Analyst Information Acquisition and Communication*

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Abstract

We examine a communication game between an analyst and a decision-maker and investigate how the presence of public information affects the precision of the information the analyst gathers and credibly communicates to the decision-maker. We characterize conditions under which public information causes the analyst to under-invest or over-invest in the information gathered relative to the case where analyst credibility is not an issue. The model also provides circumstances where the presence of public information causes the analyst to drop coverage of the firm, suggesting that the introduction of public information can make the decision-maker strictly worse off.

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1 Introduction

Decision-makers obtain information from various sources. Some sources have incentives to communicate strategically in a self-serving fashion and face limited regulation regarding their communication. Other sources have little incentive to communicate strategically or face fairly stringent regulation regarding their communication. Investors, for instance, can obtain information from sell-side analysts, who are thought to have incentives to communicate strategically and who face relatively little regulation regarding their communication, and also from a firm's audited financial statements, where regulation plays a significant role in limiting strategic communication of certain information. This study analyzes how changes in the information disclosed by a non-strategic source influences the information gathering and communication decisions of an information intermediary who is strategic.

The model we employ in this analysis has four stages and two players: an information intermediary, which we call an analyst, and a decision-maker. In the first stage, both players observe an imperfect public signal about the state of nature. In the second stage, the analyst engages in costly information gathering that determines the precision of a signal about the state of nature that he will privately observe. In the third stage, the analyst privately observes a signal and costlessly sends a message to the decision-maker. In the fourth stage, the decision-maker, given his beliefs about the state of nature, takes an action that affects both players' payoffs. The players have divergent preferences regarding the decision-maker's action. Within the context of this model, we explore how the precision of the public information that the players observe in the first stage affects the analyst's information gathering and communication in the second and third stages.

While the model can be applied to various settings where decision-makers obtain information from sources that strategically release information and also from other sources that release information in an impartial manner, we find this model useful for framing the recent evolution in the analyst market. The amount of information that firms make available directly to investors has exploded. Following the introduction of Reg FD in 2000, for instance, firms can no longer privately reveal information to analysts and hence are more likely to publicly release their forward-looking information (see Heflin, Subramanyam, and Zhang 2003). Further, firms now routinely hold conference calls following their earnings releases that are open to investors (see Bushee, Matsumoto, and Miller 2003). In addition, the $1.4 billion settlement between the large brokerage firms and the State of New York in 2002 required the investment firms to provide information to investors from unbiased sources together with their own analysis. Following this settlement, there has been a flight of equity analysts from the research departments at the large investment firms, and entire industry sectors have lost analyst coverage. As a consequence, several commentators have argued that these changes are likely to hurt individual investors and reduce stock price efficiency (see Schack 2003). A contribution of this study, therefore, is to illustrate how alternative sources of information might affect analyst information gathering activities, the integrity of their communication with investors, and whether investors are likely to be better off as a consequence of changes in the amount of publicly available information.

This paper highlights that changes in publicly observed information affects an analyst's behavior in two ways. First, when the analyst can credibly communicate privately observed information, the public information serves as a substitute for the analyst's information. As a consequence, improvements in the quality of the public information reduce the marginal value of the analyst information causing him to gather less precise information. Second, when the analyst's credibility is in doubt—because the analyst's incentives are misaligned with those of the decision-maker—improving the quality of the public information makes it more difficult for the analyst to credibly communicate. Specifically, an increase in the quality of the other information reduces the decision-maker's responsiveness to the analyst's information, which causes the analyst to exaggerate his report in an attempt to influence the decision-maker. This exaggeration undermines the analyst's credibility. As a consequence, when the quality of the public information increases, either the analyst gathers more precise information to increase the decision-maker's responsiveness to his information and thereby facilitate credible communication or he discontinues gathering information (i.e., leaves the market).

This analysis suggests that competition arising from improvements in the quality of public information has subtle consequences for analyst behavior. When credibility issues are minimal, which occurs when information gathering costs are low, an increase in the precision of public information leads to a marginal reduction in analyst information gathering. Although more precise public information crowds out some analyst information, this crowding out is not sufficient to offset the benefit of more precise public information. Consequently, the decision-maker is better off. Alternatively, when credibility issues are more pronounced and information gathering costs are moderate, more precise public information leads the analyst to improve his information gathering. The heightened precision of the analyst information coupled with more precise public information combine to make the decision maker better off. Finally, when credibility issues are more pronounced and information gathering costs are high, an increase in the precision of public information completely crowds out the analyst information and the analyst leaves the market. Although the decision-maker obtains more precise public information, the crowding out of the analyst information can be so severe that it actually reduces the total information the decision-maker obtains thereby making the decision-maker worse off.

The primary theoretical antecedent of our paper is Crawford and Sobel (1982). They consider a communication game between an informed expert and an uninformed decision-maker. The expert perfectly observes the realization of a payoff relevant state variable and sends a costless message to the decision-maker who then takes an action that affects both players. Their cheap-talk model has been extended in various directions. In work most closely related to our paper, Austen-Smith (1994) considers a communication game in which the expert chooses whether to perfectly observe the state of nature at some fixed cost and decides whether to reveal being informed, but is unable to prove being uninformed. He establishes that there exist circumstances under which the players cannot communicate when the receiver knows the expert is informed although they can do so when the receiver is uncertain about whether the expert is informed. In contrast to Austen-Smith, we consider a model in which the expert, after observing a public signal, can choose the precision of his privately observed signal; further, we allow for the possibility that the precision of the expert's signal is either publicly observed or privately chosen.

The extant literature also has extended the model in Crawford and Sobel (1982) by examining the effect of multiple experts on the communication game (e.g., Austen-Smith 1993; Krishna and Morgan 2001; Wolinsky 2002; Battaglini 2004; Morgan and Stocken 2008), by introducing multiple decision-makers (e.g., Farrell and Gibbons 1989; Newman and Sansing 1993; Gigler 1994), or by allowing the players to exchange messages (e.g., Aumann and Hart 2003; Krishna and Morgan 2004). In these studies, the expert is exogenously endowed with information. We, in contrast, examine a setting where it is costly for the expert to gather information and consider how the presence of a non-strategic information source affects the information that the expert gathers and communicates.

Our paper is also related to the voluntary disclosure literature. Verrecchia (1990) examines a discretionary disclosure setting in which the quality of information with which a manager is endowed is exogenously specified. Analogous to our result that more public information can thwart credible communication, Verrecchia establishes that an increase in the precision of the market's prior beliefs, which corresponds with an increase in the other information in our model, reduces the probability that the manager discloses. Penno (1996) considers a mandatory disclosure setting in which a manager, after observing a public signal, privately chooses the precision of the report that the firm will release. He establishes that the precision of the manager's report is inversely related to the favorableness of the public information and that the strength of this relationship diminishes as the public signal becomes less precise. Hence, like our paper, he links precision of a public signal with the amount of information communicated in a subsequent report. Both of these papers, unlike our paper, assume that the precision of the manager's information is exogenous. In more recent work, Pae (1999) explores a manager's acquisition of costly private information about the consequence of the manager's productive effort in the context of a voluntary disclosure setting. Hughes and Pae (2004) consider a setting in which an entrepreneur gathers and voluntarily discloses information truthfully about the precision of a signal of an asset's value that the entrepreneur is offering for sale. Lastly, Arya and Mittendorf (2007) explore how public disclosure might affect analyst behavior. They consider a setting where competing firms can voluntarily release information to encourage analyst following. Heightened analyst following enriches the information environment and thereby allows firms to better coordinate their production choices. A common feature of these studies, like much of the extant literature examining voluntary disclosure behavior (e.g., Verrecchia 1983; Dye 1985; Einhorn and Ziv 2008), is that private information, if it is disclosed, must be disclosed truthfully. In the analyst reporting environment, however, analysts often report in a self-serving fashion and face little regulation regarding how they report (e.g., Michaely and Womack 1999; Lin and McNichols 1998). Indeed, it was precisely this concern that motivated key provisions of the Sarbanes-Oxley Act and the legal settlement between the large brokerage firms and the State of New York in 2002.[1] We examine a reporting environment in which the analyst's disclosure is not constrained by particular disclosure rules and find the desire to communicate credibly fundamentally influences the analyst's information gathering behavior. Hence, a contribution of our paper is to provide insights into information gathering and communication behavior when reporting credibility is a key feature of the environment.[2]

Our paper is also reminiscent of the disclosure literature that considers the credibility of a firm manager's communication when investors can gather other information that allows them to assess the veracity of the manager's disclosure. For instance, Sansing (1992) and Stocken (2000) examine managers' earnings forecasting behavior when investors can use an audited earnings report to assess a forecast's credibility. In these papers, the investors are exogenously endowed with the earnings report. Further, the modeling frameworks and the questions they address differ substantially from ours.

The paper proceeds as follows: Section 2 describes the model and includes a time line that summarizes the model's notation. Section 3 characterizes the equilibrium. Section 4 examines how changes in the precision of public information influence an analyst's information gathering and communication. Section 5 considers how changes in the precision of public information affect the quality of the decision-maker's information. Section 6 relaxes the assumption that the analyst's precision choice is common knowledge and discusses how the analyst's information gathering and communication changes. Section 7 concludes. All proofs are in the Appendix.

2 Model

We consider a communication game in which an analyst can choose to obtain private information about an unknown state variable and send a report to a decision-maker who then takes an action. The unknown state variable is represented by the random variable $\tilde{\alpha}$, which has support $\{s, f\}$ where $s > f$. The common prior beliefs are that

[1] Some work has studied analyst information gathering. Hayes (1998), for instance, examines an analyst's incentives to gather and report information in an environment in which the analyst's report influences an investor's trading behavior that, in turn, determines the trading commission that the analyst receives. The analyst always reports truthfully so that issues of strategic disclosure do not arise.

[2] In addition, several studies examine how private information acquisition will change in response to a public information signal within a rational expectations framework (e.g., Verrecchia 1982; Diamond 1985; Alles and Lundholm 1993).

the successful, s, and failure, f, state realizations are equally likely to occur.[3]

The game has four stages. In the first stage, information represented by the realization of a random variable $\tilde{x}$ is publicly observed. The support for $\tilde{x}$ is $\{h, l\}$. The probability that $\tilde{x} = h$ conditional on $\tilde{\alpha} = s$ and the probability that $\tilde{x} = l$ conditional on $\tilde{\alpha} = f$ are both $q \in (1/2, 1)$. The variable q captures the precision of $\tilde{x}$, where a higher value for q implies that $\tilde{x}$ is more informative. Setting $q = 1/2$ is equivalent to supposing that the public information is absent. The public information may be viewed as the filing of a firm's audited financial statements or the release of governmental statistics that are informative about a firm's future outlook. The analyst observes the realization of the public information x before choosing the precision of his private information.

In the second or *information gathering* stage, the analyst chooses whether to invest in a costly information generating technology to acquire private non-verifiable information. The analyst's private information, if obtained, is represented by the realization of a random variable $\tilde{y}$, which has support $\{g, b\}$. Conditional on the realization of $\tilde{\alpha}$, $\tilde{x}$ and $\tilde{y}$ are independent. The probability that $\tilde{y} = g$ conditional on $\tilde{\alpha} = s$ and the probability that $\tilde{y} = b$ conditional on $\tilde{\alpha} = f$ are both $p \in [1/2, 1]$. The analyst chooses the precision p and incurs a cost $c(p)$, where $c(p)$ is a twice differentiable function that satisfies: (i) $c'(p) > 0$ and $c''(p) > 0$ for $p > 1/2$; (ii) $\lim_{p \to 1/2} c'(p)/(p - 1/2) \to 0$; (iii) $\lim_{p \to 1} c'(p) \to \infty$; and (iv) $c''(p)/c'(p) > (1 - 3p(1-p)) / (p(1-p)(p - 1/2))$ for all $p \in (1/2, 1)$. Condition (i) requires that the analyst's cost of gathering information increases in the precision of the information and at an increasing rate. Conditions (ii) and (iii) are sufficient for the analyst to choose an interior level of precision when he can credibly communicate. Condition (iv) is sufficient to insure the analyst's optimal precision choice is unique. As an example, the simple power function $c(p) = ((p - 1/2) / (1 - p))^n$, where $n > 2$, satisfies these conditions (see Appendix for details). The analyst choosing not to invest in the information technology is equivalent to the case in which the analyst's private information has precision $p = 1/2$.

The decision-maker observes the precision of the analyst's private information, but not the realization of his private information. This assumption is consistent with the sell-side equity analyst environment, which is the primary institutional application of

[3] As in this paper, many cheap-talk models assume the players' prior beliefs are diffuse (e.g., Austen-Smith 1993; Krishna and Morgan 2001; and Battaglini 2004).

our model. Analyst stock reports vary in content and often contain detailed analysis of a company, its key competitors, and its industry. The detail in the analyst's stock report, which the investor can readily observe, reflects the precision of the analyst's information. Investors, however, do not observe the analyst's procedures for evaluating and interpreting the information that is gathered. It is this interpretation and evaluation that provides the analyst with private information y. In the final section of the paper, we suppose the analyst's choice of precision is unobservable.

In the third or *reporting* stage, the analyst costlessly sends a report r to the decision-maker. The analyst need not report truthfully. The analyst's ability to communicate the privately observed signal y in his report is potentially thwarted, however, because the commonly known preferences of the decision-maker regarding her action choice differ from the commonly known preferences of the analyst. In particular, the decision-maker chooses an action $a \in \Re$ given her information Ω_d to maximize

$$U_d = -E\left[(\tilde{\alpha} - a)^2 | \Omega_d\right], \tag{1}$$

where $E[\cdot|\cdot]$ is the expectation operator. Given this objective function, it is optimal for the decision-maker to choose an action $a = E[\tilde{\alpha}|\Omega_d]$, which is analogous to investors valuing a firm at its expected value.[4] The analyst's objective function also depends on the decision-maker's action; the analyst chooses a report r given his information Ω_i to maximize

$$U_i = E\left[\phi a - (\tilde{\alpha} - a)^2 - c(p) | \Omega_i\right], \tag{2}$$

where $\phi > 0$.[5] When $\phi = 0$, the players' interests are perfectly aligned because, given the same information, both players would prefer the same action. When $\phi > 0$, however, their interests are misaligned because, for a given information set, the analyst's preferred action exceeds the decision-maker's preferred action. These utility representations are broadly descriptive of institutional settings where an analyst wants to induce a higher action than a decision-maker would prefer, but is constrained from inducing an action that is too high because of, say, (unmodeled) reputation or litigation concerns associated with misleading the decision-maker (e.g., Dugar and

[4]The presumption that investors value a firm at its expected value is standard in the voluntary disclosure literature (e.g., Verrecchia 1990; Penno 1996; and Einhorn 2007).

[5]We can also assume $\phi < 0$ without altering the flavor of the results.

Nathan 1995; Grossman and Helpman 2001; Morgan and Stocken 2003).[6]

In the fourth stage, the state of nature α is realized and the analyst's and decision-maker's payoffs are determined. All aspects of game are common knowledge except the analyst's private signal y. The time line of events and the model's notation is summarized in Figure 1.

[Figure 1]

We study *Perfect Bayesian Equilibria*, which require that: the players' beliefs satisfy Bayes' rule whenever possible; and, given beliefs, the decision-maker's action a maximizes her expected payoff $U_d = -E[(\tilde{\alpha} - a)^2|\Omega_d]$ and the analyst's choice of information precision p maximizes $U_i = E[\phi a - (\tilde{\alpha} - a)^2 - c(p)|\Omega_i]$ and, given the cost of gathering information is sunk, the analyst's report r maximizes $U_i = E[\phi a - (\tilde{\alpha} - a)^2|\Omega_i]$.

Like most cheap-talk games, there are multiple equilibria. In our model, there are, at most, two classes of equilibria: one class of equilibria in which the analyst chooses the same precision $p > 1/2$ (i.e., the analyst gathers some information) and communicates that information to the decision-maker, and one class of equilibria in which the analyst chooses $p = 1/2$ (i.e., the analyst does not gather any information), which is analogous to a babbling equilibrium in a cheap-talk game without endogenous information acquisition. There always exists equilibria in which the analyst does not gather any information. There may or may not exist equilibria in which the analyst gathers and communicates information. When there exist equilibria in which information is gathered, we focus on this class because these equilibria ex ante Pareto dominate any equilibrium in which information is not gathered.[7] Within the class of equilibria in which information is gathered, we focus on the *truthful communication* equilibrium—the equilibrium in which $r = y$ for all y. This focus is without loss of

[6] While the Sarbanes-Oxley Act enacted on July 25, 2002 was drafted to strengthen the independence of security analysts (Razaee, 2007) and the legal settlement between the large brokerage firms and the State of New York in 2002 has altered the way in which analysts are compensated, separated research and investment banking activities within investment firms, and mandated disclosure in stock reports of conflicts where they might exist, there still is evidence suggesting analysts have incentives to curry favor with firm management. For instance, Mayew (2008) finds that firm management favors those analysts in conference calls who have bullish stock recommendations on the firm.

[7] It is standard in the cheap-talk literature to focus on an ex ante Pareto dominant equilibrium; see, for instance, Crawford and Sobel (1982).

generality because when there exists an equilibrium with full revelation that involves the analyst reporting something other than y (e.g., $r \in \{b, g\}$ and $r \neq y$ for all y), it is economically equivalent to the truthful communication equilibrium.[8]

3 Equilibrium

The analyst chooses the precision of his private information after observing the public information and then decides whether to truthfully reveal his private information. We use backward induction to characterize the equilibrium and begin with the reporting stage before considering the information gathering stage.

In the reporting stage, the analyst decides whether to truthfully reveal his private information after having observed the public signal and his private information. To assess whether the analyst can communicate y to the decision-maker, note that the analyst prefers a higher action than the decision-maker given y, and that the decision-maker would take a higher action if she believes the analyst has observed $\tilde{y} = g$. It follows that the analyst is always willing to reveal when $\tilde{y} = g$, but may want to mislead the decision-maker when $\tilde{y} = b$ by claiming that $\tilde{y} = g$. Recalling that the value of the analyst's objective is increasing and then decreasing in the decision-maker's action implies that the analyst will not try to mislead when $\tilde{y} = b$ if the action induced from claiming that $\tilde{y} = g$ is much higher than the action preferred by the analyst when $\tilde{y} = b$. Hence, the analyst can communicate y if the action he would induce by misrepresenting his information is sufficiently high relative to the one he induces if he truthfully communicates his information.

For either realization of $\tilde{x}$, the difference between the actions the decision-maker might choose when she believes she knows y is

$$\Delta(p) \equiv E[\tilde{\alpha}|x, g] - E[\tilde{\alpha}|x, b] = \frac{q(1-q)(2p-1)(s-f)}{(p(1-q)+(1-p)q)((1-p)(1-q)+pq)}. \quad (3)$$

The difference $\Delta(p)$ is an increasing function of p, which implies that the decision-maker's action choice is more responsive to the analyst's information when the analyst's information is more precise. As discussed above, the analyst can credibly

[8] To the extent that it is institutionally inappropriate to focus on the properties of the most informative equilibrium when there exist a multiplicity of equilibria, then the predictive power of the claims in this paper will be reduced.

communicate y if the action he induces when he claims to have observed realization g is sufficiently large relative to the action he induces when he claims to have observed realization b, or formally

$$\Delta(p) - \phi \geq 0.$$

Hence, if p is sufficiently high, the analyst can credibly communicate y. This observation is formalized in the next lemma.

Lemma 1 *The analyst can communicate y in the presence of the other information x if and only if the precision of the analyst's information is sufficiently high; that is, there exists a minimum threshold $\bar{p}$ such that, for any x, the analyst can credibly communicate y if and only if $p \geq \bar{p}$.*

Having examined the reporting stage, we now step back and consider the information gathering stage. In this stage, the analyst chooses the precision of his private information after having observed the public signal realization $x \in \{l, h\}$. To determine the analyst's choice, it is useful to first examine how the analyst's objective function behaves in p when we assume the analyst's information y is publicly observed. Recalling that the decision-maker's action choice equals the expectation of $\tilde{\alpha}$, the analyst's objective function is

$$\begin{aligned} & E_y\left[\phi E[\tilde{\alpha}|x,y] - (\tilde{\alpha} - E[\tilde{\alpha}|x,y])^2 - c\,(p)\,|x,y\right] \\ = \; & \phi E_y[E[\tilde{\alpha}|x,y]] - \frac{p\,(1-p)\,(s-f)\,\Delta\,(p)}{2p-1} - c\,(p)\,. \end{aligned}$$

The next lemma establishes how the analyst's objective function behaves in the analyst's precision choice p.

Lemma 2 *When the analyst's information y is public, the analyst's objective function is strictly quasiconcave and attains a maximum at $p^* \in (1/2, 1)$ where p^* is such that*

$$\Delta^2\,(p^*)\,/\,(2p^* - 1) - c'\,(p^*) = 0. \tag{4}$$

Lemma 2 implies the analyst has a single-peaked objective function that is maximized at p^* when the analyst's signal y is public information. The analyst's signal y, however, is *not* publicly observed. Lemma 1 implies that p must be at least $\bar{p}$ for credible communication to occur when the analyst's signal is not publicly observed.

It follows from these two lemmas that, when y is not public information, the analyst chooses $p = p^*$ if $p^* \geq \bar{p}$. Alternatively, if $p^* < \bar{p}$, the analyst chooses $p = 1/2$ or $p = \bar{p}$. The next proposition extends this discussion and characterizes the analyst's optimal choice.

Proposition 3 *Suppose the analyst privately observes y and both players observe the other information x.*

(i) If $\phi\Delta(p^*)/(2p^* - 1) \leq c'(p^*)$, then the analyst chooses a level of precision $p^* \in [\bar{p}, 1)$ and communicates truthfully in the reporting stage.

(ii) If $\phi\Delta(p^*)/(2p^* - 1) > c'(p^*)$ and $c(\bar{p}) \leq \Delta(\bar{p})\,q(1-q)(2\bar{p}-1)(s-f)$, then the analyst chooses a level of precision $\bar{p}$ and communicates truthfully in the reporting stage.

(iii) If $\phi\Delta(p^*)/(2p^* - 1) > c'(p^*)$ and $c(\bar{p}) > \Delta(\bar{p})\,q(1-q)(2\bar{p}-1)(s-f)$, then the analyst chooses to not collect any private information.

Proposition 3 assumes the analyst chooses the precision of his private information *after* observing the realization of the public information. Analysts, however, often choose to gather information in anticipation of a public information event. Because $\Delta(p)$ does not depend on whether the public signal realization is either $\tilde{x} = h$ or l, it follows that the characterization of the equilibrium in Proposition 3 would not change if we instead assumed that the analyst chose the precision of his information *before* observing the public information. Further, there also exists an equilibrium in which the analyst does not gather any information in cases (i) and (ii) in Proposition 3. As we stated earlier, if there exists an equilibrium in which information gathering occurs, we assume it is the equilibrium that is played.

4 Analyst Information

While Proposition 3 characterizes the analyst's information gathering decision, it offers little insight into the determinants of the information the analyst chooses to gather and disseminate. To address our primary research question, we examine how the quality of the other information available to the decision-maker, q, affects the analyst's information gathering decision, p. From Proposition 3, we know that the analyst chooses information quality p^* if credible communication of the resulting information is possible, specifically $p = p^* \geq \bar{p}$. Otherwise, the analyst chooses a higher level of information quality to allow communication, $p = \bar{p} > p^*$, or he chooses to exit the market if information of higher quality is too costly to obtain, that is $p = 1/2$. Assessing how the quality of the public information, q, influences the analyst's behavior entails determining how q affects the critical values p^* and $\bar{p}$. The following corollary, which follows directly from Lemmas 1 and 2, characterizes the relation between q and the critical precision values p^* and $\bar{p}$.

Corollary 4 *The minimum precision of the analyst's private information necessary for the analyst to credibly communicate, $\bar{p}$, is* increasing *in the precision of public information q; that is, $\partial\bar{p}/\partial q > 0$. The precision of the analyst's information chosen when the analyst's information is public, p^*, is* decreasing *in the precision of the public information q; that is, $\partial p^*/\partial q < 0$ when $q \neq 1/2$ and $\partial p^*/\partial q = 0$ when $q = 1/2$.*

To develop intuition for the relation between q and $\bar{p}$, note that when the precision of the public information is low, the decision-maker's action choice is more responsive to the analyst's information because the analyst information is *relatively* precise. As a consequence of this greater responsiveness, the analyst is less inclined to exaggerate and report g when b is actually observed because, if the report is believed, the decision-maker takes an action that is undesirably high from the analyst's perspective. On the other hand, the analyst is less capable of credibly communicating when the public information is precise because the decision-maker's action choice is less responsive to the analyst's information. In this case, the analyst is more inclined to exaggerate and report g when b is actually observed because, if the report is believed, the decision-maker takes a higher action but one that is not so high that the analyst finds it undesirable. If there are incentives for such exaggeration, however, the analyst is not believed and communication does not occur in equilibrium. The relation between q and p^* is straight forward. As the precision of public information increases, the marginal benefit of the analyst's information decreases. Consequently, the level of p that maximizes the analyst's expected utility falls.

With Corollary 4 in hand, consider the case when the precision of the public information is relatively low so that $p^* \geq \bar{p}$. As the precision of the public information increases, $\bar{p}$ rises and p^* falls. Because the analyst chooses p^* when $p^* \geq \bar{p}$, the analyst's choice of p falls in q because p^* falls in q. Eventually the precision of the other information rises to a point where $p^* = \bar{p}$. As q continues to rise, communication is no longer credible if the analyst chooses p^*. Hence, the analyst must choose between the level of precision necessary for credible communication $\bar{p}$ or drop out of the market by choosing $p = 1/2$. Initially, the analyst responds by choosing $\bar{p}$ and *over-investing* in the quality of information he gathers to allow credible communication. Given that the $\bar{p}$ is increasing in q, it follows that the precision of the analyst information increases in q. At some point, however, implementing $\bar{p}$ becomes so costly that the analyst chooses not to collect any information. In these circumstances, the improvement in the public information causes the analyst to *under-invest* in the quality of information he gathers relative to that which he would gather if he could commit to credibly reveal his private information. In summary, we have the following observation.

Remark 1 *The precision of the information the analyst collects is decreasing in the precision of the public information, then increasing in the precision of the public information, and, at some sufficiently high level of precision of the public information, the analyst stops collecting private information; that is, there exists a* q^* *and* $\bar{q} > q^*$ *such that the equilibrium precision of the analyst's private information is decreasing in* q *over the range* $(1/2, q^*]$, *increasing in* q *over the range* $(q^*, \bar{q}]$, *and is uninformative for* $q > \bar{q}$.

Remark 1 provides some insight into the recent evolution of the sell-side analyst industry. Recent regulatory changes have greatly increased the amount of information firms make available directly to investors. For instance, following the introduction of Reg FD, firms can no longer privately reveal information to analysts so firms are more likely to publicly release their forward-looking information (see Heflin, et al., 2003). In addition, the $1.4 billion settlement between ten large brokerage firms and the State of New York requires these firms to distribute research reports that independent analysts have prepared along with their own analysis (see Schack 2003). Finally, firms now routinely host conference calls following earnings releases that are open to investors (see Bushee, et al. 2003). These changes have eroded stock analysts' information advantage. Remark 1 suggests that, in response to these changes in the information environment, some intermediaries have reduced the information they collect, others have increased the quality of their analysis in response to the heightened competition from other sources, and yet others have discontinued coverage of firms.

Remark 1 is empirically unsatisfying since it suggests "anything can happen". To offer more definitive guidance as to how intermediaries might alter the quality of their analysis in response to changes in public information, we consider how some environmental characteristics might influence analyst behavior. In particular, we assess how the extent of the incentive conflict, captured by ϕ, and the degree of prior uncertainty about the firm's payoffs, as captured by $(s - f)$, would alter the analyst behavior. Doing so, however, requires that we first examine how changes in these characteristics affect the critical values of precision $\bar{p}$ and p^*.

Corollary 5 *The minimum precision of the analyst's private information necessary for the analyst to credibly communicate, $\bar{p}$, is increasing in the extent of incentive misalignment ϕ and decreasing in the difference between the state payoffs $(s - f)$; that is $\partial \bar{p} / \partial \phi > 0$ and $\partial \bar{p} / \partial (s - f) < 0$. The precision of the analyst's information chosen when the analyst's information is public, p^*, is unaffected by the extent of incentive misalignment ϕ and is* increasing *in the difference between the state payoffs $(s - f)$; that is $\partial p^* / \partial \phi = 0$ and $\partial p^* / \partial (s - f) > 0$.*

To develop intuition for how $\bar{p}$ behaves, observe that the analyst is more inclined to truthfully reveal his privately observed signal when the decision-maker's actions are highly responsive to his disclosure. The decision-maker is more responsive when the analyst's information is relatively more precise or the state payoffs are more divergent. When the extent of incentive misalignment is large, the minimal precision of analyst information necessary for credible communication must be high. Alternatively, when the state payoffs are far apart and prior uncertainty is large, the decision-maker will be more responsive to the analyst's information. Therefore, the minimal precision of the analyst's information necessary for credible communication need not be high.

We now turn to how p^* behaves. This value is derived assuming the analyst's information is publicly observed. Accordingly, it is clear that the extent of the incentive misalignment between the players ϕ should not influence the choice of p^*. In contrast, as the prior variance of the firm's payoffs, which is proportional to $(s - f)$, increases, both players prefer more precise information.

Given the intuition underlying Corollary 5, we consider how the extent of incentive misalignment ϕ influences the analyst's response to increases in the precision of other information. If the extent of incentive misalignment is low, then p^* will exceed the minimum level of precision necessary for credible communication $\bar{p}$. The analyst therefore will choose p^*. Corollary 4 establishes that an increase in the quality of public information is associated with a marginal decrease in the analyst's precision choice p^*. If the extent of misalignment is moderate, so that the analyst chooses the minimum level of precision to facilitate credible communication $\bar{p}$, Corollary 4 shows that an increase in the quality of the public information is associated with a marginal increase in the precision of the analyst's information. Finally, if the extent of misalignment is high, the analyst responds to an increase in the precision of the public information by not gathering any addition information or performing any analysis. Within the sell-side analyst context, these observations suggest that intermediaries with large incentive conflicts, such as those whose employers do a great deal of banking business (see Lin and McNichols 1998) or those who have substantial equity positions in the firm's stock, may be more incline to drop coverage of that firm in response to the increase in public information. In contrast, analysts that face few conflicts of interest will respond more modestly and simply reduce their analysis. Finally, analysts with more moderate conflicts of interest will be more incline to increase their analysis in response to increases in the availability of public information.

The extent of prior uncertainty also influences the response of intermediaries to the increase in public information. Decision-makers might be more uncertain about a firm's payoffs if the firm is in an industry that uses an innovative and unproven technology. Corollaries 4 and 5 suggest that, in response to an increase in public information, firms with highly risky payoffs will face relatively modest declines in analyst attention, those with low risk payoffs will have analysts drop coverage, and those with moderately risky payoffs will receive greater analyst attention.

In summary, the paper highlights that public information influences analysts in two ways. First, improvements in public information make it more difficult for the analyst to communicate (i.e., $\bar{p}$ is increasing in q). Second, improvements in public information reduce the benefit of more precise analyst information because the public information substitutes for the analyst's information (i.e., p^* is decreasing in q). When communication credibility is not an issue (i.e., $\bar{p}$ is small relative to p^*), the analyst reduces the quality of his analysis in response to more precise public information. In contrast, when analyst communication credibility is an issue, the analyst responds to more precise public information by either gathering more precise information or alternately dropping coverage of firms.

Our model, which emphasizes the role of reporting credibility for understanding the information intermediary's behavior, contrasts with the discretionary disclosure models commonly examined in the accounting literature that assume any disclosure must be truthful, although the manager can choose to withhold information. These papers offer reasons for why managers might not voluntarily release private information. In this paper, we suggest analysts might not disclose non-verifiable information because, in anticipation of being unable to credibly reveal it, they choose to not gather any information. Further, we find the presence of a reporting stage in a model in which the analyst's credibility is an important ingredient affects the precision of information that the analyst gathers in subtle ways. It can cause an analyst to under or over-invest in information collection relative to the model where any disclosure is always truthful.

5 Quality of Decision-Maker Information

We considered how the precision of the analyst's information changes in response to increases in the precision of the other information. In some cases, we demonstrate that the analyst reduces the quality of analysis in response to an increase in precision of public information. An unanswered question in these cases is: What happens to the precision of the decision-maker's information? In this section, we examine how the quality of the decision-maker's information varies with the precision of the public information. We define the *quality of information* as a function of the decision-maker's expected posterior variance after the public signal and analyst report, $-E_y\left[var\left[\tilde{\alpha}|\Omega_d\right]\right]$. It can be shown that decision-maker's objective function and action choice is such that the quality of the decision-maker's information is equivalent to the decision-maker's expected utility.

Consider the case in which the analyst chooses a level of precision that exceeds the minimum level of precision necessary to credibly communicate in the reporting stage prior to an increase in the precision of the other information, that is $p^* > \bar{p}$. The decision-maker's quality of information when the analyst chooses $p = p^*$ is given by

$$-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right] = -\frac{p^*\left(1-p^*\right)q\left(1-q\right)\left(s-f\right)^2}{\left(p^*\left(1-q\right)+\left(1-p^*\right)q\right)\left(\left(1-p^*\right)\left(1-q\right)+p^*q\right)}.$$

As the precision of the public information q increases, it follows from our previous analysis that the precision of the analyst information decreases because the other information serves as a *substitute* for the analyst information. Nevertheless, we observe that an increase in precision of the public information q leads to an increase in the decision-maker's information; that is, $\partial \left(-E_y \left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)/\partial q > 0$.

Consider the case where the precision of the other information q has increased to a point where the analyst optimally chooses the minimum level of precision that allows credible communication, that is $p = \bar{p}$. In this case, the decision-maker's quality of information is given by

$$-E_y \left[var\left[\tilde{\alpha}|x,y;\bar{p}\right]\right] = -\frac{\bar{p}\left(1-\bar{p}\right)q\left(1-q\right)\left(s-f\right)^2}{\left(\bar{p}\left(1-q\right)+\left(1-\bar{p}\right)q\right)\left(\left(1-\bar{p}\right)\left(1-q\right)+\bar{p}q\right)}.$$

When the truth-telling condition in the reporting stage is binding, the analyst increases the precision of information he collects as the precision of the public information increases. Here the presence of the public information has a *complementary* effect on the analyst's information gathering activities. The increase in the precision of the analyst's information coupled with the increase in the precision of the public information continues to cause the decision-maker's information quality to increase with an increase in the precision of the public information; that is $\partial \left(-E_y \left[var\left[\tilde{\alpha}|x,y;\bar{p}\right]\right]\right)/\partial q > 0$.

Finally, consider the case where the precision of the other information becomes so large that the analyst's expected utility when $\bar{p}$ is chosen is less that the analyst's expected utility when no information is collected, that is $p = 1/2$. In this case, the analyst simply decides not to gather any information about the company—the analyst drops firm coverage. Since the decision-maker only observes the public information x, the decision-maker's quality of information when $p = 1/2$ is given by

$$-Var\left[\tilde{\alpha}|x\right] = -q\left(1-q\right)\left(s-f\right)^2.$$

This latter observation implies that, an increase in q above some value $\bar{q}$ causes the decision-maker's information quality to fall discontinuously at $\bar{q}$. Thus, the increase in public information drives out the analyst's willingness to collect and communicate his private information, which makes the decision-maker worse off. Of course, as the precision of the public information continues to increase, the quality of the decision-maker's information increases and the decision-maker's information quality attains a maximum value at $q = 1$. This observation is formalized in the next Corollary.

Corollary 6 *As the precision of the public information increases from $q = 1/2$, the total information the decision-maker obtains initially increases, falls discontinuously* *at $\bar{q}$ when the analyst no longer gathers private information, and then increases as q approaches one.*

Corollary 6 suggests that improving the quality of public information can crowd out the analyst's ability to credibly communicate his private information. The expected quality of the decision-maker's information does not monotonically increase in the precision of the public information. In the financial reporting environment, however, policy-makers do not choose the precision of the public information. Instead, they decide whether or not information of a given precision should be gathered and disclosed. In essence, a policy-maker's choice is between disclosure and no disclosure. To assess whether the crowding out phenomenon can make *no* disclosure the policy-maker's preferred choice, we analyze the difference between the decision-maker's information quality in the absence of disclosure, which is equivalent to $q = 1/2$, and the information quality when other information of precision q is publicly disclosed. The goal now is to determine whether there are values of the precision of the public information q for which the decision-maker is better off in the absence of the public information.

We show that the introduction of public information can make the decision-maker worse off within the context of an example with a cost function $c(p) = ((p - 1/2)/(1-p))^n$ where $n > 2$. Set $s = 2$, $f = 3/20$, $\phi = 1/2$, and $n = 3$. On one hand, consider the setting in which public information is absent. The analyst chooses $\bar{p} = 1/2 + \phi(2(s-f)) = 47/74 > p^*$; he gathers more precise information than he would gather if he could commit to truthfully reveal his privately observed information. Given the analyst chooses a level of precision $\bar{p}$ and communicates truthfully in the reporting game, the decision-maker's quality of information is given by

$$-E_y[var[\tilde{\alpha}|y;\bar{p}]] = -\frac{1}{4}\left((s-f)^2 - \phi^2\right).$$

On the other hand, consider an environment where the public disclosure of information is mandatory. It is sufficiently costly to gather information in this setting that the analyst prefers to not gather any private information at all; the analyst chooses $p = 1/2$ for all $q \in (1/2, 1)$. Although the presence of any public information crowds out the analyst's information, the decision-maker benefits from observing the public information. The decision-maker's quality of information when $p = 1/2$ is given by

$$-Var[\tilde{\alpha}|x] = -q(1-q)(s-f)^2.$$

When the precision of the public information is such that $q \in (1/2, \bar{p})$, the benefit to the decision-maker of observing the public information is not sufficient to offset the analyst's information that it displaces. The introduction of public information reduces the total quality of the decision-maker's information and makes her worse off. Alternatively, when the precision of the public information is such that $q \in (\bar{p}, 1)$, then the public information is sufficiently precise that its introduction makes the decision-maker strictly better off, even though it squashes the analyst's willingness to gather private information.

This observation that additional public information may reduce the players welfare is reminiscent of a result in Christensen's (1982) study of performance standards in an agency setting. In that study, Christensen shows that the principal may be worse-off when the players observe additional contractual information before the agent takes an action. Our setting differs from an agency setting because, in our setting, a receiver *cannot* commit (i.e., contract) to use a report in a particular way. Consequently, the character of our equilibrium and the economic forces delivering our results differ from those in Christensen (1982).

To digress briefly, we have raised the possibility that introducing mandatory disclosures of other information can reduce the total information available to the decision-maker when the state space is binary. One might be concerned that this result can arise only when the state space is discrete thereby allowing the analyst either to communicate truthfully or not to communicate at all. This possibility result, however, can also be established when the state space and message space is continuous.

The fact that variations in the precision of the public information can harm the decision-maker arises not because the state space or message space is discrete, but because of the discontinuity in the precision with which the analyst can communicate his private information. A key feature of our model is that the analyst does not bear a *direct* cost from issuing any specific message. The analyst, however, incurs an *indirect* cost from inducing the decision-maker to take an action that affects his expected payoff. When there are no direct reporting costs and the incentives of the analyst and decision-maker are not perfectly aligned, Crawford and Sobel (1982) established that the unique equilibrium is characterized by a partition of the state space and the analyst is only able to credibly reveal the interval containing his signal as opposed to the signal itself. The lengths of the intervals in a partition vary. Therefore, the precision with which the analyst can communicate his private information varies discontinuously with his signal realization.

The following example illustrates the possibility of public information harming the decision-maker within a game that features a continuous state space and message space. To simplify the illustration, consider the reporting game when the analyst's information gathering activity (that depends on the specific cost function) is taken as given. Thus, the decision-maker's and analyst's utility functions are specified in (1) and (2), respectively, but with $c(p) = 0$; set $\phi = 1/4$. Assume the state variable, $\tilde{\alpha}$, is uniformly distributed on the unit interval, and the analyst privately observes the state variable $y = \alpha$. The analyst and decision-maker publicly observe the sum of two independent signals $x = \sum_{i=1}^{2} v_i$, where each signal, v_i, is drawn from a Bernoulli distribution with an unknown parameter α; that is, $\Pr(\tilde{v}_i = 1) = \alpha$ for $i = 1, 2$. Therefore, the decision-maker's posterior distribution of $\tilde{\alpha}$ is a beta distribution with parameters $1 + x$ and $3 - x$ (see DeGroot 1970). Given these beliefs, when $\tilde{x} \in \{0, 1\}$, the analyst cannot reveal his information. In contrast, when $\tilde{x} = 2$, the analyst's message r can reveal, at most, whether the state lies in one of three intervals $\{[0, 0.06], (0.06, 0.43], (0.43, 1]\}$. When the signal x is publicly observable, the decision-maker's information quality $-E[Var[\tilde{\alpha}|x, r]] = -0.04$. However, when the public signal x is unavailable, the analyst's message can reveal whether the state lies in one of two intervals $\{[0, 0.25], (0.25, 1]\}$, and the decision-maker's information quality $-E[Var[\tilde{\alpha}|r]] = -0.03$. Hence, the decision-maker is ex ante better off when the other information is unavailable.[9]

[9] When the state is continuously distributed and the other information variable $\tilde{x}$ is such that it does not change the support of the decision-maker's beliefs, analytic solutions to the questions examined in this paper generally cannot be obtained. Characterizing the partitional equilibria to this game requires finding solutions to non-linear, second-order difference equations. These equations generally do not have analytic solutions. To obtain analytic solutions, we accordingly restrict the support of the information variables in the model.

6 Unobservable Choice of Precision

In the primary model, the analyst's choice of precision p is common knowledge. This assumption is based on the observation that it is often possible to infer an analyst's expertise from the depth and clarity of the stock report, even though it is not possible to infer exactly what the analyst believes. At times, however, the decision-maker may be unable to determine the analyst's expertise. As a consequence, in this section we modify the model and assume the analyst privately chooses the precision of his information.

As in the analysis of the primary model, it is again useful to initially consider a setting where the analyst's signal y is public information. After understanding that less constrained setting, we consider the effect of the credibility problem faced by the analyst. In contrast to the analysis in the primary model in which p is public information, analyzing the setting in which the analyst's signal y is public information involves a bit more of a game. In this game where p is not public information, the decision-maker conjectures the analyst's choice of p and the analyst conjectures the decision-maker's response to the analyst's report. In the equilibrium to this game, the choices of both players must maximize their objective functions conditional on each having conjectures that are consistent with the other player's equilibrium choices. Denote the decision-maker's conjecture regarding the analyst's choice of p as $\widehat{p}$. When the public information x and analyst information y is realized, the decision-maker's action choice must satisfy

$$a_{xg} = \frac{\widehat{p}t}{\widehat{p}t + (1-\widehat{p})(1-t)}s + \frac{(1-\widehat{p})(1-t)}{\widehat{p}t + (1-\widehat{p})(1-t)}f \tag{5}$$

and

$$a_{xb} = \frac{(1-\widehat{p})t}{(1-\widehat{p})t + \widehat{p}(1-t)}s + \frac{\widehat{p}(1-t)}{(1-\widehat{p})t + \widehat{p}(1-t)}f, \tag{6}$$

where $t = q$ when $\tilde{x} = h$ and $t = 1 - q$ when $\tilde{x} = l$. It follows that, in any equilibrium $s \geq a_{xg} \geq a_{xb} \geq f$.

Denote the analyst's conjecture regarding the decision-maker's response to realization (x, y) as $\hat{a}_{xy}$. Since in any equilibrium $s \geq a_{xg} \geq a_{xb} \geq f$, consider the analyst's decision choice given x and conjectured actions $s \geq \hat{a}_{xg} \geq \hat{a}_{xb} \geq f$. The analyst's choice of p must maximize

$$tp(\phi\widehat{a}_{xg}-(\widehat{a}_{xg}-s)^2)+(1-t)(1-p)(\phi\widehat{a}_{xg}-(\widehat{a}_{xg}-f)^2)$$
$$+t(1-p)(\phi\widehat{a}_{xb}-(\widehat{a}_{xb}-s)^2)+(1-t)p\left(\phi\widehat{a}_{xb}-(\widehat{a}_{xb}-f)^2\right)-c(p).$$

Given that $c(p)$ is sufficiently convex, an interior choice of precision p that satisfies the first-order condition maximizes the analyst's objective function. Hence, the analyst's choice of p in an equilibrium with an interior choice of p must satisfy

$$(\widehat{a}_{xg}-\widehat{a}_{xb})\left(t(2s-\widehat{a}_{xg}-\widehat{a}_{xb})+(1-t)(\widehat{a}_{xg}+\widehat{a}_{xb}-2f)+\phi(2t-1)\right)-c'(p)=0. \quad (7)$$

An equilibrium precision choice p and action choice function a_{xy} must satisfy (5), (6), and (7) for each $x\in\{h,l\}$ after substituting the players' equilibrium choices for their conjectured choices. Substituting in p for $\hat{p}$ in (5) and (6) and then taking those actions and substituting them in for $\widehat{a}_{xg}$ and $\widehat{a}_{xb}$ in (7) yields the following condition that any equilibrium choice for p, namely p^*_{no}, must satisfy

$$\Delta^2\left(p^*_{no}\right)/\left(2p^*_{no}-1\right)-c'\left(p^*_{no}\right)+\Delta\left(p^*_{no}\right)\phi(2t-1)=0. \quad (8)$$

Proposition 7 *When the analyst's choice of precision is unobservable and the analyst's information y is public, there always exists an equilibrium precision choice, p^*_{no}, in which the analyst gathers no information, $p^*_{no}=1/2$. In addition, if the public signal is favorable, $\tilde{x}=h$, there always exists an equilibrium precision choice, p^*_{no}, such that $p^*_{no}\in(1/2,1)$. Finally, if the public signal is unfavorable, $\tilde{x}=l$, there may exist one or more equilibrium precision choices such that $p^*_{no}\in(1/2,1)$.*

The first point worth noting in Proposition 7 is that there always exists an equilibrium in which the analyst does not provide any information. This equilibrium, which is analogous to the babbling equilibrium that always exists in a standard cheap-talk game, arises because: (1) the analyst has no incentive to gather information if the decision-maker does not respond to the resulting signal, and (2) the decision-maker has no reason to respond to a signal that is believed to be uninformative. Thus, in contrast to cheap-talk games without endogenous information collection that always feature a babbling equilibrium in which the analyst misrepresents his private information, in this setting in which information collection is endogenous, we find that there is always an equilibrium in which the analyst does not provide the decision-maker with any information even though the analyst's signal is public information and hence *cannot* be misrepresented. The second point worth noting is that there always exists one, and perhaps more than one, equilibrium in which the analyst does gather information for at least one of the two realizations of the public signal. It is these interior equilibrium choices for p that are the focus of our remaining analysis.

On comparing the equilibrium condition for p^*_{no} given in (8) with that for p^* given in (4), we observe that any interior precision of the analyst's information depends on the public information, which determines the value for t. Consider first the case when the public information is favorable so $\tilde{x} = h$ and $t = q$. In this case there exists only a signal interior equilibrium choice p^*_{no}. Furthermore, the observation that $\Delta\left(p^*_{no}\right)\phi(2t-1) > 0$ implies that this choice always exceeds the choice that would be made if p were observable, $p^*_{no} > p^*$. The intuition underlying why the precision choice exceeds the precision choice in the case where p is observable is as follows. When the favorable public signal is observed, the analyst believes his signal is more likely to be a good one if he selects a higher level of precision. Because the analyst prefers a higher action from the decision-maker, it follows that the analyst has an incentive to choose a higher precision level than he otherwise would choose in order to increase the probability of getting a higher level of action from the decision-maker. The cost of precision, however, still provides a disincentive to choosing the maximum precision level and an interior choice of precision is sustained as an equilibrium.

Consider the case when the public information is unfavorable so $\tilde{x} = l$ and $t = 1-q$. In this case, any equilibrium choice for the precision p is exceed by the choice made when the the precision choice is observable because $\Delta\left(p^*_{no}\right)\phi(2t-1) < 0$. In this case when the unfavorable public signal is observed, the analyst believes his signal is more likely to be good when the precision level he selects is lower. Given that he prefers a higher action from the decision-maker, it follows that the analyst has an incentive to lower the precision level than he otherwise would choose in order to increase the probability of inducing the higher action. An interior equilibrium can still exist in face of the incentive to choose a lower precision level, however. For such an interior equilibrium to exist, the decision maker's response to the good signal must result in an action that is too high from the perspective of the analyst who has chosen $p = 1/2$. Consequently, the analyst chooses a level of precision $p^*_{no} > 1/2$.[10]

[10]These predictions contrast with Penno (1996) who considers a setting where a firm manager

With an understanding of the game when y is public information established, we next consider how credibility issues affect equilibrium outcomes by assuming the analyst privately observes y. Consider first the case when the favorable public signal is realized, $\tilde{x} = h$. In this case there exists one interior value of precision that can be an equilibrium outcome in the game where credibility is not an issue. When credibility is also an issue, this value of precision, p_{no}^*, is still sustained as an equilibrium outcome if and only if it is weakly greater than $\bar{p}$. Otherwise, the only equilibrium is one in which the analyst gathers no information, $p = 1/2$. Next consider the case when the unfavorable signal is realized, $\tilde{x} = l$. If there exists an interior equilibrium in this case, it must again be true that p_{no}^* exceeds $\bar{p}$. Note, however, that the likelihood that this condition is satisfied when $\tilde{x} = l$ is lower because p_{no}^* must be lower in the case when $\tilde{x} = l$ than in the case when $\tilde{x} = h$. Hence, the analyst is more likely to not collect any information when the public information is unfavorable.

The observation that the analyst's precision choice varies with firm performance provides an explanation of empirical evidence regarding analyst coverage that McNichols and O'Brien (1997) document. They find that analysts are more likely to discontinue coverage on a firm that is performing poorly. The story they offer as an explanation for this finding is that analysts want to avoid jeopardizing their prospects of winning investment banking business by avoiding issuing a sell recommendation. Our model provides another explanation for the correlation they observe in the data: when news is unfavorable, analysts are less likely to be able to credibly communicate their information and, as a consequence, they do not gather any information—they discontinue coverage.

7 Conclusion

The Sarbanes-Oxley Act of 2002 and the settlement between the large brokerage firms and the State of New York in 2002 have led to shrinking of research departments at investment firms. The exodus of analysts has left many firms and, indeed,

observes a public signal about the firm and then privately chooses the precision of a report that the firm will subsequently issue. He finds that the precision of the report that the manager chooses is *decreasing* in the favorableness of the public signal because it lowers the weight investors will place on the subsequent report, which is likely to be less favorable than the previously observed public signal. In our model, the public signal and the analyst's private signal are positively correlated. Therefore, the analyst chooses to gather more precise information following a favorable public signal because he is more likely to observe a favorable signal.

entire industry sectors without analyst coverage, raising the ironic possibility that the new regulations might have made investors that rely on these information intermediaries worse off (see Schack 2003). Furthermore, recent regulatory changes, including Reg FD released in 2000, have greatly increased the amount of information available directly to investors. Against this background, this paper examines analyst information gathering and reporting activities in a setting in which the analyst chooses the precision of information to collect in response to changes in the precision of public information about a firm. A key feature of the model that distinguishes it from the extant reporting literature is that the analyst is not restricted to truthfully report. Rather, recognizing that analyst credibility is an important feature of the analyst environment, we assume that the analyst can report in a self-serving fashion.

Using endogenous information collection coupled with reporting credibility as primary ingredients, this model offers the following insights. First, we consider a setting where the analyst's precision choice is publicly observed and examine how the analyst's information gathering activities vary with the precision of the public information. When the analyst's reporting credibility is not an issue, increases in the precision of the public information cause the analysts to reduce the precision of information they privately collect and communicate. Nevertheless, because the public information substitutes for the private information, investors are better off. On the other hand, when an analyst reporting credibility becomes salient, an increase in the precision of public information causes the analyst to collect more precise information. In this case, the public information has a complementary effect on the analyst information gathering activities and an investor is again made better off. However, if the precision of the public information continues to increase, then a threshold is reached where an analyst can no longer economically gather sufficient information necessary to credibly communicate with investors. As a consequence, the analyst drops coverage of the firm or leaves the market. The analyst's decision to drop coverage makes the investors worse off—which aligns with the concern that the recent regulations might make investors worse off. Moreover, we find, in some circumstances, that investors would be better off if the public information was never introduced than to have the public information that drives analysts from the market.

While an analyst stock report might often evidence the precision of the analyst's information, at times investors might be uncertain about the precision of the analyst information. We find that the analyst, after observing favorable public information, gathers more precise information when the precision choice is not publicly observable than when the analyst's precision choice is publicly observable, and conversely, the analyst, after observing unfavorable public information, chooses less precise information or is more likely to discontinue coverage when the precision choice is not publicly observable relative to when the analyst's precision choice is common knowledge.

Because of the import of the recent changes in the structure of the analyst environment, the paper has focused on the information gathering and reporting activities of analysts. The model, however, is quire general. The insights might be applied to the voluntary information gathering activities of a firm manager in the presence of changes in the mandatory reporting environment, particularly when the manager's and investors' interests are imperfectly aligned and the manager's voluntary disclosure is not verifiable—such as in the case of management earnings forecasts. The insights also might be applied to the information gathering and communicating behavior of a seller of an experience good when the potential buyer has access to another sources of unbiased information—such as *Consumer Reports*—that reveals the properties of the seller's product. Alternatively, the insights might be applied to the interaction between a venture capitalist and a firm that has private information about an innovative technology for which it is seeking venture financing.

8 Appendix

This appendix contains the proofs of the lemmas, propositions, and corollaries.

Proof establishing power cost function is well defined:

Consider the power cost function

$$c(p) = \left(\frac{p-1/2}{1-p}\right)^n$$

where $n > 2$. The first and second derivatives are

$$c'(p) = \frac{n}{2(p-1/2)(1-p)}c(p) > 0$$

and

$$c''(p) = \frac{n(n+4p-3)}{(2(p-1/2)(1-p))^2}c(p) > 0 \text{ if } n > 1.$$

The second derivative divided by the first derivative is

$$\frac{c''(p)}{c'(p)} = \frac{n+4p-3}{2(p-1/2)(1-p)}.$$

Observe that

$$\frac{(1-3p(1-p))}{(p(1-p)(p-1/2))} < \frac{n+4p-3}{2(p-1/2)(1-p)} \text{ if and only if } \frac{2p^2-3p+2}{p} < n$$

Since the expression $(2p^2-3p+2)/p$ is strictly decreasingly in p, it follows that the inequality is always satisfied if $n > 2$. ■

Proof of Lemma 1:

At this stage the analyst's cost of gathering information is sunk and p, which is commonly observed, is fixed. If the analyst communicates his private information y when the other information x is realized, then the decision-maker's action after receiving the analyst's report is $a = E[\tilde{\alpha}|x,y]$. Given the decision-maker's action, the analyst reports observing g if and only if

$$E\left[\phi E[\tilde{\alpha}|x,g] - (\tilde{\alpha} - E[\tilde{\alpha}|x,g])^2|g,x\right] \geq E\left[\phi E[\tilde{\alpha}|x,b] - (\tilde{\alpha} - E[\tilde{\alpha}|x,b])^2|g,x\right]. \quad (9)$$

This truth-telling condition is trivially satisfied because the analyst never wants to dissemble and induce a lower action than the one the decision-maker would take given the analyst's information. The analyst reveals observing b if and only if

$$E\left[\phi E[\tilde{\alpha}|x,b] - (\tilde{\alpha} - E[\tilde{\alpha}|x,b])^2 |b,x\right] \geq E\left[\phi E[\tilde{\alpha}|x,g] - (\tilde{\alpha} - E[\tilde{\alpha}|x,g])^2 |b,x\right]. \tag{10}$$

This condition can be shown to be satisfied if and only if expression

$$E[\tilde{\alpha}|x,g] - E[\tilde{\alpha}|x,b] - \phi \geq 0 \tag{11}$$

is satisfied.

It follows from expression (11) that a necessary and sufficient condition for the analyst to reveal y when $\tilde{x} = l$ is

$$\begin{aligned} & E[\tilde{\alpha}|l,g] - E[\tilde{\alpha}|l,b] - \phi \\ = & \frac{(2p-1)\,q\,(1-q)\,(s-f)}{(p\,(1-q) + (1-p)\,q)\,((1-p)\,(1-q) + pq)} - \phi \geq 0, \end{aligned} \tag{12}$$

and for the analyst to reveal y when $\tilde{x} = h$ is

$$\begin{aligned} & E[\tilde{\alpha}|h,g] - E[\tilde{\alpha}|h,b] - \phi \\ = & \frac{(2p-1)\,q\,(1-q)\,(s-f)}{(p\,(1-q) + (1-p)\,q)\,((1-p)\,(1-q) + pq)} - \phi \geq 0. \end{aligned} \tag{13}$$

The incentive compatibility expressions (12) and (13) are identical; hence, without loss of generality consider (12). When $q = 1/2$, then (12) can be expressed as $(2p-1)\,(s-f) - \phi \geq 0$. Solving for p yields $p \geq 1/2 + \phi/\left(2\,(s-f)\right)$. On the other hand, when $q \in (1/2, 1)$, Solving for p in (12) yields two roots:

$$p_1 = \frac{1}{2} - \frac{2q\,(1-q)\,(s-f) + \sqrt{4q^2\,(1-q)^2\,(s-f)^2 + \phi^2\,(2q-1)^2}}{2\phi\,(2q-1)^2} < \frac{1}{2}$$

and

$$p_2 = \frac{1}{2} + \frac{\sqrt{4q^2\,(1-q)^2\,(s-f)^2 + \phi^2\,(2q-1)^2} - 2q\,(1-q)\,(s-f)}{2\phi\,(2q-1)^2} > \frac{1}{2}.$$

Hence, the truth-telling constraint requires

$$p \geq \bar{p} \equiv \frac{1}{2} + \frac{\sqrt{4q^2 (1-q)^2 (s-f)^2 + \phi^2 (2q-1)^2} - 2q(1-q)(s-f)}{2\phi (2q-1)^2}. \blacksquare \tag{14}$$

Proof of Lemma 2:

Given the first-order condition, the optimal choice of p^* is such that

$$\begin{aligned} \partial U_i (.) / \partial p &= \frac{(2p-1) q^2 (1-q)^2 (s-f)^2}{((1-p) q + (1-q) p)^2 (qp + (1-q)(1-p))^2} - c'(p) \\ &= \frac{\Delta^2 (p^*)}{(2p-1)} - c'(p^*) = 0. \end{aligned}$$

Since U_i is a twice differentiable function, evaluating $\partial^2 U_i / \partial p^2$ yields

$$\frac{\partial \left(\Delta^2 (p) / (2p-1) - c'(p) \right)}{\partial p} = \frac{2\Delta (p) \Delta' (p)}{(2p-1)} - \frac{2\Delta^2 (p)}{(2p-1)^2} - c''(p).$$

Evaluating the expression $\partial^2 U_i / \partial p^2$ at p^* where p^* is such that $c'(p^*) = \Delta^2 (p^*) / (2p-1)$ yields

$$\frac{2c'(p^*) \Delta'(p)}{\Delta (p)} - \frac{2c'(p^*)}{(2p-1)} - c''(p).$$

For a unique maximum it must be the case that

$$\frac{c''(p)}{c'(p^*)} > \left(\frac{2\Delta'(p)}{\Delta(p)} - \frac{2}{(2p-1)} \right).$$

Substituting in for $\Delta(p)$ in the right hand side of the inequality gives

$$\left(\frac{2\Delta'(p)}{\Delta(p)} - \frac{2}{(2p-1)} \right) = \frac{2}{(2p-1)} \left(\frac{1}{p(1-p)(2q-1)^2 + q(1-q)} - 3 \right).$$

Since the expression is increasing in q, the following is a sufficient condition for the objective function to be strictly quasiconcave

$$\frac{c''(p)}{c'(p^*)} > \frac{1 - 3p(1-p)}{p(1-p)(p-1/2)},$$

which the cost function $c(p)$ is assumed to satisfy. ■

Proof of Proposition 3:

For the analyst to credibly communicate his private information y in the reporting game, it follows from (13) that p must be such that

$$\begin{aligned} & \frac{q^2(1-q)^2(2p-1)(s-f)^2}{((1-p)q+(1-q)p)^2(qp+(1-q)(1-p))^2} \\ & -\frac{\phi q(1-q)(s-f)}{((1-p)q+(1-q)p)(qp+(1-q)(1-p))} \\ \geq \; & 0. \end{aligned}$$

Further, it follow from (4) that p^* is such that

$$\frac{q^2(1-q)^2(2p^*-1)(s-f)^2}{((1-p^*)q+(1-q)p^*)^2(qp^*+(1-q)(1-p^*))^2}-c'(p^*)=0.$$

It follows that $p^* \geq \bar{p}$ if and only if

$$\frac{\phi q(1-q)(s-f)}{((1-p^*)q+(1-q)p^*)(qp^*+(1-q)(1-p^*))} \leq c'(p^*).$$

When $p^* \in (1/2, \bar{p})$, the analyst will only gather information if he can credibly communicate it in the reporting game. Thus, to determine the precision of information the analyst will choose to gather, we compare the analyst's expected utility from gathering the minimum precision of information that will allow him to credibly communicate in the reporting game, i.e., $p=\bar{p}$, denoted $U_i(\bar{p})$, with the expected payoff from not gathering any private information, i.e., $p=1/2$, denoted $U_i(1/2)$. When $p^* \in (1/2, \bar{p})$, the analyst prefers $\bar{p}$ if and only if

$$U_i(1/2)-U_i(\bar{p})<0,$$

or equivalently,

$$c(\bar{p})<\frac{q^2(2\bar{p}-1)^2(1-q)^2(s-f)^2}{(\bar{p}(1-q)+(1-\bar{p})q)((1-\bar{p})(1-q)+\bar{p}q)}. \tag{15}$$

Hence, if $p^* \in (1/2, \bar{p})$ and if (15) is satisfied, then the analyst gathers more information than he would if his incentives were not misaligned with those of the decision-maker—i.e., the analyst over-invests in the quality of information he gathers.

Conversely, if $p^* \in (1/2, \bar{p})$ and if (15) is not satisfied, then the analyst gathers less information than he would if his incentives were not misaligned with those of the decision-maker—i.e., the analyst under-invests in the quality of information he gathers. ■

Proof of Corollary 4:

First consider $\partial \bar{p}/\partial q$. When $q \in (1/2, 1)$ and $\bar{p}$ given in (14), observe that

$$\begin{aligned}
\frac{\partial \bar{p}}{\partial q} &= \frac{(s-f)\sqrt{4q^2(1-q)^2(s-f)^2+\phi^2(2q-1)^2} - 2q(s-f)^2(1-q) - \phi^2(2q-1)^2}{\sqrt{4q^2(1-q)^2(s-f)^2+\phi^2(2q-1)^2}\phi(2q-1)^3} \\
&\propto (s-f)\sqrt{4q^2(1-q)^2(s-f)^2+\phi^2(2q-1)^2} - 2q(s-f)^2(1-q) - \phi^2(2q-1)^2 \\
&> 0.
\end{aligned}$$

To establish the last inequality note that

$$(s-f)\sqrt{4q^2(1-q)^2(s-f)^2+\phi^2(2q-1)^2} - 2q(s-f)^2(1-q) + \phi^2(2q-1)^2 > 0,$$

or equivalently,

$$\begin{aligned}
& (s-f)^2\left(4q^2(1-q)^2(s-f)^2+\phi^2(2q-1)^2\right) - \left(2q(s-f)^2(1-q)+\phi^2(2q-1)^2\right)^2 \\
=\;& \phi^2(2q-1)^4\left((s-f)^2-\phi^2\right) \\
>\;& 0.
\end{aligned}$$

To establish that $\phi^2(2q-1)^4((s-f)^2-\phi^2) > 0$, observe that

$$\frac{(2p-1)q(1-q)}{(p(1-q)+(1-p)q)((1-p)(1-q)+pq)} < 1$$

for all p. Therefore, for the truth-telling constraint to be satisfied, it must be the case that $\phi/(s-f) < 1$; otherwise the truth-telling condition can never be satisfied.

Second $\partial p^*/\partial q$. It follows from Lemma 2 that p^* is such that

$$\partial U_i/\partial p|_{p^*} = \frac{q^2(1-q)^2(2p^*-1)(s-f)^2}{((1-p^*)q+(1-q)p^*)^2(qp^*+(1-q)(1-p^*))^2} - c'(p^*) = 0.$$

Therefore, the implicit function theorem yields

$$\frac{\partial p^*}{\partial q}=\frac{2q\left(1-q\right)\left(2p-1\right)\left(s-f\right)^2p\left(1-p\right)\left(2q-1\right)}{\left(\left(1-p\right)q+\left(1-q\right)p\right)^3\left(qp+\left(1-q\right)\left(1-p\right)\right)^3}/\frac{\partial\left(\partial U_i\left(.\right)/\partial p|_{p^*}\right)}{\partial p^*}.$$

Since $U_i\left(p\right)$ is a strictly quasi-concave and twice differentiable function, it follows that the denominator is strictly negative. Hence,

$$\frac{\partial p^*}{\partial q}\propto\begin{cases}-\frac{2q(1-q)(2p-1)(s-f)^2p(1-p)(2q-1)}{((1-p)q+(1-q)p)^3(qp+(1-q)(1-p))^3}<0 & \text{when } q\in(1/2,1)\\ 0 & \text{when } q=1/2\end{cases}.\ \blacksquare$$

Proof of Corollary 5:

The arguments showing $\partial\bar{p}/\partial\phi>0$, $\partial\bar{p}/\partial\left(s-f\right)<0$, $\partial\bar{p}/\partial\phi=0$ are straightforward. Consider $\partial p^*/\partial\left(s-f\right)$. Applying the implicit function theorem to Lemma 2 yields

$$\frac{\partial p^*}{\partial\left(s-f\right)}=-\frac{2q^2\left(1-q\right)^2\left(2p-1\right)\left(s-f\right)}{\left(\left(1-p\right)q+\left(1-q\right)p\right)^2\left(qp+\left(1-q\right)\left(1-p\right)\right)^2}/\frac{\partial\left(\partial U_i\left(.\right)/\partial p|_{p^*}\right)}{\partial p^*}.$$

Since U_i is a strictly quasi-concave and twice differentiable function, it follows that the denominator is strictly negative. Hence,

$$\frac{\partial p^*}{\partial\left(s-f\right)}\propto\frac{2q^2\left(1-q\right)^2\left(2p-1\right)\left(s-f\right)}{\left(\left(1-p\right)q+\left(1-q\right)p\right)^2\left(qp+\left(1-q\right)\left(1-p\right)\right)^2}>0.\ \blacksquare$$

Proof of Corollary 6:

First, we establish that $\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)/\partial q>0$. Observe that

$$\begin{aligned}\frac{\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)}{\partial q} &= \frac{\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)}{\partial q}+\frac{\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)}{\partial p^*}\frac{\partial p^*}{\partial q}\\ &\propto \left(p^*\right)^2\left(1-p^*\right)^2\left(2q-1\right)+q^2\left(1-q\right)^2\left(2p-1\right)\frac{\partial p^*}{\partial q}. \quad (16)\end{aligned}$$

Consider $\partial p^*/\partial q$. Applying the implicit function theorem to (4) yields

$$\frac{\partial p^*}{\partial q} = -\frac{\frac{\partial\left(\partial U_i/\partial p|_{p^*}\right)}{\partial q}}{\frac{\partial\left(\partial U_i/\partial p|_{p^*}\right)}{\partial p^*}} = -\frac{-\frac{2q(1-q)(2p^*-1)p^*(1-p^*)(2q-1)(s-f)^2}{((1-p^*)q+(1-q)p)^3(qp^*+(1-q)(1-p^*))^3}}{\frac{2q^2(1-q)^2(s-f)^2\left(3p^*(2q-1)^2(p-1)+1-3q+3q^2\right)}{((1-p^*)q+(1-q)p^*)^3(qp^*+(1-q)(1-p^*))^3} - c''(p^*)}. \tag{17}$$

Observe that

$$\begin{aligned}\frac{\partial\left(\partial U_i/\partial p|_{p^*}\right)}{\partial p^*} &= \frac{2q^2(q-1)^2(s-f)^2\left(3p^*(2q-1)^2(p^*-1)+1-3q+3q^2\right)}{((1-p^*)q+(1-q)p^*)^3(qp^*+(1-q)(1-p^*))^3} - c''(p^*)\\ &< 0\end{aligned}$$

because U_i is a strictly quasi-concave and twice differentiable function.

Substituting (17) into (16), factoring, and using the fact that $\partial\left(\partial U_i/\partial p|_{p^*}\right)/\partial p^* < 0$ yields

$$\begin{aligned}&\frac{\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)}{\partial q}\\ \propto\ & p^*(1-p^*)c''(p^*) - \frac{2q^2(1-q)^2(1-3p^*(1-p^*))(s-f)^2}{((1-p^*)q+(1-q)p^*)^2(qp^*+(1-q)(1-p^*))^2}.\end{aligned}$$

On substituting $c'(p^*) = \Delta^2(p^*)/(2p^*-1)$, given in (4), into the assumption that $c''(p)/c'(p) > (1-3p(1-p))/(p(1-p)(p-1/2))$, yields

$$c''(p^*) > \frac{2(s-f)^2(1-q)^2q^2\left(1-3p^*+3(p^*)^2\right)}{(1-p^*)p^*((1-p^*)(1-q)+p^*q)^2(p^*(1-q)+(1-p^*)q)^2}. \tag{18}$$

Using the relation in (18), it follows that

$$\begin{aligned}&\frac{\partial\left(-E_y\left[var\left[\tilde{\alpha}|x,y;p^*\right]\right]\right)}{\partial q}\\ \propto\ & p^*(1-p^*)c''(p^*) - \frac{2q^2(1-q)^2(1-3p^*(1-p^*))(s-f)^2}{((1-p^*)q+(1-q)p^*)^2(qp^*+(1-q)(1-p^*))^2}\\ >\ & p^*(1-p^*)\left(\frac{2(s-f)^2(1-q)^2q^2\left(1-3p^*+3(p^*)^2\right)}{(1-p^*)p^*((1-p^*)(1-q)+p^*q)^2(p^*(1-q)+(1-p^*)q)^2}\right)\\ & -\frac{2q^2(1-q)^2(1-3p^*(1-p^*))(s-f)^2}{((1-p^*)q+(1-q)p^*)^2(qp^*+(1-q)(1-p^*))^2}\\ =\ & 0.\end{aligned}$$

Second, we show the decision-maker's quality of information falls discontinuously at $\bar{q}$. Observe that when $c(\bar{p}) = \Delta(\bar{p})\, q(1-q)(2\bar{p}-1)(s-f)$ and $q = \bar{q}$, then $U_i(1/2) = U_i(\bar{p})$, or equivalently,

$$\begin{aligned} & \phi E[\tilde{\alpha}|x] - q(1-q)(s-f)^2 \\ = \; & \phi E_y[E[\tilde{\alpha}|x,y]] - \frac{\bar{p}(1-\bar{p})\, q(1-q)(s-f)^2}{(\bar{p}(1-q)+(1-\bar{p})\,q)\,((1-\bar{p})(1-q)+\bar{p}q)} - c(\bar{p}) . \quad (19) \end{aligned}$$

The law of iterated expectations, $E[\tilde{\alpha}|x] = E_y[E[\tilde{\alpha}|x,y]]$ implies (19) may be expressed as

$$\begin{aligned} -Var[\tilde{\alpha}|x] & \equiv -q(1-q)(s-f)^2 \\ & = -\frac{\bar{p}(1-\bar{p})\, q(1-q)(s-f)^2}{(\bar{p}(1-q)+(1-\bar{p})\,q)\,((1-\bar{p})(1-q)+\bar{p}q)} - c(\bar{p}) \\ & < -\frac{\bar{p}(1-\bar{p})\, q(1-q)(s-f)^2}{(\bar{p}(1-q)+(1-\bar{p})\,q)\,((1-\bar{p})(1-q)+\bar{p}q)} \equiv -E_y[var[\tilde{\alpha}|x,y;\bar{p}]] . \end{aligned}$$

Hence, we observe there exists a $q = q + \varepsilon > q^*$ for $\varepsilon > 0$ such that

$$-Var[\tilde{\alpha}|x] < -E_y[var[\tilde{\alpha}|x,y;\bar{p}]] . \blacksquare$$

Proof of Proposition 7:

Because $\Delta(p = 1/2) = 0$, it follows from equation (8) that $p = 1/2$ is an equilibrium level of precision for $t = q$ or $t = 1 - q$. Consider the case in which $t = q$. Rewrite equation (**??**) as follows

$$(1/2)\Delta(p)^2 - c'(p)(p-1/2) + \Delta(p)\,\phi(2t-1)(p-1/2) = 0.$$

The first derivative with respect to p is

$$\begin{aligned} & 2\frac{\Delta'(p)}{\Delta(p)}\left((1/2)\Delta(p)^2 + \Delta(p)\,\phi(2t-1)(p-1/2)\right) \\ & -\frac{1}{(p-1/2)}\left(c'(p)(p-1/2) - \Delta(p)\,\phi(2t-1)(p-1/2)\right) \\ & -c''(p)(p-1/2) - \frac{\Delta'(p)}{\Delta(p)}\Delta(p)\,\phi(2t-1)(p-1/2). \end{aligned}$$

If the equation is satisfied at p, this expression can be rewritten as

$$2\frac{\Delta'(p)}{\Delta(p)}c'(p)(p-1/2) - c''(p)(p-1/2) - \frac{(1/2)\Delta(p)^2}{(p-1/2)}$$
$$-\frac{\Delta'(p)}{\Delta(p)}\Delta(p)\,\phi(2t-1)(p-1/2),$$

where

$$\frac{\Delta'(p)}{\Delta(p)} = \frac{1}{2(p-1/2)}\frac{1-2p(1-p)(2t-1)^2-2t(1-t)}{p(1-p)(2t-1)^2+t(1-t)}.$$

Hence, the above expression can be written as

$$\frac{1-2p(1-p)(2t-1)^2-2t(1-t)}{p(1-p)(2t-1)^2+t(1-t)}c'(p) - c''(p)(p-1/2) - \frac{(1/2)\Delta(p)^2}{(p-1/2)}$$
$$-(1/2)\frac{1-2p(1-p)(2t-1)^2-2t(1-t)}{p(1-p)(2t-1)^2+t(1-t)}\Delta(p)\,\phi(2t-1).$$

Exploiting the fact that (8) holds in equilibrium allows this expression to be rewritten as

$$\left(\frac{1}{p(1-p)(2t-1)^2+t(1-t)} - 3\right)c'(p) - c''(p)(p-1/2)$$
$$-\left(\frac{1}{2p(1-p)(2t-1)^2+2t(1-t)} - 2\right)\Delta(p)\,\phi(2t-1).$$

Noting that $p(1-p)(2t-1)^2+t(1-t)$ is decreasing in t and that $2t-1>0$ because $t=q>1/2$ implies that the above expression is greater than

$$\left(\frac{1-3p(1-p)}{p(1-p)}\right)c'(p) - c''(p)(p-1/2),$$

which is proportional to

$$(1-3p(1-p))c'(p) - p(1-p)(p-1/2)c''(p).$$

Hence, there exists only an single equilibrium in which $p\in(1/2,1)$ if

$$(1-3p(1-p))\,/\,(p(1-p)(p-1/2)) \leq c''(p)/c'(p)$$

for all p, which is true by assumption.

Finally, consider the case in which $t = 1 - q$. In this case, there may or may not exist an equilibrium in which $p \in (1/2, 1)$ and, sometimes there may exist more than one equilibrium in which $p \in (1/2, 1)$. The proof follows from an example in which there is no equilibrium when $p \in (1/2, 1)$, one equilibrium when $p \in (1/2, 1)$, and two equilibria when $p \in (1/2, 1)$. For the examples, let $c(p) = ((p - 1/2) / (1 - p))^3$ and $q = .85$. If $\phi = 2$ and $s - f = 2$, then there does not exist a $p \in (1/2, 1)$ that satisfies the equilibrium condition. If $\phi = 1$ and $s - f = 2$, then $p = .5227$ is the only $p \in (1/2, 1)$ that satisfies the equilibrium condition. If $\phi = 110$, $s - f = 150$, then $p = .9072$ and $p = .5584$ both satisfy the equilibrium condition. ■

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Figure 1: Time line of events

The unknown state α assumes the values s or f with equal probability. In stage one, the analyst and decision-maker observe the public information x, which is either h or l, with probability $Pr(h|s) = Pr(l|f) = q$.

Information gathering stage

In stage two, the analyst chooses the precision p of his private information y, which is either g or b, with probability $Pr(g|s) = Pr(b|f) = p$. The cost function $c(p)$ reflects the analyst's cost of gathering information with precision p.

Reporting stage

In stage three, the analyst observes his private information y and sends a report r, which need not be truthful, to the decision-maker. The decision-maker then chooses an action a. The parameter φ denotes extent to which the players' interests are misaligned.

In stage four, the state of nature α is realized, and the analyst's payoff U_i and the decision-maker's payoff U_d are determined.