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Synergy between Accounting Disclosures and Forward-Looking Information in Stock Prices

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ABSTRACT: It is well recognized that stock prices provide relevant feedback that can guide future firm decisions. This paper develops a model to examine how accounting disclosures affect the decision-usefulness of such stock market reactions. We demonstrate that information in accounting reports can prove useful because it helps observers better interpret and isolate the decision-relevant information embedded in the ensuing stock price reaction. This leads to natural synergies between accounting reports and stock prices in directing firm strategies—the more forward-looking information that can potentially be gleaned from stock prices, the more the firm will invest in improving precision of accounting disclosures even when such disclosures pertain to unrelated current activities.

Keywords: disclosure; reporting quality; stock market feedback.

I. INTRODUCTION

An emerging body of work provides evidence that information contained in stock prices can guide decision making in firms. In particular, studies consistently show that timely forward-looking information in stock prices provides feedback for managerial actions ranging from mergers and acquisitions to marketing strategies to project selection to day-to-day investment choices (e.g., Dye and Sridhar 2002; Luo 2005; Markovitch, Steckel, and Yeung 2005). Although the importance of such stock market feedback is well recognized, not enough is understood in terms of the firm's own role in facilitating this process. In this paper, we consider the role of the firm's accounting disclosure policy in promoting stock price guidance. Specifically, we examine the impact of accounting reports on the usefulness of stock market feedback in light of the fact that accounting reports typically provide public information only about profits from existing operations. Our study shows that even if accounting reports of current ventures have no predictive power for future decisions, such reports can prove critical because they help observers better interpret and isolate the decision-relevant information embedded in the ensuing stock price reaction. This ability to promote learning from stock prices impacts the firm's preferred accounting system choice in the first place.

To provide a concrete example, consider a firm that has just developed a new product. The firm's stock price can contain useful information to guide deployment of the new product, for it can reflect prospective users' tastes for and assessments of the new product. An accounting report on the firm's existing ventures, although not directly relevant to future decisions, helps discern the extent to which the market valuation reflects information about past versus future products. This benefit of the accounting report is two-fold. First, disclosure of the accounting report reduces some market-level uncertainty about current ventures. Consequently, any residual volatility in the firm's stock price can be more precisely attributed to the market's assessment of the new venture's efficacy. Second, as the firm expands its disclosures, stock price becomes a less noisy aggregator of firm value. This further improves the ability to read from stock price the market's pulse for the new product, thus facilitating future marketing and production decisions for the new product. It is worth emphasizing that information about past

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performance is useful in this example in guiding the future not due to the principle that past is prologue; rather, it is due to the report's ability to disentangle confounding information embedded in stock price.

Formally, we model a firm that develops a new technology whose prospects are uncertain. The firm issues an accounting report that reflects the profitability of the firm's existing ventures. The precision of this report is tied to the firm's up-front investment in the quality of its accounting system. The firm's underlying value consists of both the profits from its existing ventures and the potential profits from the newly developed technology. To examine market pricing of such value when participants may hold value-relevant information, we employ a variant of the canonical informed trader specification of Kyle (1985). Once the stock market values the firm, a decision on how to employ the new technology is made after taking into account the implicit feedback contained in the stock price.

Although the setting is one where the accounting report only provides information about past performance—not future decisions—our main result demonstrates that as the precision of the accounting report improves, more information about the new technology can be obtained from stock price for future decisions. This complementarity between the accounting report and stock price arises due to the report's ability to parse out confounding information from stock price. To elaborate, since stock price is a noisy aggregator of the firm's fundamental value, the extent to which the price proves decision-relevant to employing the new technology is affected by (1) the volatility in stock price attributable to the existing (rather than the new) technologies, and (2) the degree of uncertainty or noise in stock price introduced by the trading process. The information contained in the accounting report improves decisions by helping with regard to (1) in that a report about current technologies makes it easier to tease out such information from stock price. The second, subtler benefit comes from the accounting report being public. Issuing the report publicly erodes the informed trader's private information, giving her less ammunition to distort stock price away from its true value. This helps with regard to (2) in that it makes stock price a less noisy reflection of true firm value. As a corollary, while accounting information can prove useful when conveyed privately to a decision maker, it is more useful when all market participants are aware of it. In effect, accounting reports not only help interpret the information in stock price, but also critically alter that information. Having identified this important feature, we also demonstrate that the efficacy of (and, thus, the preferred investment in) the accounting system is inextricably tied to its public nature.

We provide several additional insights. We demonstrate whether the firm retains decision-making authority over future technology development or outsources it to a third party (e.g., a software firm relying on a hardware partner to implement its new technology), the importance of accounting reports in guiding future decisions prevails. That is, what is vital is that stock price reactions inform decisions, and not which party retains decision-making authority. Additionally, when a third party is involved in implementation, the firm's preferred disclosure precision is greater when the firm's bargaining power (*vis-à-vis* the third party) is greater. We also address how initial (primary) market value of the firm is influenced by accounting choice in light of the fact that the accounting information can alter both subsequent decisions and the losses liquidity traders face. Not only do we find that the key results persist, but also show that greater concern about losses from liquidity shocks further promotes investment in accounting precision. Finally, we reexamine the demand for accounting reports in the presence of other forward-looking information sources. While confirming that forward-looking information serves as a substitute for accounting reports in guiding decisions, we demonstrate a continuing role for reporting even when it is decidedly about past choices.

The rest of the paper is organized as follows. Section II reviews related literature and highlights the study's contributions. Section III models the economic setting. Section IV presents the main analysis, describing the impact of disclosures about existing activities on learning about the prospects of new ones. Section V details additional considerations. Section VI concludes.

II. RELATED LITERATURE

The idea that stock prices aggregate diffuse investor information is well recognized (e.g., Fama 1976; Kyle 1985). More recent work shows how market participants and firm management can learn from informative stock prices and incorporate the received feedback in decision making. In line with such thinking, Dow and Gorton (1997) and Dye and Sridhar (2002) formally examine the mechanics of how information contained in stock prices can guide subsequent managerial decisions. Subrahmanyam and Titman (1999) argue that stock market feedback can be a sufficiently powerful impetus for even the firm's decision to go public or maintain its private status. Luo (2005) provides evidence of managerial learning from stock prices in the context of mergers and acquisitions: when a firm proposes a merger and the stock market reaction to the announcement is adverse, the manager cancels the deal. The influence of stock prices on a firm's investment decisions is studied by Chen, Goldstein, and Jiang (2007). Using market microstructure measures of private information, this study establishes sensitivity of subsequent investment decisions to stock price feedback. Similar findings are provided by, among others, Kau, Linck, and Rubin (2008) and Bakke and Whited (2010). Markovitch et al. (2005) establish that firms' marketing decisions are often guided by stock market feedback. For a comprehensive survey of the emerging field on the feedback effect of stock prices, see Bond, Edmans, and Goldstein (2012).

Given the usefulness of stock market feedback, a natural next step is in understanding the firm's own role in eliciting such feedback. With this as focus, Kumar, Langberg, and Sivaramakrishnan (2012) find that the stock price feedback effect on finetuning the firm's investment decision forces managers to disclose bad news, in addition to the favorable news that they otherwise prefer to disclose. In a similar vein of promoting efficiency of investments, Langberg and Sivaramakrishnan (2010) show that a manager desirous of eliciting feedback from analysts is willing to disclose negative news and take a temporary hit to the firm's stock price. In these studies, the firm's disclosed information is forward-looking and, thus, has a direct bearing on future investment decisions. In contrast, our study considers the impact of disclosing current information with a focus on disentangling and refining the feedback provided by the stock market.

The above is not to say that better firm disclosures are always linked to improved real decisions. Gao and Liang (2013) demonstrate that disclosure discourages information gathering by equity traders, and this crowding out of private information production naturally thwarts information feedback from stock prices. Goldstein and Yang (2014), too, highlight the consequences of disclosure on price informativeness by considering a model in which two uncertain components multiplicatively influence the profit from a future decision. In their setting, both components are decision-relevant and the difference between the two pieces is the extent to which decision makers hold private information about them. They demonstrate that public disclosure that focuses on the less known (more known) component may prove harmful (helpful) in generating price-based information about the less known component. In a related vein, Ramanan (2015) stresses how timely accounting can be detrimental, since the ensuing market reaction is on multiple pieces making untangling problematic. In contrast to these studies, we show that "better" accounting disclosure can unequivocally increase the decision-usefulness of stock prices. The distinguishing feature giving rise to this effect is that disclosures pertain to existing, rather than forward-looking, performance and are, thus, not directly decision-relevant. In other words, multiple interacting uncertainty dimensions or multiple opportunities for spreading disclosure are not issues herein, yet accounting reports still stand to influence decision making tied to price, and do so to improve efficiency: by disclosing about existing ventures and "clearing the air," the firm makes it easier to sift out information in equity price about an unrelated component of firm value (new ventures).

Finally, our results complement those in Gigler and Hemmer (1998) and Gigler and Jiang (2011) that demonstrate the confirmatory role of accounting in disciplining forward-looking reports. In our setting, the forward-looking information is naturally embedded in the stock price, and the role of accounting manifests itself in governing the information environment that surrounds trading that generates the stock price.

III. MODEL

A firm has a portfolio of existing business ventures that yields terminal payoff (cash flow) of $\tilde{x}$, $\tilde{x} \sim N\left(\mu_x, \frac{1}{h_x}\right)$. Also, the firm is developing a new technology that it can use internally, as well as license for external use (say, e.g., a touch screen-based operating system). The new technology will increase firm profitability by $\tilde{y}$, $\tilde{y} \sim N\left(\mu_y, \frac{1}{h_y}\right)$, where $\tilde{y}$ can be viewed as a measure of consumer taste or demand for the new technology. Profit from the new technology may reflect, for example, product adoption by existing customers seeking an upgrade. To fully exploit the new technology, the firm also sells rights to use it to a third-party manufacturer (e.g., a hardware manufacturer is given the rights to build and sell tablets around the new operating system) for a mutually agreed price, T. In particular, this transfer payment is determined based on the familiar (generalized) Nash bargaining process between the firm and manufacturer, with $\alpha \in (0,1]$ denoting the firm's bargaining power. The manufacturer can employ the technology to make q units of a new product, the marginal cost of which is normalized to zero. The market price p for this product is given by the standard downward sloping (inverse) demand function $p = \omega\tilde{y} - \frac{\gamma}{2}q$, with $\omega, \gamma > 0$. Naturally, the payoff from this new product is tied to customers' taste or demand for the underlying technology, as reflected in y affecting the demand intercept. The manufacturer's goal is to maximize its expected revenue pq net of cost T.

Although a firm's accounting disclosures are not geared to convey if a newly developed technology will succeed in the future, they typically do provide information pertaining to profitability of existing product lines. In this regard, assume that, up-front, the firm establishes an accounting system of precision h to generate a publicly observed accounting report of x, where the report, r, is $r = x + \tilde{\varepsilon}$ with $\tilde{\varepsilon} \sim N\left(0, \frac{1}{h}\right)$. To reflect the fact that more precise accounting estimates are costly to generate and credibly convey, let the accounting system's cost be $c(h)$, which satisfies standard regularity assumptions $c'(h) \geq 0$, $c''(h) > 0$, $c'(0) = 0$, and $\lim_{h\to\infty} c'(h) \to \infty$.

Of course, accounting reports are not the only source of information about the firm. The stock market aggregates all information about the firm, including forward-looking information about the prospects of the newly introduced technology. Formally, we model this aspect of the stock market by presuming an informed individual privately observes x and y based on her ability to be an astute evaluator of different aspects of firm value.[1] Following Kyle (1985), the firm's equity market consists of this (risk-neutral) informed trader, some liquidity traders, and a risk-neutral market maker who sets the price. Based on her private information, the informed trader places a market order $z \equiv z\,(x, y, r; h)$ for the firm's shares. Her order is designed to

[1] The model is readily extended to multiple informed traders, each of whom has a (possibly imperfect) signal of x and y. Extending the model in this fashion does not alter the primary conclusions.

maximize her expected trading profits at the expense of liquidity traders. Let $\tilde{u} \sim N(0,\ \sigma_u^2)$ denote the quantity demanded by the liquidity traders, with u uncorrelated to all other variables in the model. A market maker observes the aggregate order flow $f = z + u$ for the firm's shares; based on the order flow f and the publicly available report r, he sets price P to break even in expectation and provides the liquidity necessary to clear the market.

The precision h of the information system is chosen to maximize expected firm value, where firm value is given by $V = x + y - c(h) + T(h)$. Here, the function $T(h)$ recognizes that the value of the new technology and, thus, the transfer payment may be affected by the firm's disclosure policy.

The question we ask in this setting is how disclosures about current activities can influence the way in which market prices can inform future decisions. As such, the sequence necessarily (and optimally) entails the manufacturer delaying its production choice until after the firm's stock price is determined. Notice that since the firm's disclosure (report r) is only on existing ventures (x), and provides no information on the profitability of the new technology (y), the technology transfer to the manufacturer can occur either before or after the report. That is, as long as the sale to the manufacturer occurs prior to the equity market price being set, the timing of sale to the manufacturer does not impact the terms of the sale. Of course, if the transfer occurs after the price is set or, equivalently, if the firm itself were to implement the proposed productive decision, the familiar problem of circularity results. That is, when the stock price emerges as a function of a prospective productive decision that, in turn, depends on the stock price itself, standard pricing models lose tractability (for a detailed discussion of this issue, see Subrahmanyam and Titman [1999]). As in Ramanan (2015), our model overcomes this technical issue by considering a setting in which the firm utilizes a third party to make the future productive decision. This permits the third party to take full advantage of the information feedback from the firm's stock price, while allowing the expected benefits of such feedback on future decisions to be fully recognized in the contract. And since the contract is priced prior to the stock market's clearing, the contract's value remains a constant in subsequent market valuation of the firm and, thus, permits a fixed point in market pricing. (We examine an alternative modeling approach to this feedback problem in Section V.)

This completes the description of the model. The sequence of events is summarized by the timeline in Figure 1.

IV. DISCLOSURE POLICY

The key focus of this analysis is on how disclosures about existing activities can facilitate learning about a new and independent technology and, consequently, improve its use and profitability. To this end, we first examine the effects of a given disclosure on the equity market equilibrium; next, we study implications of this equilibrium for the use of the new technology; we then step back to endogenize the firm's optimal disclosure policy; the final subsection emphasizes the criticality of the public nature of disclosures by contrasting the outcome with that obtained under private communication.

Equity Market Equilibrium

The ideal number of units of the new product to manufacture is critically tied to the prospects of the new technology. Useful information on this front can be obtained from the stock market's reaction. The issue of interest in this study is whether and how the firm's report r can facilitate this feedback from the stock market. Recall that report r pertains to the firm's existing technology and not to the new technology. On the face of it, such information is not particularly useful as no decisions are contingent on it. However, before reaching such a conclusion, it is important to recognize that report r and stock price P interact, because of which report r can prove useful to the manufacturer in deciphering the prospects of the new technology from stock price P. Thus, as a first step, we simply note how the firm's disclosure impacts the equity market equilibrium. (All proofs are detailed in Appendix A.)

Proposition 1: Given reporting precision h, the equity market equilibrium for a report r is described by:

$z = \frac{\psi_x + \psi_y}{2\lambda}$ and $P = E[V|r;\ h] + \lambda f$, where

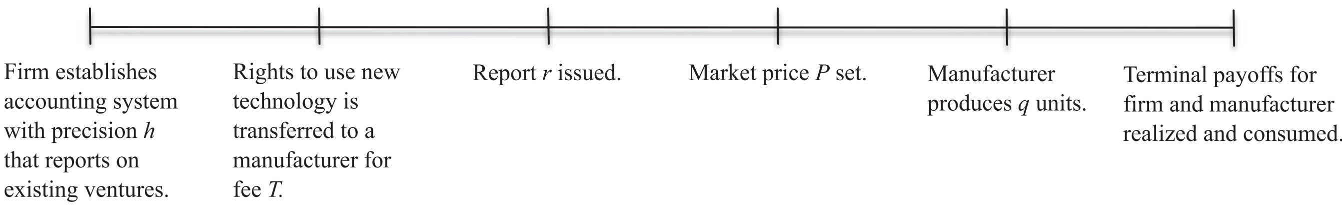
$\psi_x = \frac{h\ [x-r] + h_x\ [x-\mu_x]}{h+h_x}$, $\psi_y = [y - \mu_y]$, and

$\lambda^2 = \frac{1}{4\sigma_u^2}[var(\psi_x) + var(\psi_y)]$ with

$var(\psi_x) = \frac{1}{h+h_x}$ and $var(\psi_y) = \frac{1}{h_y}$.

To see how the equity market equilibrium comes about, consider first the incentives of the informed trader. Given just the report r under policy h, the market maker's best guess of firm value is $E[V|r; h] = \frac{h\ r + h_x\ \mu_x}{h+h_x} + \mu_y - c(h) + T(h)$. The informed investor has better knowledge of the firm's underlying value, allowing her to value the firm at $x + y - c(h) + T(h)$. The difference in their valuation is $x - \frac{h\ r + h_x\ \mu_x}{h+h_x} + y - \mu_y = \psi_x + \psi_y$; thus, ψ_x and ψ_y reflect the informed trader's advantage in valuing the existing and new technologies of the firm, respectively. Clearly, the greater the difference in these valuations, the

Figure 1
Timeline



more the informed investor benefits from trading. What prevents the informed trader from exploiting such arbitrage by buying (or when $\psi_x + \psi_y$ is negative, selling) infinitely many shares is that the market maker's pricing function adjusts price based on order flow, reflected in $\lambda > 0$. Thus, the informed trader seeks to balance the number of shares traded at arbitrage pricing with the per-unit profitability from such trades, since greater trading shrinks the wedge between price and fundamental value. These offsetting priorities are reflected in the fact that order flow is increasing in $\psi_x + \psi_y$, the difference of perceived value between the informed investor and the market maker, and compressed by λ, the sensitivity of stock price to order flow.

The market maker's pricing function reflects publicly available information $E[V|r;\, h]$ adjusted for the order flow f. Given the linear equilibrium and normal distributions, the optimal weight on the order flow is simply the least squares weight, $\lambda = cov(V, f)/var(f)$, which simplifies to the expression in the proposition. This least squares weight effectively scales the order flow to minimize the losses the market maker suffers in trading with the informed trader. Thus: (i) the greater the informed trader's advantage in trading, the more the market maker weights the order flow, i.e., λ increases in $var(\psi_x) + var(\psi_y)$; and (ii) the more the liquidity trading, the less trade fluctuations reflect informed trader activity, and the less he needs to protect himself, i.e., λ decreases in σ_u^2.

Given our focus on extracting forward looking information from an aggregate measure such as stock price, it is important to identify the different pieces of information incorporated in it. The following proposition helps to do that.

Proposition 2: The stock price can be re-expressed as $P = E[V|r;h] + \frac{1}{2}[\psi_x + \psi_y + \delta]$, where $\delta \sim N\Big(0, var(\psi_x) + var(\psi_y)\Big)$ is noise uncorrelated with V, r, ψ_x, or ψ_y.

The stock price consists of two components: $E[V|r;\, h]$ reflects the publicly available information, and $\frac{1}{2}[\psi_x + \psi_y + \delta]$ reflects the information uncovered through equity trading. Trading reveals information about y, the viability of the new technology (via ψ_y). How much can be learned about y from observing P, in turn, depends on information about other aspects of the firm (ψ_x) and noise introduced by the trading process (δ).

From Proposition 2, $var(\psi_x) + var(\psi_y) = var(\delta)$. In effect, although liquidity trading is independent of the informed investor's informational advantage, the volatility in stock price due to liquidity trading, i.e., $var(\delta)$, is proportional to the degree of the informed investor's informational advantage. This is because the impact of liquidity trading on stock price is directly tied to λ, the sensitivity of stock price to order flow. As already indicated in Proposition 1, as the trader's informational advantage increases, λ increases correspondingly, and this allows liquidity trading to have a bigger impact on stock price.

Having identified how information is ultimately reflected in stock price, we next examine how this information influences the efficient use of the new technology and how that, in turn, affects valuation.

Exploiting the New Technology

The manufacturer of the new product faces a decision about how widely to make use of the firm's technology, particularly given uncertainty about its efficacy. This is a nontrivial decision because the manufacturer faces diminishing marginal returns from its production. In particular, its manufacturing decision based on observing the firm's disclosures and market price is:

$$\underset{q}{Max}\; E[pq|r, P; h] - T(h) \equiv E\Big[\Big(\omega\tilde{y} - \frac{\gamma}{2}q\Big)q|r, P; h\Big] - T(h).$$

Solving, its implementation choice yields:

$$q(r, P; h) = \frac{\omega}{\gamma}E[y|r, P; h],\ \text{or}\ q(r, P; h) = \frac{\omega}{\gamma}\left[\mu_y + \frac{h + h_x}{h + h_x + h_y}(P - E[V|r; h])\right].$$

Intuitively, when the new technology's prospects are great, the stock price reflects such optimism. Taking its cue from the positive market response, the manufacturer makes more use of the new technology, as reflected in q increasing in P.

In this setting, the question about how useful accounting disclosures are is tied to their real effects, i.e., how they influence decision making. Here, the manufacturer's implementation choice represents such a critical decision. And while the accounting report itself is not directly relevant to that choice (report r relates to existing technologies x), it can alter the extent to which market price is relevant to that choice. To see the role of accounting most clearly, note that the sensitivity of q to stock price P increases in accounting precision, i.e., $\frac{\partial}{\partial h}\left[\frac{dq(r,P;h)}{dP}\right] = \frac{\omega h_y}{\gamma[h+h_x+h_y]^2} > 0$. In other words, the more precise the accounting report on existing technologies, the more precise the manufacturer's information about the new technology; this despite the presumption that the two technologies are independent. This conclusion is confirmed by the following proposition.

Proposition 3: Greater precision in the accounting report of x results in greater precision in the manufacturer's estimate of y, i.e., $var(y|r, P;\, h)$ decreases in h.

Before examining how the connection between accounting precision and decision-usefulness of stock prices translates to firm value, some explanation for how reporting precision boosts the usefulness of stock price is in order. Recall that the accounting report does not directly convey anything about y, the new technology. Rather, it changes the information conveyed by stock price in two ways. First, since price (imperfectly) reflects private information about $x + y$, greater disclosures of x make it easier for the manufacturer to extract the y-portion of such $x + y$ information contained in price. A second, more subtle effect is that greater disclosures of x actually enhance the degree to which price reflects private information. That is, as disclosures of x improve, each informed trader's information advantage about the value of the firm is reduced. This reduction means that the market maker is at less risk of being exploited by the orders of the informed investor and so reduces λ, the consequences of order flow for stock price. The ultimate result is that stock price embeds less noise δ and is, therefore, more informative. This two-pronged information benefit of improving accounting precision is confirmed in the following corollary.

Corollary: Greater precision in the accounting report of x:

(a) reduces the amount of confounding information in price about existing technologies, i.e., $var(\psi_x)$ decreases in h, and
(b) reduces the amount of noise in stock price introduced by the trading process, i.e., $var(\delta)$ decreases in h.

Clearly, both forces in the corollary work in concert to improve the manufacturer's learning about the efficacy of the new technology. Given the predictable effect of disclosure precision on the manufacturer's ability to employ the new technology efficiently, the expected surplus from the new technology, denoted $\Pi(h)$, can be computed at the negotiation stage as follows:

$$\begin{aligned}\Pi(h) &= E_{r,P}\left[E\left[\left(\omega\tilde{y} - \frac{\gamma}{2}q(r,P;h)\right)q(r,P;h)|r,P;h\right]\right]\\ &= \frac{\omega^2}{2\gamma}\left[\mu_y^2 + \frac{1}{h_y} - var(y|r,P;h)\right]\\ &= \frac{\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h+h_x}{2h_y[h+h_x+h_y]}\right]. \end{aligned} \tag{1}$$

The transfer payment $T(h)$ depends on how the two parties agree to split this expected surplus. As alluded to in Section III, we envisage the familiar Nash bargaining process. In the event of successful bargaining, the firm's expected payoff is $\mu_x + \mu_y - c(h) + T(h)$ and the manufacturer's expected payoff is $\Pi(h) - T(h)$. Their *status quo* payoffs corresponding to failed bargaining (the disagreement point) are $\mu_x + \mu_y - c(h)$ and 0, respectively. Thus, the bargaining process characterized by α being the seller's bargaining power maximizes the following (generalized) Nash product:

$$\underset{T(h)}{Max}\ [T(h)]^{\alpha}\,[\Pi(h) - T(h)]^{1-\alpha}.$$

The above problem yields the following transfer payment:

$$T(h) = \alpha\,\Pi(h). \tag{2}$$

As can be expected, an information environment that cultivates more confident and circumstance-contingent usage of the new technology by the manufacturer translates into a higher willingness to pay and, thus, a higher transfer payment.

Having established how accounting precision relates to the transfer payment, we next consider the firm's optimal accounting choice.

Preferred Accounting Precision

Using $T(h)$, the firm's benefit from the new technology derived previously, the firm's expected value at the time accounting precision gets chosen is:

$$E[V] = \mu_x + \mu_y - c(h) + T(h). \tag{3}$$

Using $T(h)$ from (2) and, in turn, $\Pi(h)$ from (1), the first-order condition of (3) reveals the unique value-maximizing accounting precision, as identified in the next proposition.

Proposition 4: The firm's optimal choice of accounting precision, h^*, is the unique positive h-value that solves:

$$[h + h_x + h_y]^2\, c'(h) = \frac{\alpha\omega^2}{4\gamma}.$$

Intuitively, the proposition details the trade-offs in choosing accounting policy. Greater precision is costly, but can also boost the benefits of the new technology and, thus, its profitability to the firm. The nature of this trade-off is governed by how much of the benefits of the new technology the firm can extract (α), how important the technology commercialization is (ω), how much uncertainty there is about the technology's value (h_y), and how much uncertainty there is about the firm's other endeavors (h_x). In particular, the more potential information that can be gleaned from price (lower h_x and/or h_y) and the greater the potential benefit from revealing that information (higher α and/or ω), the more precise the optimal accounting report. As the next proposition confirms, each of these factors not only influences accounting policy, but also affects firm value in a clear manner. In writing this proposition, we let $E[V^*]$ denote the expected firm value at the optimal accounting precision level, i.e., $E[V^*] = \mu_x + \mu_y - c(h^*) + T(h^*)$.

Proposition 5:

(a) The firm's optimal precision level h^* increases with its bargaining power α and with the importance ω of the new technology, and decreases with precisions h_x and h_y, i.e., $\frac{dh^*}{d\alpha} > 0$, $\frac{dh^*}{d\omega} > 0$, $\frac{dh^*}{dh_x} < 0$, and $\frac{dh^*}{dh_y} < 0$.

(b) The expected firm value $E[V^*]$ increases with α, ω, and h_x, and decreases with h_y, i.e., $\frac{dE[V^*]}{d\alpha} > 0$, $\frac{dE[V^*]}{d\omega} > 0$, $\frac{dE[V^*]}{dh_x} > 0$, and $\frac{dE[V^*]}{dh_y} < 0$.

From the proposition, notice that not only is the desirability of a more precise accounting report closely tied to the degree to which disclosure can boost efficiency in the use of the new technology, but so is the firm's value. This value manifests itself along two dimensions.

First, the more the firm stands to benefit from the new technology's usefulness, the more it can gain from information enhancing its effective use. This is reflected in value increasing in bargaining power (α) and commercialization potential (ω). It is also reflected in the fact that firm value is decreasing in h_y—given the convex payoffs from the technology, the manufacturer benefits from a high-variance hit-or-miss technology, provided it is able to judiciously employ the technology with the right information.

This leads to the second dimension: the more potential learning the manufacturer can glean from market price, the greater the value of the technology. This second feature is reflected in value increasing in h_x—the less confounding information in price that pertains to current ventures, the more the manufacturer can glean decision-relevant information from stock price.

The analysis in this section considers the disclosure policy that maximizes long-term firm value. Alternately, one could have conducted the same analysis with a manager who fixates on stock price and, thus, seeks to maximize the expected value of P. It is comforting to note that such a manager's accounting choice is identical to the h^* in Proposition 4. Since the objective of the current disclosure policy is to improve the informativeness of stock price, the benefits of the firm's disclosure are fully recognized in the firm's stock price and, thus, the chosen accounting precision is equally effective in both the short term and the long term.

Public Disclosure versus Private Dissemination

Recall that the emphasis in this study is on how public accounting reports of current business can help intensify the decision-usefulness of private information embedded in equity prices. While the analysis thus far focuses on the information content in the accounting report, we now consider the importance of the report being publicly disseminated.

After all, if the objective of learning r is simply for the manufacturer to tease out information pertaining to current technologies from stock price, then can the same objective not be met by the firm privately communicating the information to the manufacturer? Or can it even help to keep strategic market participants in the dark about performance to maximize information in stock price?

The following proposition indicates that the public disclosure of report r brings informational value beyond that of just the information contained in it. (We use a ^ to represent the outcome in the private communication setting to distinguish it from the public communication modeled thus far.)

Proposition 6: Public disclosure of the accounting report of x results in greater precision in the manufacturer's estimate of y, i.e., $var(y|r,P;h) < var(y|r,\hat{P};h)$.

There are two aspects to the firm's report—the information contained in it and the public nature of its dissemination. Each has a role to play. Recall from the corollary to Proposition 3 that the benefit of disclosure in boosting the decision-usefulness of equity prices is two-fold: (i) it allows the manufacturer to tease out confounding information pertaining to the existing technology from the prevailing price; and (ii) it further improves informativeness of stock price by reducing the noise content.

The information revealed in the report leads to (i) and, thus, private communication of the accounting information achieves (i). However, it is the public nature of the report's dissemination that leads to (ii). To get a feel for why this is the case, note that disclosing the report publicly curtails the informed investor's informational advantage. Consequently, and as already discussed in Proposition 2, noise content in stock price goes down. This important effect on stock price cannot be achieved when the report is privately observed by the manufacturer.

That the report is less valuable when communicated privately than when disseminated publicly has wider ramifications on the firm's accounting policy choice. To examine these additional consequences, we repeat the main analysis as before, assuming that the accounting report is privately disseminated (only to the manufacturer) in time for the production decision q. The following proposition summarizes the results.

Proposition 7: In the private communication setting:

(a) The firm acquires and communicates less information, i.e., $\hat{h}^* < h^*$, where $\hat{h}^*$ is the unique h-value that solves:

$$2[h + h_x + h_y + \frac{h\, h_y}{2h_x}]^2 c'(h) = \frac{\alpha\omega^2}{4\gamma}.$$

(b) Expected firm value is lower relative to the public disclosure setting, i.e., $E[\hat{V}^*] < E[V^*]$, where:

$$E[\hat{V}^*] = \mu_x + \mu_y - c(\hat{h}^*) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{\hat{h}^* + h_x}{2h_y\left[\hat{h}^* + h_x + h_y + \frac{\hat{h}^*\, h_y}{2h_x}\right]}\right].$$

Not only does private dissemination affect the informational value of a given accounting report, but it also influences the precision of the report in the first place. The smaller benefit from the private report adversely influences the firm's investment in its accounting system. This manifests as a report of lower precision $\hat{h}^*$, which, in turn, depresses both the value of the technology and the benefits the firm can derive from it.

V. ADDITIONAL CONSIDERATIONS

The previous section demonstrates that public disclosures about existing operations can help extract actionable forward-looking information from stock price about a new product and that this feature, in turn, impacts the design of the preferred accounting information system. This section examines additional modeling considerations that inform when the results are most likely to arise, as well as identify related characteristics that further fine-tune the accounting system.[2] In particular, we (i) step back to address how trading in a primary market impacts the chosen precision of the accounting system; (ii) analyze an alternative formulation wherein the firm retains decision authority over the new technology; and (iii) examine the consequences for the accounting system when an additional information source that directly provides forward-looking information (e.g., forecasts) is also available.

[2] We thank the referees for suggesting the issues in this section.

Reporting Precision and Primary Market Valuation

The focus thus far is on how the existence of a (secondary) trading market with an informed investor can influence decisions, and how accounting reports on current operations can facilitate inferences that are drawn from the stock price. In doing so, we presume that the preferred accounting system is one that maximizes the expected trading price of the firm (i.e., expected firm value), aware that the interactions between the informed trader and liquidity traders result in a zero-sum game, with the market maker breaking even in expectation.

However, given that the accounting system is established at the onset of the game, one may ask how the precision choice is impacted if an initial round of trading takes place in a (primary) market with investors on an equal information footing, each of whom may subsequently face liquidity shocks. Of course, rational investors would only participate in this market if they are compensated for expected losses in subsequent trading with better-informed individuals. The primary market valuation of the firm reflects this consideration, and the impact on the choice of accounting precision is analyzed herein.

Formally, we introduce a primary market that trades after the firm sets the disclosure policy. This market is populated by rational investors who collectively expect to experience subsequent liquidity shocks drawn from the distribution $N(0, \sigma_u^2)$ that would force them to trade in the secondary market in the future. Firm value in the primary market will, thus, reflect expected secondary market value, discounted for investors' expected trading losses. The rest of the model remains the same as in Section III.

For a given σ_u, we now derive the firm's disclosure policy $h^*(\sigma_u)$ that maximizes the firm value in the primary market. Denote the expected trading gains of the informed trader in the secondary market and, thus, the expected loss of liquidity traders by $L(\sigma_u)$:

$$L(\sigma_u) = E[(V - P)z|r;\ h].$$

Substituting appropriate values from Proposition 1 and simplifying, we obtain:

$$L(\sigma_u) = \frac{1}{4\lambda}[var(\psi_x) + var(\psi_y)] = \frac{\sigma_u}{2}\sqrt{\frac{h + h_x + h_y}{[h + h_x]h_y}}. \tag{4}$$

Since the traded firm value in the primary market reflects this expected loss from liquidity trading, the chosen accounting precision solves:

$$\underset{h}{Max}\, E[V] - L(\sigma_u).$$

Solving, the optimal policy $h^*(\sigma_u)$ is the h-value that satisfies:

$$[h + h_x + h_y]^2 c'(h) - \frac{\sigma_u\sqrt{h_y}}{4}\left[\frac{h + h_x + h_y}{h + h_x}\right]^{3/2} = \frac{\alpha\omega^2}{4\gamma}. \tag{5}$$

A simple comparison with the h^* derived in Proposition 4 shows that $h^*(\sigma_u) > h^*$. The intuition is straightforward. Note from Equation (4) that as h increases, investors' expected secondary market trading losses decrease. Thus, in addition to the demand for h recognized in the main analysis, there is an incremental demand for h in this setting for limiting the price discount to offset losses from liquidity trading.

Alternative Model Formulation

In the main analysis, the firm sells the new technology to a third party who then infers information about demand from the stock price to guide decisions about how best to employ the technology. While this is representative of many circumstances, the presumption of a third party making use of the technology also provides a key modeling convenience. As discussed previously in the paper, if the firm had retained discretion on the technology's use, then the well-known circularity problem in pricing would arise. In particular, stock price would both *reflect* and *affect* the endogenous firm value.

That said, the model's primary insights persist if other means of reconciling the circularity problem are employed. Consider the following alternative model (that follows the approach of Subrahmanyam and Titman [1999]) in which the firm retains the right to use the new technology.

Model

As in Figure 1, the timeline has the firm first establishing an accounting system of precision h that reports on x, its existing ventures, at cost $c(h)$. Second, the firm issues a report $r = x + \tilde{\varepsilon}$. Third, the firm spins off (sells) cash flows from existing business ventures in an equity market. The future cash flows from the assets being sold are $S = x + y - c(h)$. We denote the resulting equity price by P_S. The price is determined by trading between noise traders and an informed investor who is endowed with private signals x and $y + \tilde{\eta}_i$, where $\tilde{\eta}_i \sim N\left(0, \frac{1}{h_i}\right)$. Given that the firm retains the new technology, we assume that the firm is also endowed with a private signal $y + \tilde{\eta}_f$, $\eta_f \sim N\left(0, \frac{1}{h_f}\right)$; η_i and η_f are independent of all other variables in the model. Based on the signal $y + \eta_f$ and information feedback from stock price P_S, the firm chooses the number of units q to produce. Finally, the firm consumes the resulting payoff $P_S + pq$, where, recall from the main model, $p = \omega\tilde{y} - \frac{\gamma}{2}q$. Under this formulation, the firm chooses h to maximize its expected payoff $E[P_S + pq]$.

Analysis

The stock price for a given r and h can be represented as follows:

$$P_S = E[S|r; h] + \psi_x + \psi_y + \delta, \tag{6}$$

where $\psi_x = x - E[x|r] = \frac{h[x-r]+h_x[x-\mu_x]}{h+h_x}$, $\psi_y = E[y|y+\eta_i] - \mu_y = \frac{h_i[y+\eta_i-\mu_y]}{h_i+h_y}$ and $\delta \sim N\Big(0, var(\psi_x) + var(\psi_y)\Big)$, where δ is independent of all other variables in the model. On observing the private signal $y + \eta_f$ and stock price P_S in (6), the firm selects the production quantity q that maximizes expected payoff:

$$P_S + E[pq|r, P_S, y + \eta_f; h] = P_S + E\Big[\Big(\omega y - \frac{\gamma}{2}q\Big)q|r, P_S, y + \eta_f; h\Big].$$

The optimal q is, thus, given by:

$$q(r, P_S, y + \eta_f; h) = \frac{\omega}{\gamma}E[y|r, P_S, y + \eta_f; h]. \tag{7}$$

Now, stepping back to the disclosure policy h, at the time the policy is chosen, the firm anticipates the impact on q as noted in (7) and, thus, selects h to maximize expected firm payoff as follows:

$$\underset{h}{Max}\ E\Big[P_S + \Big(\omega y - \frac{\gamma}{2}q(r, P_S, y + \eta_f; h)\Big)q(r, P_S, y + \eta_f; h)\Big], \tag{8}$$

where P_S is as in (6) and q is as in (7). Solving (8), the following proposition identifies the unique payoff maximizing accounting precision.

Proposition 8: The firm's optimal choice of accounting precision is the unique positive h-value that satisfies:

$$c'(h) = \frac{\omega^2 h_i^2 h_y^2 [h_i + h_y]^2}{\gamma[\{2h_y^3 + 2h_i h_y[h + h_x + 2h_y]\}\{h_f + h_y\} + h_i^2\{2h_y[h + h_x + h_y] + h_f[h + h_x + 2h_y]\}]^2}.$$

Proposition 8 proves that the theme of the main analysis is robust. As h increases, more information about y becomes available in the stock price and, consequently, the firm's efficiency in choosing q improves. To see the equivalence between the base model and this setting formally, note that our base model corresponds to the choice of $h_f = 0$ and $h_i \rightarrow \infty$. With these values plugged in Proposition 8, the result simplifies to $[h + h_x + h_y]^2 c'(h) = \omega^2/4y$, the same condition as that derived in Proposition 4, with $\alpha = 1$. Stated differently, what is critical for the demand for accounting disclosure is that stock market feedback be used efficiently to inform future decisions, not who retains discretion over such decisions.

Public Information about the New Technology

To present the main ideas succinctly, the base model presumes that all information about the new technology comes from the prevailing stock price. In practice, however, there are other sources of forward-looking information, such as firm forecasts, analyst reports, macroeconomic indicators, etc., from which decision makers may learn. We next reexamine the role of the firm's accounting report about existing technologies in the presence of such information.

In particular, say the firm is endowed with the signal $s = y + \tilde{\eta}_f$ about the new technology that it disseminates publicly.[3] The following proposition evaluates whether the firm would still invest in the precision of its accounting report about the existing technology.

[3] The issue of whether the firm would, in fact, want to disclose the information publicly is considered shortly.

Proposition 9:

(a) The firm's optimal choice of reporting precision, $h^*(h_f)$, decreases in h_f, i.e., $\frac{dh^*(h_f)}{dh_f} < 0$, where $h^*(h_f)$ is the unique positive h-value that solves:

$$[h + h_f + h_x + h_y]^2 c'(h) = \frac{\alpha\omega^2}{4\gamma}.$$

(b) Expected firm value $E[V^*(h_f)]$ increases with h_f, i.e., $\frac{dE[V^*(h_f)]}{dh_f} > 0$, where:

$$E[V^*(h_f)] = \mu_x + \mu_y + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{2h_f^2 + h_x h_y + h^*(h_f)[2h_f + h_y] + 2h_f[h_x + h_y]}{2h_y[h_f + h_y][h^*(h_f) + h_f + h_x + h_y]}\right] - c\Big(h^*(h_f)\Big).$$

From the proposition, it follows that both the results about optimal accounting precision choice and firm value generalize when other forward-looking sources of information are available. Thus, the key to promoting investment in h is that equity market participants have some private information useful to decision makers, not that they have access to the only information.

Intuitively, the more the information available to guide the manufacturer's choice, the greater the technology's value and, thus, the greater the firm value: firm value increases in h_f. And, as expected, the firm's information about the new technology and the firm's accounting precision are substitutes. If the firm knows more about y from other sources, there is a less compelling reason for it to make investments in h to make stock price more informative of y. That is, h is a decreasing function of h_f. And as long as the firm does not know everything about the new technology, the market always has some information to offer and, consequently, investments in h are always made, i.e., $h > 0$ for any finite h_f.

Next, we examine, as in the main analysis, the firm's preference for public information dissemination over private dissemination.

Proposition 10:

(a) irrespective of whether r is disclosed publicly or privately, both reporting precision h and expected firm value $E[V]$ are greater when s is disseminated publicly than when it is disseminated privately; and
(b) irrespective of whether s is disseminated publicly or privately, both reporting precision h and expected firm value $E[V]$ are greater when r is reported publicly than when it is reported privately.

Recall that the role of the accounting report, r, is to facilitate the manufacturer's ability to learn about y from stock price, and it does so by minimizing confounding information in stock price. As discussed earlier, there are two pieces of confounding information in stock price—information about x and noise. Any public disclosure, be it about x or about y, reduces private information in the stock market, thus reducing noise in stock prices and improving the ability to infer from stock prices. In effect, the public disclosure of either s or r creates more value for the firm than merely making the information available privately to the decision maker. Furthermore, by curtailing noise in stock price, the public nature of each report only serves to improve the effectiveness of accounting report r in eliminating confounding information. This allows the firm to derive greater benefit from the accounting report by investing more in h, when either report is made public.

VI. CONCLUSION

The relationship between accounting reports and stock market participants reflects an intriguing paradox. On one hand, accounting presents an incomplete picture of value-relevant events by incorporating information about the results of current and past decisions, thereby leading many to note the potential for its importance diminishing as other sources of forward-looking information proliferate (Lundholm 1999; Bradshaw and Sloan 2002). On the other hand, the eagerness with which market participants await earnings releases to see if and how they comport with market expectations of future profitability cannot be ignored. In line with this dichotomy, we formally model a circumstance wherein accounting reports provide no direct information to guide future decisions, and yet such reports prove useful because they help observers better interpret guidance for decision making embedded in stock prices. In other words, we show a key complementarity between information contained in accounting reports and in stock prices.

In particular, we show that by reducing uncertainty about the profitability of a company's current technologies, accounting disclosures make it easier to sift out the information embedded in equity prices that can help guide decisions about newly developed technologies. Besides demonstrating a natural complementarity between accounting reports and market feedback as it pertains to decision making, the model also develops clear predictions about the determinants and consequences of more precise accounting reports when they are used to create an informationally rich decision-relevant context.

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APPENDIX A

Proof of Proposition 1

Conjecture a linear pricing rule of the form $P = E[V|r;\, h] + \lambda f$ and a linear trading strategy of the form $z = b_0 + b_x\psi_x + b_y\psi_y$. The informed trader's maximization problem is:

$$\underset{z}{Max}\; E[(V-P)z|r,x,y;h].$$

Taking the conjectured pricing rule P as given and noting that $E[u] = 0$, the profit maximization condition is:

$$\underset{z}{Max}\; [V - E[V|r;h] - \lambda z]z.$$

Noting that $V - E[V|r;\, h] = \psi_x + \psi_y$ and solving the informed investor's problem yields:

$$z = \frac{\psi_x + \psi_y}{2\lambda}.$$

Consider the proposed linear pricing rule $z = b_0 + b_x\psi_x + b_y\psi_y$; comparing coefficients with the above and simplifying, we obtain:

$$b_0 = 0 \text{ and } b_x = b_y = \frac{1}{2\lambda}. \quad (9)$$

Next, consider the market maker. His pricing rule is chosen to ensure zero expected profit as follows:

$$P = E[V|r,f;h].$$

Expanding given normal distributions and simplifying:

$$P = E[V|r;h] + \lambda f$$

where:

$$\lambda = \frac{cov(V,f)}{var(f)}.$$

Substituting for the conjectured trades:

$$\lambda = \frac{[b_x\, cov(x,\psi_x) + b_y\, cov(y,\psi_y)]}{b_x^2\, var(\psi_x) + b_y^2\, var(\psi_y) + \sigma_u^2}. \tag{10}$$

Jointly solving (9) and (10) after noting $cov(x, \psi_x) = var(\psi_x)$ and $cov(y, \psi_y) = var(\psi_y)$ yields:

$$\lambda^2 = \frac{1}{4\sigma_u^2}[var(\psi_x) + var(\psi_y)] \text{ where} \tag{11}$$

$$var(\psi_x) = \frac{1}{h+h_x} \text{ and } var(\psi_y) = \frac{1}{h_y}; \text{ and}$$

$$b_x = b_y = \frac{1}{2\lambda} = \sqrt{\frac{\sigma_u^2\,[h+h_x]\,h_y}{[h+h_x+h_y]}}.$$

Proof of Proposition 2

Using the equilibrium trading strategies z in the pricing function derived in Proposition 1, we get:

$$P = E[V|r;h] + \lambda[\frac{\psi_x + \psi_y}{2\lambda} + u].$$

Denoting $2\lambda u = \delta$ and noting that δ is uncorrelated to all other variables (follows from properties of u), the above can be rewritten as $P = E[V|r;h] + \frac{1}{2}[\psi_x + \psi_y + \delta]$. Using (11), the variance of δ is given by:

$$var(\delta) = 4\lambda^2\sigma_u^2 = var(\psi_x) + var(\psi_y). \tag{12}$$

Proof of Proposition 3

From Proposition 2:

$$\begin{aligned} var(y|r,P;h) &= var(y|r,\psi_x + \psi_y + \delta;h) \\ &= \frac{1}{h_y} - \frac{h+h_x}{2h_y[h+h_x+h_y]}. \end{aligned} \tag{13}$$

Differentiating with respect to *h:*

$$\frac{d\, var(y|r,P;h)}{dh} = -\frac{1}{2[h+h_x+h_y]^2} < 0.$$

Proof of Corollary

(i) From (11), $var(\psi_x) = \frac{1}{h+h_x}$. Differentiating with respect to h yields:

$$\frac{d[var(\psi_x)]}{dh} = -\frac{1}{[h+h_x]^2} < 0.$$

(ii) Using $var(\delta)$ from (12), substituting for $var(\psi_x)$ and $var(\psi_y)$ from (11), and then differentiating with respect to *h:*

$$\frac{d[var(\delta)]}{dh} = -\frac{1}{[h+h_x]^2} < 0.$$

Proof of Proposition 4

Substituting from (1) into (2):

$$T(h) = \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h+h_x}{2h_y[h+h_x+h_y]}\right].$$

Using the above, we compute $E[V]$ as follows:

$$E[V] = \mu_x + \mu_y - c(h) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h+h_x}{2h_y[h+h_x+h_y]}\right]. \tag{14}$$

Differentiating the above expression twice with respect to h, we obtain:

$$\frac{d^2E[V]}{dh^2} = -\frac{\alpha\omega^2}{2\gamma[h+h_x+h_y]^3} - c''(h) < 0.$$

The sign of the second derivative indicates that the solution to the maximization problem $Max_h\ E[V]$ is unique and that it satisfies $\frac{dE[V]}{dh} = 0$. Solving, we obtain:

$$[h+h_x+h_y]^2 c'(h) = \frac{\alpha\omega^2}{4\gamma}. \tag{15}$$

Denoting the optimal h derived above by h^* establishes the proof.

Proof of Proposition 5

(a) The left-hand side of (15) is increasing in h while the right-hand side is free of h. The result then follows from the fact that the left-hand side increases with h_x and h_y while the right-hand side increases with α and ω.

(b) Applying the envelope theorem:

$$\frac{dE[V^*]}{d\alpha} = \frac{\partial E[V]}{\partial \alpha}\bigg|_{h=h^*} = \Pi(h^*) > 0;$$

$$\frac{dE[V^*]}{d\omega} = \frac{\partial E[V]}{\partial \omega}\bigg|_{h=h^*} = \frac{2\alpha\Pi(h^*)}{\omega} > 0;$$

$$\frac{dE[V^*]}{dh_x} = \frac{\partial E[V]}{\partial h_x}\bigg|_{h=h^*} = c'(h^*) > 0;\ \textit{and}$$

$$\frac{dE[V^*]}{dh_y} = \frac{\partial E[V]}{\partial h_y}\bigg|_{h=h^*} = -\frac{[h^*+h_x][h^*+h_x+2h_y]\ c'(h^*)}{h_y^2} < 0.$$

Proof of Proposition 6

Following the same arguments as the proof of Proposition 1, the trading equilibrium in this private information dissemination setting is identical to the one in Proposition 1 with $h = 0$ (effectively, no report).

Consider:

$$var(y|r,\hat{P};h) = \frac{1}{h_y} - \frac{h+h_x}{2h_y\left[h+h_x+h_y+\frac{h\,h_y}{2h_x}\right]}.$$

Comparing with $var(y|r, P; h)$ from (13):

$$var(y|r,\hat{P};h) - var(y|r,P;h) = \frac{h[h+h_x]}{2[h+h_x+h_y][2h_x\{h_x+h_y\}+h\{2h_x+h_y\}]} > 0.$$

Proof of Proposition 7

(a) The production quantity $\hat{q}$ in this setting is given by:

$\hat{q} = \frac{\omega}{\gamma} E[y|r, \hat{P}; h].$

In a manner analogous to that in Section IV, we first determine the value of the new technology; then we evaluate the firm's fraction from it; and finally, we derive the expected firm value given precision h:

$$E[\hat{V}] = \mu_x + \mu_y - c(h) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h + h_x}{2h_y\left[h + h_x + h_y + \frac{h\,h_y}{2h_x}\right]}\right]. \quad (16)$$

The optimal information precision is the h-value that solves $\frac{dE[\hat{V}]}{dh} = 0$. This yields:

$$2\left[h + h_x + h_y + \frac{h\,h_y}{2h_x}\right]^2 c'(h) = \frac{\alpha\omega^2}{4\gamma}.$$

Denoting the optimal h by $\hat{h}^*$ and comparing with h^* in (15) establishes $\hat{h}^* < h^*$.

(b) $E[V]$ in (14) is maximized at $h = h^*$, so $E[V]|_{h=h^*} > E[V]|_{h=\hat{h}^*}$. Further, comparing (14) and (16), $E[V]|_{h=\hat{h}^*} > E[\hat{V}]|_{h=\hat{h}^*}$, since the right-hand side of expression $E[\hat{V}]$ has an extra term in the denominator. Thus, the result $E[V]|_{h=h^*} > E[\hat{V}]|_{h=\hat{h}^*}$ follows.

Proof of Proposition 8

Using values for P_S and q from (6) and (7) in (8), and ignoring constant terms, the maximization problem reduces to:

$$\underset{h}{Max}\ \frac{\omega^2}{2\gamma}\left[\frac{2h_f h_y^3 + 2h_i h_f h_y[h + h_x + 2h_y] + h_i^2\{[h + h_x]h_y + h_f[h + h_x + 2h_y]\}}{h_y[\{2h_y^3 + 2h_i h_y[h + h_x + 2h_y]\}\{h_f + h_y\} + h_i^2\{2h_y[h + h_x + h_y] + h_f[h + h_x + 2h_y]\}]}\right] - c(h).$$

Solving:

$$c'(h) = \frac{\omega^2 h_i^2 h_y^2 [h_i + h_y]^2}{\gamma[\{2h_y^3 + 2h_i h_y[h + h_x + 2h_y]\}\{h_f + h_y\} + h_i^2\{2h_y[h + h_x + h_y] + h_f[h + h_x + 2h_y]\}]^2}.$$

Proof of Proposition 9

(a) Deriving the trading equilibrium in a manner analogous to Proposition 1:

$z = \frac{\psi_x + \psi_y}{2\lambda}$ and $P = E[V|r, s; h, h_f] + \lambda f,$ where

$\psi_x = \frac{h[x - r] + h_x[x - \mu_x]}{h + h_x},$

$\psi_y = \frac{h_f[y - s] + h_y[y - \mu_y]}{h_f + h_y},$ and

$\lambda^2 = \frac{1}{4\sigma_u^2}[var(\psi_x) + var(\psi_y)]$ with

$var(\psi_x) = \frac{1}{h + h_x}$ and $var(\psi_y) = \frac{1}{h_f + h_y}.$

The production quantity in this setting is: $q(r, s, P; h, h_f) = \frac{\omega}{\gamma} E[y|r, s, P; h, h_f]$. Using this quantity, the expected firm value is:

$$E[V(h_f)] = \mu_x + \mu_y + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{2h_f^2 + h_x h_y + h[2h_f + h_y] + 2h_f[h_x + h_y]}{2h_y[h_f + h_y][h + h_f + h_x + h_y]}\right] - c(h).$$

As before, the optimal information precision is the h-value that solves $\frac{dE[V(h_f)]}{dh} = 0$. This yields:

$$[h + h_f + h_x + h_y]^2 c'(h) = \frac{\alpha\omega^2}{4\gamma}. \tag{17}$$

Denoting the solution for h by $h^*(h_f)$ establishes the preferred disclosure precision.

The left-hand side of (17) is increasing in h while the right-hand side is free of h. The comparative statics follow from the fact that the left-hand side increases in h_f.

(b) Noting that $E[V^*(h_f)] = E[V(h_f)]|_{h=h^*(h_f)}$, i.e.:

$$E[V^*(h_f)] = \mu_x + \mu_y + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{2h_f^2 + h_x h_y + h^*(h_f)[2h_f + h_y] + 2h_f[h_x + h_y]}{2h_y[h_f + h_y][h^*(h_f) + h_f + h_x + h_y]}\right] - c\Big(h^*(h_f)\Big).$$

Applying the envelope theorem:

$$\frac{dE[V^*(h_f)]}{dh_f} = \frac{\alpha\omega^2[h^2 + 2h_f^2 + h_x^2 + 2h_x h_y + 2h_y^2 + 2h\{h_f + h_x + h_y\} + 2h_f\{h_x + 2h_y\}]}{4\gamma[h_f + h_y]^2[h + h_f + h_x + h_y]^2} > 0.$$

Proof of Proposition 10

We present and compare the optimal h value, denoted h_j, and expected firm value, denoted $E[V_j]$, across four cases—both r and s are public (corresponding to $j = 1$); r is public and s is private (corresponding to $j = 2$); r is private and s is public (corresponding to $j = 3$); and both r and s are private (corresponding to $j = 4$).

We derive these values in a manner analogous to the analysis in Section IV to get:

$$c'(h_1) = \frac{\alpha\omega^2}{2\gamma}\frac{1}{2[h_1 + h_f + h_x + h_y]^2},$$

$$c'(h_2) = \frac{\alpha\omega^2}{2\gamma}\frac{2h_y^2}{[2h_y\{h_x + h_y\} + h_2\{h_f + 2h_y\} + h_f\{h_x + 2h_y\}]^2},$$

$$c'(h_3) = \frac{\alpha\omega^2}{2\gamma}\frac{h_x^2}{[2h_x\{h_f + h_x + h_y\} + h_3\{h_f + 2h_x + h_y\}]^2}, \text{ and}$$

$$c'(h_4) = \frac{\alpha\omega^2}{2\gamma}\frac{h_x^2 h_y^2}{[h_4\{h_f[h_x + h_y] + h_y[2h_x + h_y]\} + h_x\{2h_y[h_x + h_y] + h_f[h_x + 2h_y]\}]^2}.$$

$$E[V_1] = \mu_x + \mu_y - c(h_1) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{2h_f^2 + h_x h_y + h_1[2h_f + h_y] + 2h_f[h_x + h_y]}{2h_y[h_f + h_y][h_1 + h_f + h_x + h_y]}\right],$$

$$E[V_2] = \mu_x + \mu_y - c(h_2) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h_x h_y + h_2[h_f + h_y] + h_f[h_x + 2h_y]}{h_y[2h_y\{h_x + h_y\} + h_2\{h_f + 2h_y\} + h_f\{h_x + 2h_y\}]}\right],$$

$$E[V_3] = \mu_x + \mu_y - c(h_3) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h_x[2h_f^2 + h_x h_y + 2h_f\{h_x + h_y\} + h_3\{h_f^2 + h_x h_y + h_f[2h_x + h_y]\}]}{h_y[h_f + h_y][2h_x\{h_f + h_x + h_y\} + h_3\{h_f + 2h_x + h_y\}]}\right], \text{ and}$$

$$E[V_4] = \mu_x + \mu_y - c(h_4) + \frac{\alpha\omega^2}{2\gamma}\left[\mu_y^2 + \frac{h_4[h_x h_y + h_f\{h_x + h_y\}] + h_x[h_x h_y + h_f\{h_x + 2h_y\}]}{h_y[h_4\{h_f[h_x + h_y] + h_y[2h_x + h_y]\} + h_x\{2h_y[h_x + h_y] + h_f[h_x + 2h_y]\}]}\right].$$

Employing the same arguments as used in the Proof of Proposition 7, it follows that $h_1 > h_2$ and $h_3 > h_4$, as well as $E[V_1] > E[V_2]$ and $E[V_3] > E[V_4]$, proving part (a). Similarly, $h_1 > h_3$ and $h_2 > h_4$, as well as $E[V_1] > E[V_3]$ and $E[V_2] > E[V_4]$, proving part (b).