

Self-imposed Investment Rationing in Light of Discretionary Disclosures

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Abstract

The role of investment rationing by one party to discipline reporting of private information by another is well recognized. Formally, adverse selection models succinctly capture this effect via the crisp information rents vs. efficiency tradeoff. This paper takes a different slant to investment rationing by showing that production cuts can also be self-imposed: by scaling down his upfront investments, an entrepreneur can discipline his own subsequent aggressive reporting behavior. In particular, in this paper, a higher investment by an entrepreneur raises his stakes, magnifying his incentives to acquire and selectively disclose information in order to manipulate market price. Of course, the rational market is not fooled and responds by suitably discounting price. As a consequence, the upfront lowering of investment permits the entrepreneur to credibly signal to the market that he will limit his shenanigans thereby also limiting retaliatory market penalties.

1 Introduction

The ubiquity of private information in both intra- and inter-firm relationships is routinely noted by academics and practitioners alike. The detrimental concerns linked with operating in such an information environment have also been stressed. Examples abound. A head-quarter governing capital budgeting decisions may set a hurdle rate greater than the cost of capital to curb managerial budget padding; a public project may be under funded when individual users are unwilling to reveal the true value they derive from the project; procurement contracts and auctions may result in bids being accepted from less efficient parties when bidder characteristics are private; incentive contracts may impose excessive risk to motivate appropriate behavior; downstream supply chain partners may procure and process fewer inputs when unsure of production costs of upstream participants; etc.

The above examples portray a picture wherein one party distorts meaningful real decisions in response to information advantage held by another. This view is formalized by principal-agent adverse selection models that succinctly demonstrate the production-rents trade-off.¹ In effect, the principal resorts to rationing (production cuts) to reduce the agent's penchant for misreporting to earn slack (information rents). In this paper, rationing continues to be the key theme but, surprisingly, is self-imposed. That is, an entrepreneur engages in rationing upfront so as to reduce his own down-the-road temptation to selectively disclose and manipulate market price. Broadly viewed, the paper demonstrates that an entrepreneur's investment decision and his information acquisition and disclosure decisions are inextricably linked.

To elaborate, we consider a model in which an entrepreneur makes an upfront investment that provides an uncertain payoff in the long run. Subsequent to the investment, the

¹Mirrlees (1971) conducted the first formal analysis of the adverse selection problem in the context of optimal income taxation. Laffont and Tirole (1993) and Laffont and Martimort (2001) are standout textbooks that both detail the solution technique and document the numerous applications in this arena. A crisp linear formulation of the problem in light of capital budgeting was presented in Harris et al. (1982) and Antle and Eppen (1985). The tractability of this approach is credited with spawning multiple follow-up applications. See Antle and Fellingham (1997) and Rajan and Reichelstein (2004) for excellent reviews.

entrepreneur may acquire information, at some personal cost, about the investment's future payoff. To capture the feature that firms are often going concerns while individual associations with firms are relatively short term, we assume the entrepreneur sells the firm at an intermediate date in a competitive marketplace. The fact that the buyer (the second generation owner) acquires the rights to the investment's down-the-road payoff while private information pertaining to the payoff potentially resides with the seller (the entrepreneur) creates a demand for disclosures at the time of sale. Not surprisingly, the entrepreneur is willing to disclose favorable information to boost market price, but equally guards against the release of unfavorable information. The reason non disclosure by the entrepreneur does not lead to a complete unraveling of his private information (as in, Grossman 1981 and Milgrom 1981), is because the market cannot ascertain whether the entrepreneur is actually uninformed or whether he is informed but withholding bad news. The ability to influence the market price through acquisition and selective disclosure of information puts the entrepreneur in the driver's seat *ex post*. *Ex ante*, however, is a different story.

In particular, the paper shows that the entrepreneur devotes excessive resources in pursuit of information, i.e., more than that dictated by the information's productive use (for fine tuning any follow-up investment decision by the buyer). The entrepreneur's incentive to over acquire information is tied to his desire to exploit the associated "option value": the entrepreneur has the right but not the obligation to disclose what he learns.

Although, this option is valuable to the entrepreneur *ex post*, the market correctly anticipates that such options are exercised at its expense. As a consequence, it rationally price protects itself, leaving the entrepreneur to bear the cost. In other words, in the non cooperative game being played between the market and the entrepreneur, the market sets the price for the firm expecting the entrepreneur to have strategically exercised his selective disclosure option. And, cognizant of such discounting, the entrepreneur indeed follows through with expected behavior.

As the above discussion suggests, the selective disclosure option is actually detrimental

to the interests of the entrepreneur (a dead weight cost) and therefore it is to his advantage to restrict its value. This desire to curtail option value is precisely what leads to the spillover to the production problem: the larger the entrepreneur's upfront investment, the greater is the impact of disclosure on market price (boosting the value of the entrepreneur's selective disclosure option), and the bigger is the retaliatory penalty imposed by the market. By curtailing his own upfront investment, i.e., lowering his stake, the entrepreneur credibly conveys to the market that he has less reason to seek and exercise the option of selective disclosure. Stated a bit differently, by *ex ante* tying his own hands via scaled down investment, the entrepreneur also scales down his *ex post* aggressiveness in acquiring information and manipulating market price.

From this paper's analysis, it follows that self-rationing is critical in environments in which investments have long-term repercussions; future payoffs are uncertain; and ownership changes hands in trade wherein the seller holds a distinct information edge having both the incentives and the opportunity to "advertise" selectively. In light of such considerations, the paper makes modest connections to two settings where such features seem natural. First, we discuss the case of CEO retirement wherein incentives to boost stock price and disclose without being held to account are obvious. Interestingly, there is both anecdotal and formal empirical evidence that suggests that top management changes are accompanied by excessively favorable disclosures and investment rationing. Second, we comment on the case of initial public offerings (IPOs) where concern for allocative efficiency is paramount. In the context of IPOs, it is intriguing to note that regulations govern disclosures in specific ways, mandating disclosure via specific channels (e.g., the prospectus) while disabling other avenues of communication (e.g., the "quiet period"). Despite these connections, we note that our broader point here is to merely stress that either of the extremes of disclosure regulation – one that mandates all disclosure and one that prohibits any disclosure – can have an upside in the paper's model by limiting the entrepreneur's selective disclosure option thereby alleviating the pressure to ration investments.

In terms of links to existing literature, this paper both borrows from and builds on two distinct streams of work. Given the vital role of the entrepreneur's private information in deriving the paper's results, there is a natural tie-in to other information-based explanations for investment distortions in firms. These include investment cuts undertaken to curtail misreporting by agents (Antle and Eppen 1985); managers engaging in myopic resource allocations to inflate current earnings and mislead stock price (Stein 1989); managers avoiding profitable long-term projects cognizant of early termination threats by investors (von Thadden 1995); and managers shying away from investments when they fear the market will attribute failure to their lack of talent rather than to poor project characteristics (Holmstrom 1999). We contribute to this literature by demonstrating that the option of selective disclosure fueled by private information can alone lead to investment rationing.

Naturally, our paper is also closely tied to the large literature on discretionary disclosure in accounting. This literature deals with how and why private information may not unravel along the lines initially suggested by Grossman (1981) and Milgrom (1981). Verrecchia (1983) shows that the existence of disclosure related costs can prevent unraveling, while Dye (1985) demonstrates that uncertainty about a manager's information endowment also provides disclosure discretion. Subsequent work has attempted to endogenize aspects of these two explanations. In particular, Wagenhofer (1990) and Darrough and Stoughton (1990) consider multiple recipients with diverse interests (e.g., the product and capital markets) in an attempt to endogenize the cost of disclosures. Similarly, Shavell (1994) establishes that the degree of uncertainty about information endowment critical to the Dye explanation can itself be endogenized when the manager can acquire information at an uncertain cost.² Of course, the focus of these papers is on characterizing firms' non trivial disclosure policy. In contrast, our focus is on how a firm's disclosure policy can interact with its production decision and, in fact, lead to underinvestment.

The remainder of the paper is organized as follows. Section 2 details the model. Section

²For more comprehensive surveys of the voluntary disclosure literature, see Verrecchia (2001), Dye (2001), and Beyer et al. (2010).

3 presents the results: section 3.1 derives the benchmark solution, wherein the entrepreneur *ex ante* commits to his disclosure strategy; section 3.2 derives the equilibrium under discretionary disclosure, highlighting the option-fueled demand for excessive information acquisition and the resulting need for self-imposed investment rationing by the entrepreneur. Section 4 concludes the paper.

2 Model

A firm owned and managed by a risk-neutral entrepreneur possesses a risky production technology that calls for investments I_1 and I_2 to be made sequentially over two time periods. Each investment I_t comes at a cost $I_t^2/2$. The payoff V from this technology is received at the end of the second time period and is described by:

$$V = \tilde{\theta} [I_1 + kI_2].$$

The random variable $\tilde{\theta} \in [0, \infty)$ represents the uncertain return from the technology and is associated with cumulative distribution function (CDF) F , probability density function (PDF) f , mean μ , and variance σ^2 . The parameter k , $k \geq 0$, permits the follow-up investment to have differential impact on the technology's payoff relative to the entrepreneur's base investment. Thus, for example, $k = 0$ reduces the setting to one in which only the base investment is critical.

The investments also naturally differ in terms of the information on which they can be made contingent, with more information potentially available for the later investment. In particular, at the time of the initial investment I_1 , the precise value of θ is not known. However, the entrepreneur may learn about the uncertain return in time, allowing for possible circumstance contingent follow-up investment I_2 . This specification captures the dynamic nature of long-term projects where investments in later stages can be based on more information.

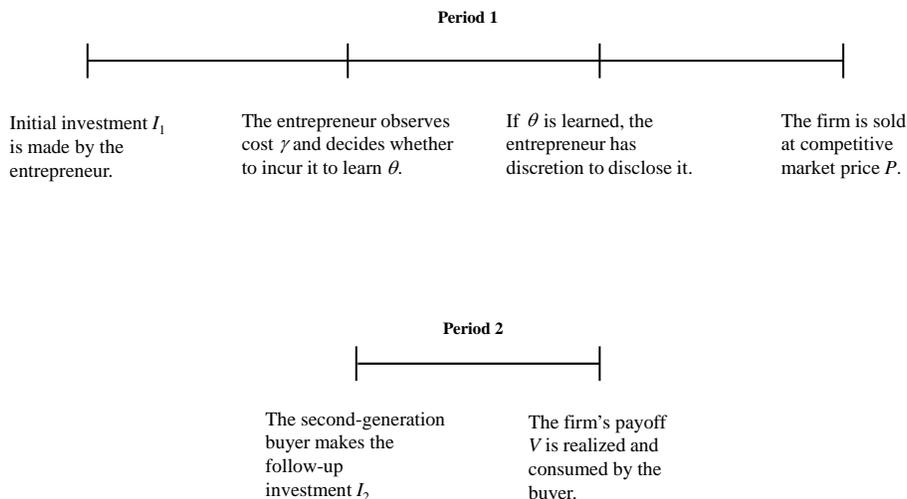


Figure 1: Timeline

We model the entrepreneur’s information acquisition process about the technology’s return as follows. Acquiring information is a costly activity requiring time and diligent effort, and upfront the entrepreneur is assumed to be uncertain of the precise cost of gathering information. Specifically, the cost of acquiring information about $\tilde{\theta}$ is represented by $\tilde{\gamma} \in [0, \infty)$ with associated PDF and (strictly) increasing CDF functions denoted by g and G , respectively. After the initial investment is made, the entrepreneur privately observes γ and decides whether or not to acquire information; if he chooses to incur the cost γ , he learns θ .

We assume the ownership of the firm changes hands at the end of the first period, say for liquidity reasons. Such timing is also consistent with the notion that firms are often going concerns, whereas individual associations with firms are relatively short term. A competitive market values the firm at price P , and the firm is sold to a second-generation buyer at that price. Once ownership is transferred, the second-generation buyer makes the follow-up investment I_2 and consumes the payoff V at the end of the second period. For expositional convenience we henceforth refer to the entrepreneur as “he” and “him” and to the second-generation buyer as “she” and “her”.

The market price and the follow-up investment can be conditioned on the observation of the initial investment I_1 and any information about the firm’s prospects θ disclosed by

the entrepreneur. Since the realization of $\tilde{\gamma}$ and the information acquisition decision are private, the entrepreneur retains complete discretion over disclosing θ when he observes it. As is standard in the voluntary disclosure literature, disclosure when made is assumed to be honest. The timeline in Figure 1 summarizes this sequence of events.

The focus of this paper is on the entrepreneur's investment, information acquisition, and disclosure decisions.

3 Results

3.1 Benchmark case

We begin by presenting a setting where we presume the entrepreneur can commit *ex ante* to his information acquisition and disclosure strategy. Proposition 1 characterizes the results, and highlights that the firm's production and information problems separate.

Proposition 1 *Under commitment to information acquisition and disclosure, the entrepreneur's optimal strategy is to invest $I_1^* = \mu$; acquire information if $\gamma \leq \gamma^* = k^2\sigma^2/2$; and disclose all acquired information.*

Since information is useful in fine-tuning the follow-up investment, committing to disclose all information acquired is naturally desirable – after all, the more the investments are circumstance contingent, the more the entrepreneur is rewarded by a higher expected market price. This is not to say that the entrepreneur always acquires information in the first place. In particular, information is acquired if and only if the cost of the entrepreneur's time and effort is commensurate with the expected incremental efficiency gains stemming from the follow-up investment. As expected, then, the γ -threshold for acquiring information increases both with return uncertainty σ^2 and the marginal impact k of the follow-up investment on eventual payoff.

Notice the initial investment decision I_1^* is made prior to any knowledge of θ , and, thus, contains no information about the uncertain return component. Given this, the investment decision has no impact on the entrepreneur's subsequent information acquisition. The decomposition of the production and information environments implies the initial investment choice merely maximizes the net expected payoff from such investments, i.e., I_1 is chosen to maximize $\mu I_1 - I_1^2/2$.

The entrepreneur's ability to commit to maintaining a fully transparent environment is critical in deriving Proposition 1 – it is presumed that on learning θ , the entrepreneur will follow through with his stance of disclosing all that he learns. Of course, on observing a poor return realization, the entrepreneur's initial willingness to share information is no longer credible since he recognizes such disclosures will be met with distinct negative market reaction. It is this *ex post* temptation to deviate from *ex ante* desires that gives meaningful bite to the subsequent analysis that presumes disclosures are discretionary.

3.2 Equilibrium: Selective disclosure and self-rationing

We now evaluate the equilibrium strategies in the absence of *ex ante* commitments. The profile of strategies in this game follow a sequential equilibrium, which we characterize through the process of backward induction. Thus, we start with the last decision node in the game – that of the follow-up investment.

3.2.1 Follow-up investment I_2

The efficiency of the follow-up investment hinges on information about prospects θ of the technology. If the entrepreneur discloses θ , the second-generation buyer makes an informed decision in setting the follow-up investment I_2 . In other words, for each disclosed θ , she chooses I_2 to maximize $k\theta I_2 - I_2^2/2$.

In contrast, in the absence of disclosure, the second-generation buyer (and the market) forms a rational belief about the likelihood that the entrepreneur is informed, and forms an

inference about the expected return from the technology. Based on this expectation, she determines the follow-up investment. In particular, let q represent the buyer's expectation of the probability that the entrepreneur is informed, and let $\theta_\varnothing(q)$ characterize her estimate of the technology's expected return in the event the entrepreneur makes no disclosure. That is, $\theta_\varnothing(q) = E[\theta|\varnothing, q]$, where \varnothing signifies a lack of disclosure by the entrepreneur. Using this estimate of θ , I_2 is chosen in an analogous fashion as before to maximize $k\theta_\varnothing(q)I_2 - I_2^2/2$.

Solving for the optimal follow-up investment \hat{I}_2 under both the disclosure and non disclosure circumstance yields:

$$\begin{aligned}\hat{I}_2 &= k\theta \text{ if } \theta \text{ is disclosed; and} \\ &= k\theta_\varnothing(q) \text{ if } \theta \text{ is not disclosed.}\end{aligned}\tag{1}$$

Of course, the impact of these decisions on the market price of the firm, and the consequences of that for the entrepreneur's information acquisition, disclosure, and investment decisions are still to be derived. And, when they are detailed, the values of q and $\theta_\varnothing(q)$ (utilized in this subsection) will be determined endogenously.

3.2.2 Market price of the firm

In this step, we derive the competitive market price of the firm, P , at the end of the first period. This price equals the expected payoff for a second-generation buyer net of her follow-up investment cost. Calculating the market price requires evaluating the impact of each disclosure outcome on the payoff from the firm's technology.

First, consider the case when the entrepreneur discloses θ . From (1), it is clear that the follow-up investment will be $k\theta$. Thus, given initial investment I_1 and disclosure θ , the market price equals:

$$P(\theta) = \theta [I_1 + k\{k\theta\}] - \frac{[k\theta]^2}{2} = \theta \left[I_1 + \frac{k^2\theta}{2} \right].\tag{2}$$

Next, consider the no disclosure case. Under no disclosure, the market cannot distinguish between whether the entrepreneur is uninformed or whether he is informed but is strategically withholding his information. In either instance, the buyer's follow-up investment will be $k\theta_\emptyset(q)$, as noted in (1). Thus, given initial investment I_1 and the lack of disclosure, the market price equals:

$$P(\emptyset) = \theta_\emptyset(q) [I_1 + k \{k\theta_\emptyset(q)\}] - \frac{[k\theta_\emptyset(q)]^2}{2} = \theta_\emptyset(q) \left[I_1 + \frac{k^2\theta_\emptyset(q)}{2} \right]. \quad (3)$$

From (2) and (3), it is obvious that the entrepreneur's disclosure of θ has a distinct impact on the market price, and this ability to sway market price can incentivize him to report selectively. A question of course is whether the market can see through the entrepreneur's lack of disclosure thereby forcing a quick "unraveling" of his private information (e.g., Grossman 1981; Milgrom 1981). However, the fact that information acquisition is costly and the entrepreneur may thus have rationally selected to be uninformed, disables full unraveling in equilibrium. We investigate this issue next.

3.2.3 Discretionary disclosure

Expressions (2) and (3) fully characterize the firm's market price as a function of the entrepreneur's disclosure strategy. Identifying the disclosure strategy is obviously moot if the entrepreneur opts not to acquire any information in the first place. But if he does acquire information about the firm's return, then he discloses strategically aiming to maximize price P . Formally, this translates into the entrepreneur only disclosing θ -values that satisfy $P(\theta) > P(\emptyset)$. Given the market's conjecture q , and since market price $P(\theta)$ in (2) increases with the signal θ , there exists a threshold $\hat{\theta}(q)$, such that for all signals $\theta \geq \hat{\theta}(q)$, disclosure occurs. For all signals $\theta < \hat{\theta}(q)$, the entrepreneur keeps silent.³

Given the pricing functions in (2) and (3), the entrepreneur's disclosure threshold follows

³At the indifference point $\theta = \hat{\theta}(q)$, without loss of generality we assume that the entrepreneur discloses the signal.

immediately:

$$\hat{\theta}(q) = \theta_{\varnothing}(q). \quad (4)$$

The disclosure threshold in (4) simply indicates that if the entrepreneur believes that non disclosure leads the market to estimate the technology's return at $\theta_{\varnothing}(q)$, then he does not reveal any signals that will guide the market's estimate lower.

From the rational market's perspective, its estimate $\theta_{\varnothing}(q)$ in the absence of disclosure is appropriate in that it correctly anticipates the likelihood that the entrepreneur is informed and recognizes that when informed he adopts the $\hat{\theta}(q)$ -threshold disclosure rule. More specifically, in the event of non disclosure, the market believes that: (i) with probability $\frac{1-q}{1-q+qF(\hat{\theta}(q))}$, the entrepreneur is uninformed, in which case, the expected value of θ is μ ; and (ii) with probability $\frac{qF(\hat{\theta}(q))}{1-q+qF(\hat{\theta}(q))}$ the entrepreneur is informed of unfavorable information that he withholds, in which case, the expected value of θ is $\int_0^{\hat{\theta}(q)} \theta f(\theta) d\theta / F(\hat{\theta}(q))$. The market cannot distinguish between (i) and (ii), so its estimate based on the probability-weighted average of the two yields:

$$\theta_{\varnothing}(q) = \frac{[1-q]\mu + q \int_0^{\hat{\theta}(q)} \theta f(\theta) d\theta}{[1-q] + qF(\hat{\theta}(q))}. \quad (5)$$

From (4), it follows that the entrepreneur's disclosure threshold $\hat{\theta}(q)$ is the same as the value of $\theta_{\varnothing}(q)$ derived above in (5). Some simple manipulations then lead to:

$$\hat{\theta}(q) = \mu - \frac{q}{[1-q]} \int_0^{\hat{\theta}(q)} F(\theta) d\theta. \quad (6)$$

The threshold in (6) is familiar (see, for example, Jung and Kwon (1988) and Shavell (1994)). If the seller is always informed, $q = 1$ and θ -values are fully revealed to the market, i.e., the standard unravelling result applies. At the other extreme, when the seller is always uninformed, $q = 0$ and no disclosure occurs. However, for intermediate q -values, $0 < q < 1$,

both the non disclosure and the disclosure intervals are non-trivial. The extent to which the market confronts an informed seller (i.e., the value of q) is endogenous in our setting since the entrepreneur is also strategic about information acquisition, an issue we directly proceed to next.

3.2.4 Information acquisition

The entrepreneur acquires information with a view to maximizing the firm's expected market price at the time of sale. He recognizes that acquiring information does not compel him to disclose, but rather gives him the option to disclose selectively.

To determine the entrepreneur's information acquisition decision, we first estimate the firm's expected market price conditional on his becoming informed. Using (2), (3), and (6) then:

$$\begin{aligned}
 E [P|\text{Information is acquired}] &= \int_0^{\hat{\theta}(q)} P(\emptyset) f(\theta) d\theta + \int_{\hat{\theta}(q)}^{\infty} P(\theta) f(\theta) d\theta & (7) \\
 &= \int_0^{\hat{\theta}(q)} \hat{\theta}(q) \left[I_1 + \frac{k^2 \hat{\theta}(q)}{2} \right] f(\theta) d\theta + \int_{\hat{\theta}(q)}^{\infty} \theta \left[I_1 + \frac{k^2 \theta}{2} \right] f(\theta) d\theta.
 \end{aligned}$$

Notice the expression in (7) accounts for the fact that, in equilibrium, the entrepreneur will disclose if and only if $\theta \geq \hat{\theta}(q)$, where $\hat{\theta}(q)$ is derived in (6).

The next step involves evaluating the market price when the entrepreneur remains uninformed. Of course, being uninformed precludes any disclosure, and so leads to a constant market price as noted below:

$$\begin{aligned}
 E [P|\text{Information is not acquired}] &= P(\emptyset) \\
 &= \hat{\theta}(q) \left[I_1 + \frac{k^2 \hat{\theta}(q)}{2} \right]. & (8)
 \end{aligned}$$

For any given realization of γ , then, the entrepreneur contrasts the payoffs under the two

possible strategies, accounting for the cost γ of becoming informed. That is, the entrepreneur chooses to be informed if and only if:

$$\int_0^{\hat{\theta}(q)} P(\emptyset) f(\theta) d\theta + \int_{\hat{\theta}(q)}^{\infty} P(\theta) f(\theta) d\theta - \gamma \geq P(\emptyset). \quad (9)$$

Using (7) and (8) in (9), the cost threshold $\hat{\gamma}(q)$ below which the entrepreneur becomes informed equals:

$$\hat{\gamma}(q) = \int_{\hat{\theta}(q)}^{\infty} I_1 [\theta - \hat{\theta}(q)] f(\theta) d\theta + \frac{k^2}{2} \int_{\hat{\theta}(q)}^{\infty} [\theta^2 - \hat{\theta}^2(q)] f(\theta) d\theta. \quad (10)$$

The market of course rationally anticipates the entrepreneur's information acquisition incentives. Thus, the market's equilibrium belief that the entrepreneur is informed must satisfy:

$$q = G(\hat{\gamma}(q)). \quad (11)$$

We denote the unique q -value that satisfies expression (11) by \hat{q} . For expositional convenience, with a slight abuse of notation, we henceforth represent $\hat{\theta}(\hat{q})$ by $\hat{\theta}$ and $\hat{\gamma}(\hat{q})$ by $\hat{\gamma}$.

An appropriate comparison here is to contrast the entrepreneur's information acquisition under voluntary disclosure with information acquisition in the benchmark case wherein the entrepreneur could commit to all decisions. The next proposition addresses this issue.

Proposition 2 *Under discretionary disclosure the entrepreneur acquires excessive information in equilibrium, i.e., $\hat{\gamma} > \gamma^*$.*

The intuition for Proposition 2 is as follows. The entrepreneur acquires information with the expectation of disclosing favorable signals $\theta \geq \hat{\theta}$ and withholding unfavorable signals. When the lower tail values of θ (i.e., $\theta < \hat{\theta}$) do not get disclosed, the market's assessment of payoff from the initial investment is a constant $I_1 \hat{\theta}$. This is because the market cannot

identify the true reason behind non disclosure – it does not know if the lack of disclosure was because no information was acquired or because unfavorable information was observed. For $\theta \geq \hat{\theta}$, however, information acquisition proves valuable to the entrepreneur since acquisition leads to disclosure, which enhances the market’s assessment of the initial investment’s payoff from the constant $I_1\hat{\theta}$ to the linear θ -contingent payoff $I_1\theta$.

The one-sided upper-tail gains described above imply that the entrepreneur’s information acquisition decision has an inherent option-like feature. The first term in the right-hand-side of expression (10) formally represents this “option value” of information. Acquiring information can be viewed as the entrepreneur procuring I_1 number of options on θ with an exercise price of $\hat{\theta}$.

The second term in the right-hand-side of expression (10) incorporates the ability of disclosure to fine-tune the follow-up investment and provide productive (real) gains. Given these twin benefits, the entrepreneur naturally acquires more information than in the full-commitment setting, where information only provides efficiency gains for the follow-up investment.

As stressed earlier, the initial investment I_1 corresponds to the number of options the entrepreneur can potentially exercise at $\hat{\theta}$. Thus, intuitively, increasing initial investment increases the option value of information and, thereby, motivates enhanced information acquisition. The formal result noted below is in line with such thinking.

Proposition 3 *Due to the embedded option-feature, the entrepreneur’s information acquisition increases with his level of initial investment, i.e., $\frac{d\hat{\gamma}}{dI_1} > 0$.*

The comparative statics in Proposition 3 links the firm’s investment environment to its information environment: boosts on one front accompany boosts on the other. This interaction suggests that in making the initial investment decision, the entrepreneur needs to account for not just productive gains but also informational consequences. The next sub-section conducts precisely this analysis.

3.2.5 Initial investment I_1

From the previous analysis, the initial investment level is critically tied to the option value linked with selective disclosure. This raises the issue of whether the option provides any real gains for the entrepreneur or, since it is derived at the expense of the future buyer, does it merely create a conflict with the buyer leading to an unfortunate dead weight cost.

To answer this question, consider the entrepreneur's investment decision accounting for his own subsequent information acquisition decision (noted in (10)), disclosure strategy (noted in (6)), and the equilibrium condition in (11). In particular, the entrepreneur chooses I_1 to maximize his net expected payoff as noted below:

$$\begin{aligned}
& \text{Max}_{I_1} E [P] - \frac{I_1^2}{2} - \int_0^{\hat{\gamma}} \gamma g(\gamma) d\gamma \\
\iff \text{Max}_{I_1} & G(\hat{\gamma}) \left[\int_0^{\hat{\theta}} \hat{\theta} \left[I_1 + \frac{k^2 \hat{\theta}}{2} \right] f(\theta) d\theta + \int_{\hat{\theta}}^{\infty} \theta \left[I_1 + \frac{k^2 \theta}{2} \right] f(\theta) d\theta \right] \\
& + \{1 - G(\hat{\gamma})\} \hat{\theta} \left[I_1 + \frac{k^2 \hat{\theta}}{2} \right] - \frac{I_1^2}{2} - \int_0^{\hat{\gamma}} \gamma g(\gamma) d\gamma. \tag{12}
\end{aligned}$$

The first order condition of the maximization problem in (12) yields:

$$\mu - I_1 - \frac{dG(\hat{\gamma})}{dI_1} \int_{\hat{\theta}}^{\infty} I_1 [\theta - \hat{\theta}] f(\theta) d\theta = 0. \tag{13}$$

Focusing on the left-hand-side of (13), the term $\mu - I_1$ equals the marginal benefit of the initial investment in the full commitment regime ($\frac{d}{dI_1} [\mu I_1 - I_1^2/2]$). The next term $\frac{dG(\hat{\gamma})}{dI_1} \int_{\hat{\theta}}^{\infty} I_1 [\theta - \hat{\theta}] f(\theta) d\theta$ on the left-hand-side of (13) represents the entrepreneur's expected incremental payoff from investment due to the option-like feature of information. The expression $\frac{dG(\hat{\gamma})}{dI_1} = g(\hat{\gamma}) \frac{d\hat{\gamma}}{dI_1}$ captures how the entrepreneur's investment impacts the likelihood that he will acquire the option in the first place (i.e., gain private information). From Propo-

sition 3, $\frac{dG(\hat{\gamma})}{dI_1} > 0$, i.e., the more the entrepreneur invests, the more likely he is to acquire information. And, as previously noted, the expression $\int_{\hat{\theta}}^{\infty} I_1 [\theta - \hat{\theta}] f(\theta) d\theta > 0$ characterizes the option value of acquired information.

From (13), it is clear that the option provides no real gains to the entrepreneur. Rather, it acts to diminish his expected payoff. Put differently, a unit increase in initial investment I_1 leads the market to anticipate a cost of $\frac{dG(\hat{\gamma})}{dI_1} \int_{\hat{\theta}}^{\infty} I_1 [\theta - \hat{\theta}] f(\theta) d\theta$, due to the entrepreneur exercising his option to disclose selectively. Since the market is rational, its price protects itself, making the entrepreneur bear this cost. The last term in expression (13) represents precisely this. In other words, the only impact of the option is to decrease the entrepreneur's *ex ante* expected payoff by the option value without providing any real benefits. As a consequence of this, it is in the entrepreneur's best interest to restrict his option value. An effective avenue open to him is through the choice of I_1 .

In effect, the dependence of the option value on initial investment I_1 implies that the investment and information problems interact under discretionary disclosure. The interaction suggests that the optimal investment level \hat{I}_1 will balance considerations in both problems and will deviate from the solution which will be best when each problem is viewed in isolation.

Proposition 4 *Under discretionary disclosure, investment is rationed in equilibrium, i.e., $\hat{I}_1 < I_1^*$.*

Rationing in Proposition 4 is self-imposed by the entrepreneur: by scaling down initial investment, the entrepreneur also scales back his own subsequent opportunistic reporting. The essential ingredients that undergird rationing in our model are: (i) the investment is long-term with uncertain payoff and (ii) the entrepreneur has the opportunity and the incentive to influence market price via disclosures pertinent to the investment's future uncertain payoff. In this context, we note that R&D investments tend to be long term and uncertain; senior management often holds private information about the likely success of such investments; and high level management changes (e.g., CEO retirement) are ripe times for stock manipulation. In light of this, the empirical observation that there are often reductions in

R&D investments in years prior to top management changes (e.g., Dechow and Sloan 1991) is somewhat comforting. Not to put too fine a point on it, but there is also anecdotal evidence consistent with such linkage between disclosure and rationing. In 2007, Sidney Taurel, the retiring CEO of Eli Lilly, disclosed favorable information about the progress of R&D investments in the firm, including details of six drugs that the firm had planned to launch between then and 2011 (see USA today dated 12/18/07). Yet, the R&D investments had been subject to a significant cut during Taurel's final two years in office.⁴

Turning back to formal analysis, using (6), (10), (11), and (13), the equilibrium in the voluntary disclosure setting can be characterized as presented below:

Proposition 5 *Under discretionary information acquisition and disclosure, the entrepreneur's optimal strategy is to invest \hat{I}_1 ; acquire information if $\gamma \leq \hat{\gamma}$; and disclose if $\theta \geq \hat{\theta}$ where $(\hat{I}_1, \hat{\gamma}, \hat{\theta})$ is the unique solution that solves the following system of equations:*

$$\hat{I}_1 = \frac{\mu}{1 + \frac{g(\hat{\gamma})[\mu - \hat{\theta}]^2}{G^2(\hat{\gamma})}};$$

$$\hat{\gamma} = \int_{\hat{\theta}}^{\infty} \hat{I}_1 [\theta - \hat{\theta}] f(\theta) d\theta + \frac{k^2}{2} \int_{\hat{\theta}}^{\infty} [\theta^2 - \hat{\theta}^2] f(\theta) d\theta; \text{ and}$$

$$\hat{\theta} = \mu - \frac{G(\hat{\gamma})}{1 - G(\hat{\gamma})} \int_0^{\hat{\theta}} F(\theta) d\theta.$$

To provide better intuition for this equilibrium, we consider a case with $k = 0$ (so, the focus is entirely on the entrepreneur's initial investment) and uniform distributions $\theta \sim U(0, \bar{\theta})$ and $\gamma \sim U(0, \bar{\gamma})$. Here the solutions are crisp. With no constraints on his ability to commit (i.e., Proposition 1), the entrepreneur selects $I_1^* = \bar{\theta}/2$ and never acquires information since there is no follow-up investment that need be contingent on θ .

⁴Prior to Taurel's retirement, R&D investments in Eli Lilly as a function of revenues declined almost 10% between 2005 and 2007. Tellingly, the ratio recovered, gaining over 12% during the first year under Taurel's successor.

In contrast, the entrepreneur acquires information under the discretionary disclosure setting solely due to his desire and ability to manipulate the market price. His ability to disclose favorable news but conceal unfavorable outcomes relies on the fact that he may actually be uninformed in the first-place. The rub though is that if he does gather information and recognizes it is unfavorable, he does not disclose knowing the market cannot ascertain the precise reason behind non disclosure. Of course, the market anticipates such manipulation and prices the firm accordingly.

Corollary *With uniform distributions and no follow-up investment, i.e., $\theta \sim U(0, \bar{\theta})$, $\gamma \sim U(0, \bar{\gamma})$, and $k = 0$, the entrepreneur:*

(i) *acquires information solely for its option value, i.e., $\gamma^* = 0$ and $\hat{\gamma} = [\bar{\theta} - \hat{\theta}]^2 \hat{\theta} / 2\bar{\theta} > 0$; and*

(ii) *engages in investment rationing from $I_1^* = \bar{\theta}/2$ to $\hat{I}_1 = \hat{\theta}$ where $\hat{\theta} \in (0, \bar{\theta}/2)$ is the unique value that solves $[\bar{\theta} - \hat{\theta}]^4 \hat{\theta} = 2\bar{\theta}^2 [\bar{\theta} - 2\hat{\theta}] \bar{\gamma}$.*

The bottom line is that, relative to the *ex ante* desired level, the selective disclosure environment leads the entrepreneur to exploit the option value of information at the expense of the market. Curtailing his own initial investment then serves as a brake on his own aggressive stance. Roughly stated, increased rationing reduces the entrepreneur's skin in the game, and curbs his *ex post* aggressive posture. In line with such intuition, and utilizing Proposition 5, the discretionary disclosure solution for the uniform distribution case is characterized in the Corollary.

In this paper's setting, the entrepreneur has the option to selectively disclose. And, as has been stressed, this option, and its ability to mislead, is recognized by the market. The rational market responds by penalizing the entrepreneur, a penalty the entrepreneur minimizes by committing to lower investments. Given the entrepreneur is forced to distort investment levels to curb his own option to selectively disclose suggests the entrepreneur may be welcoming of regulation that eliminates the option. The following proposition confirms

that the extremes of either mandating all disclosure or prohibiting any disclosure do just that and, in doing so, each restores the entrepreneur's incentives to invest. In other words the entrepreneur engages in no rationing in either of the two regulatory disclosure regimes.

Proposition 6 *(i) Under regulation that enforces disclosure, the entrepreneur invests $I_1 = \mu$ and acquires information if and only if $\gamma \leq k^2\sigma^2/2$. In other words the solution is the same as under full commitment.*

(ii) Under regulation that prohibits all disclosure, the entrepreneur invests $I_1 = \mu$, but never acquires information. When k is sufficiently small, such regulation may benefit the entrepreneur.

The insight derived so far is that the firm's disclosure policy has a bearing on both the entrepreneur's base investment and the buyer's subsequent follow-up investment. From the entrepreneur's perspective, mandatory disclosure of all acquired information is ideal since it restores his own incentives to invest as well as permits fine-tuned follow-up investment by the buyer, thus, increasing the market's willingness to pay.

In practice, regulators often mandate disclosures of certain information especially when the firm's ownership changes hands. A case in point is an initial public offering (IPO) wherein requirements of a well-defined prospectus and detailed filings with the Securities and Exchange Commission (SEC), coupled with threats of severe penalties, create an environment which compels firms to disclose certain information. Our analysis suggests that "compel" may be an incorrect characterization – the firms may actually be willing conscripts. After all, with the selective disclosure option curtailed, investment efficiency improves.

Admittedly, in practice, a related issue is whether mandatory disclosure regulations can be effectively implemented for all types of information. After all, with certain kinds of information (e.g., forward looking information), an entrepreneur's information endowment is truly private and cannot be established or challenged easily in a court of law. In such instances, an entrepreneur can feign ignorance even when mandatory disclosure laws are in

place, essentially converting the setting back to the discretionary disclosure regime studied in this paper.

An alternative means to eliminate disclosure discretion is to prohibit disclosures. Such a regulatory approach too restores the entrepreneur’s incentives to invest, but has the downside of not permitting contingent follow-up investment. Of course, if the follow-up investment has only a small impact on the eventual payoff (i.e., k is small), then even this disclosure regime may be preferred by the entrepreneur. Interestingly, subsequent to a firm filing for an IPO registration, there is a legal “quiet period” requirement that restricts the firm’s discretionary disclosures. In particular, “gun jumping” regulations codified in section 5(c) of the 1933 Securities Act are intended “to increase reliance on the prospectus by limiting the use of other communication channels that the firm can use to influence potential investors’ perceptions of the company” (Lang and Lundholm 2000, p. 654).⁵

Our broader point here is not to debate the implementability of rules that either mandate or prohibit disclosures. Rather, the goal is to stress that, while polar opposites, these two extreme disclosure regimes may each provide a common benefit of curtailing production distortions and, thus, even be welcomed by the firms subject to the regulatory constraints.

4 Conclusion

Stated simply, this paper demonstrates that a firm’s reporting strategy and its production strategy are interwoven in unexpected ways. In particular, an entrepreneur, concerned with his own aggressive reporting stance, may optimally react by purposefully underinvesting. That is, in our setting, investment rationing is neither imposed on the entrepreneur nor chosen by the entrepreneur to discipline others. Rather, rationing is self-imposed and is intended for self-disciplining.

In the paper’s model, an entrepreneur’s ability to privately acquire information followed

⁵In response to improvements in communication technology, the SEC has recently relaxed some of these regulations, but the key principle restricting selective disclosures remains in place. For details, see <http://www.sec.gov/answers/quiet.htm>.

by his option to selectively disclose provides him with the means and the ability to manipulate the firm's market price at the time of sale. Anticipating that the entrepreneur's option is exercised at its expense, the market rationally price protects itself by discounting the market price to the full extent. In other words, the selective disclosure option, one whose exercise *ex post* is hard-to-resist by the entrepreneur, turns out to be detrimental to his interests. The tie-in to the production problem arises because the value of the disclosure option is naturally linked to the entrepreneur's "stake in the game", here, his scale of investment. As a consequence, by voluntarily rationing investment, the entrepreneur credibly conveys to the market that he will also engage in less exploitative voluntary disclosures.

The paper makes modest connections with disclosure regulations and investment decisions preceding top management changes and IPO issuance by firms. The setting, and the forces at play, also seem ripe to serve as a basis for future work that attempts to explain the oft-discussed but contentious notion of "managerial myopia" and the practice of "relay succession." As regards myopia, it has been noted that managers sometimes shun long-term projects in favor of those with shorter horizons. Our work suggests that short-term projects at least provide the silver lining that their payoffs are realized in a timely fashion, thus eliminating the need for selective disclosures about down-the-road payoffs and the accompanying market penalties. Relay succession, the idea that decision power is shared between the departing CEO and his internally appointed successor during a brief transition period, can also prove helpful in minimizing the selective disclosure option and the market penalty. After all, a departing CEO often has reasons to disclose favorable news to boost stock price at time of exit. In contrast, a successor may have opposing incentives since he wants to disclose unfavorable news and set a lower performance benchmark for himself. The net consequence may be that any information, if collected, is disclosed by one of the two parties in the firm, i.e., the *ex ante* full disclosure policy may be enforced. Pursuing this line of inquiry in future work may be worthwhile.

Appendix

Proof of Proposition 1:

Consider an arbitrary disclosure policy in which signals belonging to a set D are disclosed while all other signals in Θ (where Θ represents the universe of feasible θ values) are withheld. Given a profile of strategies $\{I'_1, \gamma', D\}$, let $\theta_N = \frac{[1-G(\gamma')]\mu + G(\gamma') \int_{\theta \notin D} \theta f(\theta) d\theta}{[1-G(\gamma')] + G(\gamma') \int_{\theta \notin D} f(\theta) d\theta}$. That is, θ_N represents the best estimate of θ in light of non disclosure. Thus, the optimal follow-up investment I_2 given no disclosure equals $k\theta_N$.

Denote the entrepreneur's net expected payoff for the arbitrary profile of strategies $\{I'_1, \gamma', D\}$ by $\pi(I'_1, \gamma', D)$, so that $\pi(I'_1, \gamma', D) = E[P(I'_1, \gamma', D)] - \frac{[I'_1]^2}{2} - \int_0^{\gamma'} \gamma g(\gamma) d\gamma$.

Expanding the entrepreneur's payoff function π , we have:

$$\begin{aligned} \pi(I'_1, \gamma', D) &= I'_1 \mu - \frac{[I'_1]^2}{2} - \int_0^{\gamma'} \gamma g(\gamma) d\gamma + G(\gamma') \int_{\theta \in D} \frac{k^2}{2} \theta^2 f(\theta) d\theta + \\ &G(\gamma') \int_{\theta \notin D} \left\{ k\theta [k\theta_N] - \frac{k^2 \theta_N^2}{2} \right\} f(\theta) d\theta + [1 - G(\gamma')] \int_0^{\infty} \left\{ k\theta [k\theta_N] - \frac{k^2 \theta_N^2}{2} \right\} f(\theta) d\theta. \end{aligned}$$

Noting that the value of I_2 that maximizes the function $k\theta I_2 - \frac{I_2^2}{2}$ is $I_2 = k\theta$, it follows:

$$\begin{aligned} \int_{\theta \notin D} \left\{ k\theta [k\theta] - \frac{k^2 \theta^2}{2} \right\} f(\theta) d\theta &> \int_{\theta \notin D} \left\{ k\theta [k\theta_N] - \frac{k^2 \theta_N^2}{2} \right\} f(\theta) d\theta; \text{ and} \\ \int_0^{\infty} \left\{ k\theta [k\mu] - \frac{k^2 \mu^2}{2} \right\} f(\theta) d\theta &> \int_0^{\infty} \left\{ k\theta [k\theta_N] - \frac{k^2 \theta_N^2}{2} \right\} f(\theta) d\theta. \end{aligned}$$

Applying the above inequalities to the expression for $\pi(I'_1, \gamma', D)$ yields:

$$\pi(I'_1, \gamma', \Theta) > \pi(I'_1, \gamma', D) \text{ for all } I'_1, \gamma', D \neq \Theta.$$

Thus, full disclosure of information is optimal.

Having established the optimal disclosure policy, the optimal γ^* and I_1^* follow immediately

from first order conditions of the following maximization problem:

$$\gamma^*, I_1^* \in \arg \max_{\gamma', I_1'} \pi(I_1', \gamma', \Theta).$$

Proof of Proposition 2:

For a given investment level I_1 , expression (10) can be rewritten as (at $q = \hat{q}$):

$$\hat{\gamma} = \int_{\hat{\theta}}^{\infty} I_1 [\theta - \hat{\theta}] f(\theta) d\theta + \frac{k^2 \sigma^2}{2} + \frac{k^2}{2} \int_0^{\hat{\theta}} [\mu^2 - \theta^2] f(\theta) d\theta + \frac{k^2}{2} \int_{\hat{\theta}}^{\infty} [\mu^2 - \hat{\theta}^2] f(\theta) d\theta.$$

Since $\mu > \hat{\theta}$ (follows from (6)), the third and fourth terms in the above expression are positive. The first term is obviously positive. Thus,

$$\hat{\gamma} > \frac{k^2 \sigma^2}{2} = \gamma^*, \text{ completing the proof.}$$

Proof of Proposition 3:

Differentiating expression (10) (at $q = \hat{q}$) with respect to I_1 yields (after applying Leibniz integral rule):

$$\frac{d\hat{\gamma}}{dI_1} = \int_{\hat{\theta}}^{\infty} [\theta - \hat{\theta}] f(\theta) d\theta > 0, \text{ establishing the proof.}$$

Proof of Proposition 4:

The proof follows from solving (13) for I_1 and comparing with I_1^* (recall $I_1^* = \mu$ from Proposition 1).

Proof of Proposition 5:

The expression for $\hat{\theta}$ follows from (6) and (11). The expression for $\hat{\gamma}$ follows from (10). The expression for \hat{I}_1 is obtained by solving (13) for I_1 .

Next, we establish uniqueness. Clearly, the LHS of (11) is increasing in q . Further, from (10), $\hat{\gamma}(q)$ is increasing in q and, hence, the RHS of (11) is also increasing in q . Additionally, at $q = 0$, LHS of (11) < RHS of (11) while, at $q = 1$, LHS of (11) > RHS of (11). With

G a strictly increasing function, it therefore follows that there exists exactly one root for equation (11). That $\hat{\theta}$ is unique follows from the observation that the RHS of expression (6) decreases in $\hat{\theta}$ and the LHS increases in $\hat{\theta}$. Given a unique $\hat{\theta}$ and \hat{q} , uniqueness of $\hat{\gamma}$ and \hat{I}_1 simply follow from the expressions derived in the proposition.

Proof of the Corollary:

Substituting $k = 0$, $\theta \sim U(0, \bar{\theta})$, and $\gamma \sim U(0, \bar{\gamma})$ into Proposition 5 leads to the results presented in the Corollary.

Proof of Proposition 6:

(i) When full disclosure is mandated, the residual problem becomes identical to that in Proposition 1. That is, the entrepreneur's maximization problem is to pick $\{\hat{I}_1, \hat{\gamma}\}$ to maximize $\pi(\hat{I}_1, \hat{\gamma}, \Theta)$. Thus, the investment and information acquisition strategies are the same as those in Proposition 1.

(ii) When disclosure is prohibited, naturally, no information acquisition occurs. Then, the entrepreneur's investment decision reduces to picking the level of investment that maximizes $\mu I_1 - I_1^2/2$. The solution is $I_1 = \mu$. It is easy to see that when $k = 0$, such regulation enhances the entrepreneur's net expected payoff. Through a continuity argument, the result extends to sufficiently small values of k .

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