

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 in a self-serving fashion and face limited regulation regarding their communication. Other sources have little incentive to dissemble or face fairly stringent regulation regarding their communication. Investors, for instance, can obtain information from sell-side analysts who face relatively little regulation regarding their communication and also from a firm's audited financial statements where regulation plays a significant role in the information disclosed. This study analyzes how changes in the disclosure of public information influences an information intermediary's costly information gathering activities and subsequent strategic communication to a decision-maker.

In our model, an information intermediary, which we call an analyst, acquires private information about a firm and communicates with a decision-maker who takes an action that affects the interests of both players. As is typical in the equity analyst environment, the analyst's and decision-maker's interests diverge (see Michaely and Womack 1999; Lin and McNichols 1998). In addition to the analyst's report, the decision-maker also observes public information about the firm. We explored how the precision of this other public information affects the analyst willingness to gather costly information about the firm and then communicate it to the decision-maker.

This paper highlights that changes in publicly observed information affects an analyst's behavior in two ways. When the analyst can credibly communicate privately observed information, we find 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 so the analyst has greater incentives to gather lower quality information. We find that the improvement in the other information, however, offsets the fall in the quality of the analyst's information. Consequently, the quality of the decision-maker's information increases when the quality of the public information increases even though the quality of the analyst information decreases.

The second way in which public information can affect an analyst's behavior arises when the analyst's credibility is in doubt, possibly because the analyst's incentives

are sufficiently misaligned with those of investors. In these circumstances, improving the quality of the public information makes it harder for the analyst to credibly communicate. In particular, an increase in the quality of the other information or a decrease in the quality of the analyst's information makes the decision-maker's action less responsive to the analyst's information. If the decision-maker is not sufficiently responsive to the analyst's information, the analyst exaggerates his report in an attempt to influence the decision-maker. This exaggeration undermines the analyst's ability to communicate credibly. As a consequence, when the quality of the other information becomes sufficiently high, the analyst responds by choosing to acquire higher quality information to facilitate credible communication, or he simply gives up and discontinues firm coverage. When the analyst drops coverage, we find that an improvement in the quality of the public information can lead to fall in the total quality of the decision-maker's information.

In summary, the model suggests that competition arising from improvements in the quality of the other information lead to a marginal reduction in analyst information gathering when credible communication issues are minimal, marginal increases in analyst information gathering when credible communication issues are more pronounced and information gathering costs are low, and the analyst dropping coverage (or leaving the market) when credible communication issues are more pronounced and information gathering costs are high. In the first instance, the other information partially crowds out analyst information but such crowding out is not sufficient to undermine the benefit obtained from higher quality public information. In the second instance, the other information leads the analyst to improve his information gathering, which suggests that the public information offers an incremental benefit to the decision-maker. In the final instance, the other information completely crowds out the analyst information and such crowding out actually can reduce the total information the decision-maker obtains.

More generally, these insights might be applied to any setting where decision-makers obtain information from sources that strategically release information and also from sources that release information in an impartial manner. For example, our analysis suggests that auditors may obtain less information from managers for assessing the fair valuation of an asset when the auditor has greater access to outside expertise regarding the valuation of such assets; or it suggests consumers may obtain less information from self-interested sellers when consumers have access to information

from *Consumer Reports*, a non-profit organization that provides unbiased product ratings and reviews.

While the model's insights can be applied to various settings, we find them to be quite useful in 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. 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 analyst 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). An important contribution of this study, therefore, is to show how alternative sources of information affect analyst information gathering activities, the integrity of their communication with investors, and whether investors are ultimately better off as a consequence of changes in the amount of publicly available information.

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. A substantial literature has built on the cheap-talk model first examined in Crawford and Sobel (1982). One strand related to our paper has extended this model by examining the effect of multiple experts (e.g., analysts) on the communication game (e.g., Austen-Smith 1993; Krishna and Morgan 2001; Wolinsky 2002; Battaglini 2004; and Morgan and Stocken 2008). We can interpret the other information source in our model as an unbiased expert. In contrast to these papers that exogenously endow the experts with information, we examine a setting where it is costly for the expert to gather information and consider how the presence of the unbiased information source affects the information that the expert gathers and

communicates.¹

Several papers examine disclosure models in which information gathering is endogenous. Hayes (1998) examines an analyst's incentives to gather and truthfully 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. Pae (1999) explores a manager's acquisition of costly private information about the consequence of the manager's productive effort in an environment where the manager can decide to disclose the information but must do so truthfully. 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. In addition, much work examines 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). A feature of this work, like much of the extant literature examining information reporting decisions (e.g., Verrecchia 1983; Dye 1985; Penno 1997; 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. Hence, a contribution of our paper is to examine information gathering activities when reporting credibility is an important characteristic of the reporting environment.

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. Their modeling frameworks and the questions they address, however, 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 influences an analyst's information gathering and communication. Section 5 considers how

¹Other studies within the cheap talk literature extend the Crawford and Sobel (1982) framework by introducing multiple decision-makers (e.g., Farrell and Gibbons 1989; Newman and Sansing 1993; and 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.

changes in the precision of public information affects 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 information intermediary, which we call 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 the successful, s , and failure, f , state realizations are equally likely to occur.²

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 $x = h$ conditional on $\alpha = s$ and the probability that $x = l$ conditional on $\alpha = f$ 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 analyst observes the realization of the public information x before choosing the precision of his private information. 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.

In the second or *information gathering* stage, the analyst chooses whether to invest in a costly information generating technology to acquire private 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) $\lim_{p \rightarrow 1/2} c'(p)/(p - 1/2) \rightarrow 0$; (iii) $\lim_{p \rightarrow 1} c'(p) \rightarrow \infty$; and (iv) $c''(p)/c'(p) > (1 - 3p(1 - p))/(p(1 - p)(p - 1/2))$

²As 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).

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 $p = 1/2$.

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 $a \in \mathfrak{R}$ given her information Ω_d to maximize

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

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. When the analyst chooses a report r , the cost of gathering information is sunk, and consequently, the analyst chooses the report r given his information Ω_e to maximize

$$U_i = E[\phi a - (\tilde{\alpha} - a)^2 | \Omega_e], \quad (2)$$

where $\phi > 0$.³ 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 Nathan

³We can also assume $\phi < 0$ without altering the flavor of the results.

1995, Grossman and Helpman 2001; Morgan and Stocken 2003).⁴

In the fourth stage, the state of nature α is realized and the analyst's and decision-maker's payoffs are determined. 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 $U_i = E[\phi a - (\tilde{\alpha} - a)^2 - c(p) | \Omega_e]$ and the analyst's report r maximizes $U_i = E[\phi a - (\tilde{\alpha} - a)^2 | \Omega_e]$.

Like most cheap-talk games, there are multiple equilibria. However, because the analyst's private information takes the form of a binary signal, there are only two possible classes of equilibria: one in which the analyst fails to communicate any of his private information—the decision-maker is unable to infer y ; and one in which the analyst communicates all of his private information—the decision-maker is able to infer y . There always exists equilibria in which the analyst does not communicate his private information (i.e., babbling equilibria). There may or may not exist equilibria in which the analyst communicates his private information. Within the class of equilibria in which communication occurs, we focus on the *truthful communication* equilibrium—the equilibrium in which $r = y$ for all y . This focus is without loss of 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. When a truthful communication equilibrium exists, we say the analyst communicates his private information, and conversely, when a truthful communication equilibrium fails to exist, we say the analyst fails to communicate.

⁴While the Sarbanes-Oxley Act enacted on July 25, 2002 was drafted to strengthen the independence of security analysts (Razae, 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, Mayhew (2008) finds that firm management favor those analysts in conference calls who have bullish stock recommendations on the firm.

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. The decision-maker observes the precision of the analyst's private information, but not the realization of his private information. Institutionally, 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.

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 information signal and his private information signal. 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 $y = g$. It follows that the analyst is always willing to reveal when $y = g$, but may want to mislead the decision-maker when $y = b$ by claiming that $y = g$. 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 $y = b$ if the action induced from claiming that $y = g$ is much higher than the action preferred by the analyst when $y = b$. 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 for \tilde{x} , the difference in actions selected by the decision-maker when he believes he knows y is

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

$\Delta(p)$ 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 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

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

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*

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

In our setting where the analyst's signal is privately observed, Lemma 1 implies that only levels of precision in excess of \bar{p} permit credible communication. As a

consequence, the analyst must choose a p in excess of \bar{p} if he wishes to affect the decision-maker's action. If the analyst selects a p in excess of \bar{p} , his utility is identical to that in the case where y is observed. Hence, if the analyst restricts himself to a choice in excess of \bar{p} , he would choose p^* if $p^* \geq \bar{p}$. Given that the objective is quasiconcave in p , if $p^* < \bar{p}$, then the analyst can choose \bar{p} and communicate or choose $p = 1/2$ and not impact the decision-maker's action. The next proposition characterizes the analyst's optimal choice of the precision of his private information and whether or not communication occurs.

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 y after observing the realization of the public information $x \in \{h, l\}$. 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 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 x .

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 that maximizes the analyst's objective 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 imprecise 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 firm 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, Matsumoto, and Miller 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 amount of information they collect, others have responded to the competition from other sources by increasing the quality of their analysis, and yet others have discontinued coverage of firms.

Remark 1 is empirically unsatisfying since it suggests that “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 that maximizes the analyst’s objective 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 report is credible, or equivalently, 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.

With the intuition underlying Corollary 5 in hand, 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 additional 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 or those who have substantial equity positions in the firm's stock, may be more inclined 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 coverage. Finally, analysts with more moderate conflicts of interest will be more inclined to increase their coverage 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 payoffs about which decision-makers are highly and are viewed as having high risk, will face relatively modest declines in analyst attention, those that decision-makers view as having low risk will have analysts drop coverage, and those that are viewed as being moderately risky 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, then the analyst responds to more precise public information by either gathering more precise

information or alternately dropping coverage of firms.

The presence of a reporting stage in which reporting credibility is an important ingredient dramatically affects the precision of information that the analyst gathers. Our model, which emphasizes the role of reporting credibility for understanding the information intermediary’s behavior, contrasts with some of the discretionary disclosure models commonly examined in the accounting literature that assume any disclosure must be truthful, although the sender—typically a firm—can choose to withhold information (e.g., Verrecchia 1983; Dye 1985; Jung and Kwon 1988; Arya and Mittendorf 2007). Thus, our model offers an additional reason why in voluntary disclosure settings in which information is non-verifiable (such as in the case of earnings forecasts), senders might choose to invest excessively in gathering information, or alternatively choose to not gather and disclose any information.

5 Quality of Decision-Maker Information

We considered how the precision of the analyst 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. In this model, the 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 U_d .

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 expected utility—or quality of information—when the analyst chooses $p = p^*$ is given by

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

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, using the envelope theorem, we observe that an increase in precision of the public information q leads to an increase in the decision-maker's information; in particular, observe

$$\begin{aligned} & \frac{\partial U_d(p^*)}{\partial q} \\ &= \partial(-E_y[\text{var}[\tilde{\alpha}|x, y; p^*]])/\partial q + \frac{dp^*}{dq} \partial(-E_y[\text{var}[\tilde{\alpha}|x, y; p^*]])/\partial p^* \\ &= \frac{(2q-1)(p^*)^2(1-p^*)^2(s-f)^2}{(p^*(1-q) + (1-p^*)q)^2((1-p^*)(1-q) + p^*q)^2} > 0. \end{aligned}$$

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 $p = \bar{p}$. For this level of precision, the decision-maker's expected utility is given by

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

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 expected utility to increase with an increase in the precision of the public information; that is $\partial U_d(\bar{p})/\partial q > 0$.

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 than 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 expected utility is given by

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

This latter observation implies that, an increase in q above some value \bar{q} causes the decision-maker's expected utility 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 expected utility 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, verified, 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 expected utility in the absence of disclosure, which is equivalent to $q = 1/2$, and the expected utility 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 it 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

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

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 $q \in (1/2, 1)$. While the presence of any public information crowds out the analyst's information, the decision-maker, however, benefits from observing the public information. The decision-maker's quality of information is given by

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

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.

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 length 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; 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 $3 - x$ (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 ex ante expected utility $U_d = -E[Var[\tilde{\alpha}|x, r]] = -0.04$. 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 ex ante expected utility is $U_d = -E[Var[\tilde{\alpha}|r]] = -0.03$. Hence, the decision-maker is ex ante better off when the other information is unavailable.⁵

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

⁵When 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 partitioned equilibria to this game requires finding solutions to non-linear, second-order difference equations. These equations generally do not have analytic solutions.

expertise from the depth and clarity of a stock report, even though it is not possible to infer exactly what the analyst believes. At times, however, the decision-maker is 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, we again determine the choice of p depending on whether the analyst is able to communicate in the reporting stage. When the analyst cannot communicate his private information in the reporting stage, the analyst chooses $p = 1/2$, as in the case in which the decision-maker observes the analyst's choice of p . On the other hand, in the case in which the analyst is able to communicate his private information, the precision of the analyst's information when the analyst's choice is observed is *different* from that when the analyst's choice is not observed.

In the reporting stage when the analyst's choice of p is not observed, 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 equilibrium, 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 \hat{p} . When the public information x and analyst information y is realized, the decision-maker's action choice must satisfy

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

and

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

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

$$\begin{aligned} & tp(\phi\hat{a}_{xg} - (\hat{a}_{xg} - s)^2) + (1 - t)(1 - p)(\phi\hat{a}_{xg} - (\hat{a}_{xg} - f)^2) \\ & + t(1 - p)(\phi\hat{a}_{xb} - (\hat{a}_{xb} - s)^2) + (1 - t)p(\phi\hat{a}_{xb} - (\hat{a}_{xb} - f)^2) - c(p). \end{aligned}$$

Given that $c(p)$ is 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

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

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 \hat{a}_{xg} and \hat{a}_{xb} in (7) yields the following condition that any equilibrium choice p must satisfy

$$\frac{\Delta(p)^2}{2p - 1} + \Delta(p) \phi(2t - 1) - c'(p) = 0. \quad (8)$$

Lemma 7 *When the analyst choice of precision is unobservable, the analyst's objective function is strictly quasiconcave and attains a maximum at $p_{no}^* \in (1/2, 1)$ where p_o^* is such that*

$$\Delta^2(p_{no}^*) / (2p - 1) + \Delta(p_{no}^*) \phi(2t - 1) - c'(p_{no}^*) = 0. \quad (9)$$

On comparing the equilibrium condition for p_{no}^* given in (9) with that for p^* given in (4), we observe that the analyst chooses a higher level of precision when his choice is not observable than when his precision choice is observable, that is $p_{no}^* > p^*$. The intuition for this result is as follows. Because there are no direct costs from misreporting, the analyst can only credibly communicate if dissembling causes the decision-maker to choose an action that the analyst finds undesirable. When the analyst gathers more precise information and the decision-maker believes his report, the analyst's report causes the decision-maker to take one of two significantly different actions. If the analyst was to deviate and collect information that was less precise than p_{no}^* , then the decision-maker, who does not observe the analyst's precision choice, would continue to respond to the report as if it had a higher level of precision than that which the analyst actually chose. The analyst, however, has less precise information and hence is more likely to induce the decision-maker to take an action that he finds undesirable. This possibility discourages the analyst from collecting less precise information than the equilibrium level of precision p_{no}^* . Alternatively, the analyst has

no incentive to deviate and collect information that is more precise than p_{no}^* because it is costly to do so and it does not affect the decision-maker's responsiveness to his report.

The fact that p_{no}^* is the only interior equilibrium p when p is not observable but communication is assumed implies that it is the only possible interior equilibrium p when p is not observable and communication must be credible. Therefore, when communication must be credible, we also know that p_{no}^* is implementable as an equilibrium if and only if it is weakly greater than \bar{p} .

Finally, as q increases, it can be shown that p_{no}^* decreases. Therefore, if p_{no}^* is implemented when $q = 1/2$, it follows that as q increases above $1/2$, p_{no}^* moves towards \bar{p} (i.e., p_{no}^* decreases and \bar{p} increases). Once $p_{no}^* < \bar{p}$, there is no interior equilibrium p so the analyst drops coverage of the firm (i.e., chooses $p = 1/2$). This finding is in contrast to the case where p is observable because in that case, the analyst's precision increases once the credible communication constraint became binding.

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, entire industry sectors without analyst coverage, raising the ironic possibility that the new regulations might have make 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. When the analyst precision choice is not publicly observable, we find an analyst gathers more precise information than would be gathered in the case where the analyst's precision choice is publicly observable.

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 quite 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. Alternatively, the insights 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 that reveals the properties of the seller's product.

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

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

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

$$E[\phi E[\tilde{\alpha}|x, b] - (\tilde{\alpha} - E[\tilde{\alpha}|x, b])^2 | b, x] \geq E[\phi E[\tilde{\alpha}|x, g] - (\tilde{\alpha} - E[\tilde{\alpha}|x, g])^2 | b, x]. \quad (11)$$

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

$$E[\tilde{\alpha}|x, g] - E[\tilde{\alpha}|x, b] - \phi \geq 0 \quad (12)$$

is satisfied.

It follows from expression (12) that a necessary and sufficient condition for the analyst to reveal y when $x = l$ is

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

and for the analyst to reveal y when $x = h$ is

$$\begin{aligned} & E[\tilde{\alpha}|h, g] - E[\tilde{\alpha}|h, b] - \phi \\ &= \frac{(2p-1)q(1-q)(s-f)}{(p(1-q) + (1-p)q)((1-p)(1-q) + pq)} - \phi \geq 0. \end{aligned} \quad (14)$$

The incentive compatibility expressions (13) and (14) are identical; hence, without loss of generality consider (13). When $q = 1/2$, then (13) can be expressed as $(2p-1)(s-f) - \phi \geq 0$. Solving for p yields $p \geq 1/2 + \phi/(2(s-f))$. On the other hand, when $q \in (1/2, 1)$, Solving for p in (13) 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

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

Proof of Lemma 2:

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

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

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

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

Evaluating the expression $\partial^2 U_i(\cdot) / \partial p^2$ 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. \blacksquare

Proof of Proposition 3:

For the analyst to credibly communicate his private information y in the reporting game, it follows from 14 that p must be such that

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

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., $p = \bar{p}$, with the expected payoff from not gathering any private information, i.e., $p = 1/2$. 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

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

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 $q \in (1/2, 1)$. 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,

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

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

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

Therefore, the Implicit function theorem yields

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

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

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

Proof of Corollary 5:

The arguments showing $\partial \bar{p}/\partial \phi > 0$, $\partial \bar{p}/\partial (s-f) < 0$, $\partial \bar{p}/\partial \phi = 0$ are straightforward. Consider $\partial p^*/\partial (s-f)$. The Implicit function theorem yields

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

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

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

Proof of Corollary 6:

To establish the claim, it remains to show that U_d falls discontinuously at \bar{q} . Observe that when $c(\bar{p}) = \Delta(\bar{p})q(1-q)(2\bar{p}-1)(s-f)$, then $U_i(1/2) = U_i(\bar{p})$, or equivalently,

$$\phi E[\tilde{\alpha}|x] - q(1-q)(s-f)^2 = \phi E[\tilde{\alpha}|x] - \frac{\bar{p}(1-\bar{p})q(1-q)(s-f)^2}{(\bar{p}(1-q) + (1-\bar{p})q)((1-\bar{p})(1-q) + \bar{p}q)} - c(\bar{p}).$$

This expression implies

$$\begin{aligned} -q(1-q)(s-f)^2 &= -\frac{\bar{p}(1-\bar{p})q(1-q)(s-f)^2}{(\bar{p}(1-q) + (1-\bar{p})q)((1-\bar{p})(1-q) + \bar{p}q)} - c(\bar{p}) \\ &< -\frac{\bar{p}(1-\bar{p})q(1-q)(s-f)^2}{(\bar{p}(1-q) + (1-\bar{p})q)((1-\bar{p})(1-q) + \bar{p}q)}. \end{aligned}$$

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

$$U_d(1/2) < U_d(\bar{p}). \blacksquare$$

Proof of Lemma 7:

Rewrite the equation in (8) 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

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

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

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

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

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

Exploiting the assumption that (8) holds 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 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 unique 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 . ■

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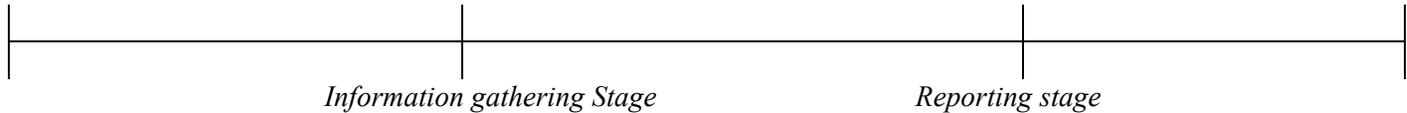
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Figure 1: Time line of events



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 $Pr(h/s) = Pr(l/f) = q$.

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 .

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.