follows that

$$\frac{q}{(N - N_I)^2}[\lambda \Pr(\pi \leq \hat{P})(\hat{P} - E(\pi|\pi \leq \hat{P}))] < \frac{1}{q}[\lambda \Pr(\pi \leq E(\pi))(E(\pi) - E(\pi|\pi \leq E(\pi)))]. \tag{A13}$$

Thus, one can conclude that for $\delta > \hat{\delta}$ we obtain that at the optimum $\left.\frac{\partial \Upsilon}{\partial N_I}\right|_{N_I = N_I^*} < 0$ and therefore there exists a unique equilibrium interior mass of informed investors N_I^*. □

Proof. Corollary 2 (Propensity to Disclose). Since $\frac{\partial \hat{P}}{\partial N_I} < 0$, in order to establish the comparative statics it suffices to show that $\frac{\partial N_I}{\partial \delta} < 0$, $\frac{\partial N_I}{\partial q} > 0$, and $\frac{\partial N_I}{\partial N} < 0$. We use the Implicit Function Theorem and the result established above that $\left.\frac{\partial \Upsilon}{\partial N_I}\right|_{N_I = N_I^*} < 0$ for $\delta > \hat{\delta}$. Notice that

$$\frac{\partial \Upsilon}{\partial \delta} = -N_I < 0, \quad \frac{\partial \Upsilon}{\partial q} = \frac{1}{N}(1 - \lambda)(E(\pi) - \hat{P}(N_I)) > 0, \text{ and}$$

$$\frac{\partial \Upsilon}{\partial N} = -\frac{q}{N^2}(1 - \lambda)(E(\pi) - \hat{P}(N_I)) - \frac{q}{N^2}(1 - \lambda)\frac{\partial \hat{P}(N_I)}{\partial N} < 0.$$

The latter result follows since the IPO issue price is decreasing in the fraction of informed investors given by $\frac{N_I}{N}$, that is, $\frac{\partial \hat{P}(N_I)}{\partial N} > 0$. This implies that

$$\frac{\partial N_I}{\partial \delta} = -\frac{\partial \Upsilon}{\partial \delta}\Big/\frac{\partial \Upsilon}{\partial N_I} < 0, \quad \frac{\partial N_I}{\partial q} = -\frac{\partial \Upsilon}{\partial q}\Big/\frac{\partial \Upsilon}{\partial N_I} > 0, \text{ and } \frac{\partial N_I}{\partial N} = -\frac{\partial \Upsilon}{\partial N}\Big/\frac{\partial \Upsilon}{\partial N_I} < 0.$$

□

Proof. Corollary 3 (Underpricing). Follows directly from Corollary 1 and the proof of Corollary 2. □

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