J. Finan. Intermediation 18 (2009) 259–283

Contents lists available at ScienceDirect

J. Finan. Intermediation

www.elsevier.com/locate/jfi

Regulating securities analysts

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A R T I C L E   I N F O

Article history:
Received 3 September 2005
Available online 8 August 2008

Keywords:
Analysts
Regulation
Disclosure
Investment banking
Recommendations
Conflict of interest
Information production
Career concerns

A B S T R A C T

We examine the effects of regulations designed to address the potential conflict of interest that arises when sell-side analyst research is not independent of investment banking. We focus on two types of regulation: (1) internal barriers between equity research and investment banking that restrict communication; and (2) disclosure requirements relating to analyst compensation. We find that information barriers can increase research effort and improve report quality by limiting an investment bank's ability to distort its analyst's incentives. However, this type of regulation can also reduce information production and lower the quality of reports if an investment bank benefits directly from research activity. Disclosure requirements, on the other hand, unambiguously lead to more informative prices and a higher report quality relative to either information barriers or no regulation.

1. Introduction

Retail and institutional investors have long relied on research conducted by brokerage (sell-side) analysts to help inform their investment decisions. Recently, however, securities firms and their analysts have been the objects of intense scrutiny by lawmakers and market participants for allegedly producing overly optimistic research in order to attract and retain investment banking clients. To address the widespread concern over the influence of investment banking on analyst research, various regulatory agencies have introduced rules governing the relationships among securities firms, analysts, and investors. Many observers perceive the reforms to be a necessary step in curbing conflicts

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1042-9573/$ – see front matter
doi:10.1016/j.jfi.2008.07.001

of interest related to investment banking. At the same time, some market participants have argued that the reforms could compromise the quality of analyst research.[1]

In this paper, we provide a theoretical examination of the effects of conflict-of-interest regulations on analyst research. Our modeling approach is founded on the notion that analysts' incentives are the main channel through which investment banking concerns can distort research reports.[2] This point of view is consistent with regulators' recent emphasis on analyst compensation. For example, in outlining to U.S. Congress the April 2003 Global Settlement involving ten of the largest Wall Street firms, securities regulators stated their belief that the firms "used a compensation system that created an improper incentive for analysts to issue research that was overly positive, inaccurate, or otherwise lacked objectivity" (U.S. Senate, 2003). Thus, given the recent public policy focus on the linkage between analysts' incentives and the conflict-of-interest problem, it becomes critical to understand how regulations can lead to a restructuring of these incentives and to a concomitant change in research effort, reporting behavior, and overall research quality.

To address these issues, we consider a stylized model in which both the production and the dissemination of information by an analyst can depend endogenously on the regulatory regime. In the model, an investment bank employs an analyst to conduct costly research on a company and to issue stock reports to the public. The analyst is motivated partly by career concerns, which provide him with an incentive to increase long-term accuracy by generating information and reporting objectively. The investment bank, however, seeks to win future business from the company and will design the analyst's incentives to induce optimistic reporting and support the company's stock price. Absent any regulation, this conflict of interest dampens research effort and diminishes the value of analysts' reports to investors.[3]

The analysis focuses on two regulatory approaches to this problem that have dominated public discussion and guided recent policy changes. Both regulatory approaches fundamentally affect what information is observable by different market participants. The first approach aims to insulate equity research from investment banking activities by erecting or significantly strengthening internal barriers that limit the flow of information between an analyst and the rest of the securities firm. Many of the recently-adopted structural reforms can be broadly interpreted as attempts to achieve such a separation.[4] We refer to such structural remedies as *information barriers*. The second type of regulation seeks to impose *disclosure requirements* on securities firms so that investors are better informed about the true incentives underlying an analyst's reporting behavior.[5]

[1] Regarding Rule 2711 of the National Association of Securities Dealers (NASD) on "Research Conflicts of Interest," Marc E. Lackritz, president of the Securities Industry Association, commented: "[It] will impose technical regulatory requirements at significant costs that may impair the ability of firms and their analysts to provide timely, relevant investment recommendations." (Opdyke, 2002).

[2] Other possible sources of conflict exist, including using analyst recommendations internally in advance of their public dissemination ("front-running"), allowing analysts to trade on their personal accounts, avoiding negative recommendations to retain asset management clients, or using research reports to churn stocks and generate trading commissions. While such distortions are potentially important, we do not consider them here as they are less directly relevant to the much-publicized problem of how investment banking concerns can compromise analyst research.

[3] One might argue that investment banks are often able to directly interfere with the content of their analysts' reports rather than having to indirectly elicit optimistic reporting. Our modeling approach subsumes such a case, since even with direct interference the bank would have to compensate the analyst for changes in the report that adversely affected the analyst's long-term career prospects.

[4] Reforms instituted by the NYSE and the NASD in 2002 include requirements that (1) analysts not be supervised by the investment banking department; (2) investment banking personnel be prohibited from discussing research reports with analysts prior to distribution, unless personnel from a firm's legal/compliance department are present; and (3) analysts not be allowed to attend "pitch meetings" in which investment bankers solicit underwriting business from corporate clients (National Association of Securities Dealers, 2002; New York Stock Exchange, 2002). Likewise, as part of the 2003 Global Settlement, ten of the largest Wall Street firms agreed to erect physical and operational firewalls to insulate analyst research from investment banking.

[5] For example, the U.S. Securities and Exchange Commission's Regulation Analyst Certification (AC), adopted in April 2003, requires analysts to disclose in research reports whether they received any direct or indirect compensation for their report. Analysts who cannot certify that they did not receive compensation for a specific report must disclose the magnitude and source of compensation (Securities and Exchange Commission, 2003). Likewise, in its 2003 Statement of Principles for Addressing Sell-Side Analyst Conflicts of Interest, the International Organization of Securities Commissions (IOSCO) recommended that jurisdictions consider requiring analyst employers to disclose how their analysts are compensated (IOSCO, 2003).

We show that imposing information barriers can sometimes increase the informational content of analyst reports, thus leading to more informative stock prices. The intuition is that making the analyst's information unobservable to the rest of the investment bank makes it costlier for the bank to distort reporting behavior through monetary incentives. The bank reacts by reducing the incidence of distortion. Because less research effort now goes to waste, the analyst is motivated to produce more information. The net result is that the quality of stock reports increases and investors enjoy better information about the client firm.

We then examine the effects of disclosure regulation, focusing on the requirement that the securities firm publicly disclose, ex post, the magnitude of incentive payments made to the analyst. We find that, even though the introduction of disclosure requirements causes the investment bank to restructure the compensation contract, such regulation nevertheless provides the investment bank with greater incentives to encourage information production. And since disclosure forces the bank to provide information beyond what is present in the analyst's written opinion, the overall amount of information available to investors always increases.

Comparing the two forms of regulation, we show that the quality of analysts' reports is always at least as high under disclosure as under information barriers. This occurs because the additional information about the underlying state provided by disclosure regulation is always beneficial to investors and guarantees an improvement in report quality. By contrast, since information barriers reduce the flow of information, the bank's desire to extract the analyst's information often limits the extent to which such regulation increases informativeness. The net effect is that disclosure regulation unequivocally leads to more informative reports, suggesting that disclosure may be a better regulatory tool than internal structural barriers.

This last conclusion is strengthened when we consider the case where the analyst's research has the potential to yield direct benefits to the securities firm, such as through more accurate deal pricing or improved due diligence. Surprisingly, when such benefits are sufficiently large, information barriers can actually lead to a *reduction* in the quality of reports. The reason is that information barriers place additional constraints on the incentive design problem, forcing the bank to extract information from the analyst that would it otherwise be able to obtain for free. As a result, information barriers cap the degree to which the compensation scheme can be used to reward information generation. Thus, barriers can actually be counterproductive, reducing effort in settings where analyst research is directly beneficial to the bank. Disclosure regulation, by contrast, never suffers from this problem: it always increases the overall flow of information between the various parties, yet again pointing to the superiority of this regulatory approach.

Our model provides some novel empirical implications. For example, we show that conflict-of-interest regulations should increase the observed frequency of unfavorable research reports and increase the "credibility," or price impact, of favorable reports. Recent empirical evidence is consistent with both of these predictions. We also establish a number of untested predictions about the stock price impact of analyst research. For instance, the model shows that disclosure regulation and information barriers should cause the price difference following favorable versus unfavorable reports to increase. Moreover, such regulations should have a larger impact on research effort when analysts have strong career concerns or when companies' underlying values are highly uncertain.

A growing literature examines analysts' role in providing information to capital markets. For instance, Womack (1996), Barber et al. (2001), and Jegadeesh et al. (2004) document that analyst stock recommendations provide useful information to investors. Several other articles examine how distortions in analysts' incentives can lead to biased forecasts and recommendations. One possible source of bias, studied theoretically by Trueman (1994) and established empirically by Hong et al. (2000) and Welch (2000), is that analysts may "herd" in their forecasts and recommendations in order to develop reputations for ability. Analysts may also issue optimistically-biased reports to compensate for the lack of an established relationship with a client firm (Ljungqvist et al., 2006) or to curry favor with a client's management in order to retain access to privileged information (Lim, 2001). Benabou and Laroque (1992) study how analysts or their employers may have incentives to profit by trading directly on their superior information. Morgan and Stocken (2003) examine how conflicts of interest related to investment banking can lead to biased analyst recommendations and less informative stock reports. To the best of our knowledge, ours is the only study to analyze how the flow of information between equity research and investment banking gives rise to conflicts of interest and how incentives for information production depend endogenously on the profit-maximizing behavior of securities firms.

Finally, our work is indirectly related to a broad literature that deals with information production in capital markets (see, e.g., Allen, 1990) and firms' incentives to disclose information to investors (see, e.g., Diamond, 1985 or Boot and Thakor, 2001). Our work has some relationship to studies of how regulation can promote disclosure by firms (Fishman and Hagerty, 1990; Admati and Pfleiderer, 2000), although our focus is on third-party generation of information. Also related are papers that examine how agents' long-term career concerns can provide them with incentives to produce information (see, e.g., Milbourn et al., 2001) and how conflicts of interest may prevent the full disclosure of information (see Bolton et al., 2007). In our model, career concerns play an important role, but they are counterbalanced by short-term monetary compensation that also influences an analyst's incentives to produce information.

The rest of the paper is organized as follows. The next section describes the basic model. Section 3 examines equilibrium information production and report quality in the absence of regulation. In Section 4, we study the effects of regulation. Section 5 extends the basic model to the case where the analyst's research activity yields direct benefits to the securities firm. Section 6 outlines some key empirical implications, and Section 7 concludes. Proofs of results are given in Appendix A.

2. The model

We consider a setting with a profit-maximizing securities firm,[6] an analyst, a client firm, and investors. The client firm is involved (or may potentially become involved) in an underwriting or advisory relationship with the investment bank. The analyst is employed by the investment bank to conduct research on the client firm's ongoing operations and to issue a report to the investing public. While the client's fundamental value V is initially unknown, it is common knowledge that, with equal probability, the value is either good (V^G) or bad (V^B). The client firm wishes to be viewed favorably by investors, and thus the investment bank expects to win future deals from the client if and only if the client's stock price rises subsequent to the analyst's report. This is the source of the fundamental conflict of interest: the bank may seek to increase future business by supporting the stock price with aggressively optimistic analyst reports.[7]

We assume for simplicity that winning deals in the future gives the investment bank a constant payoff $\alpha > 0$.[8] Investors are competitive, rational, and risk-neutral, and they determine the client firm's current and intermediate-term stock price.

The analyst's efforts at generating information yield a noisy signal $s \in \{G, B\}$ about the client firm's value. The signal is observed by the analyst and, possibly, by the securities firm. The signal has precision ϕ in the sense that $\Pr(s = G \mid V = V^G) = \phi = \Pr(s = B \mid V = V^B)$. There are two possible precision levels for the signal: ϕ^H and $\frac{1}{2}$, with $\frac{1}{2} < \phi^H < 1$. By exerting costly effort $e \in [0, \frac{1}{2}]$, the analyst can increase the chances of getting a high precision signal. Specifically, we assume that $\phi = \phi^H$ with probability p and $\phi = \frac{1}{2}$ with probability $1 - p$, where $p = \frac{1}{2} + e$. Upon learning the signal and the precision, the analyst issues a public stock report $R(s, \phi)$ that provides either a favorable (V^G) or unfavorable (V^B) assessment of the client firm.[9]

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[6] In what follows, we will use the phrases "securities firm" and "investment bank" interchangeably.

[7] Ample empirical evidence shows that analysts do tend to issue more optimistic stock recommendations when there are sizable investment banking fees at stake (see, e.g., Agrawal and Chen, 2007; Dugar and Nathan, 1995; Kolasinski and Kothari, 2007; Lin and McNichols, 1997; Ljungqvist et al., 2006, 2007; Michaely and Womack, 1999).

[8] In practice, the payoff to an investment bank from winning a client's business could vary with how "successful" the client is, i.e., how much its stock price rises. In our model, assuming that the payoff from winning the client's business varies proportionally with the client's stock price would not qualitatively change our main results. The essential modeling feature for our purposes is that the bank's payoff is zero (or sufficiently small in magnitude) when the client's stock price falls.

[9] Discreteness in the analyst's reporting space is not crucial for our main results. Allowing the analyst to select from a continuous reporting space yields similar results, as the analyst will endogenously choose to limit the number of different reports he makes. See Morgan and Stocken (2003) for a related analysis.

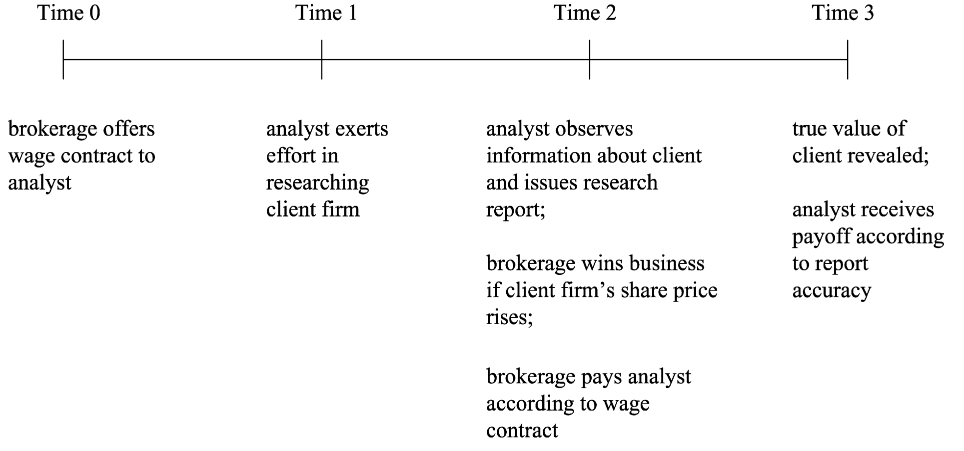

Fig. 1. Timing of events.

The analyst faces labor market or reputational concerns and incurs disutility from issuing reports that ultimately turn out to be inaccurate.[10] Let $\underline{w}$ denote the extent to which the labor market penalizes the analyst for inaccuracy. The analyst's utility function is given by

$$U = w - \frac{k}{2}e^2 - \underline{w}(R - V)^2, \tag{1}$$

where w is any compensation received and $\frac{k}{2}e^2$ is the analyst's cost of research effort. In addition, the analyst can secure an outside level of utility $\overline{U}$ from alternative employment. The securities firm has discretion over the analyst's monetary incentives w, but w must be nonnegative due to limited liability. Payments cannot be conditioned directly on the level of research effort since it is unobservable to the firm.

In order to focus on the effects of regulation in a setting where a conflict-of-interest problem does in fact exist and is significant, we make two assumptions. The first is that $\alpha \geqslant 4\underline{w}(V^G - V^B)^2$, so that the profits from winning the client's future business are sufficiently large relative to the analyst's penalty for inaccuracy. This is consistent with empirical evidence showing that the compensation investment banks receive from securities offerings is often substantial (see, e.g., Chen and Ritter, 2000; Yeoman, 2001). The second assumption is that $k \geqslant \frac{8\alpha^2}{(\phi^H - \frac{1}{2})\underline{w}(V^G - V^B)^2}$, or that the analyst's marginal cost of producing information is eventually large relative to investment banking profits. When these two parameter restrictions are not satisfied, the benefit to the bank of distorting the analyst's reporting is low relative to the analyst's career concerns, and the severity of the conflict of interest is greatly attenuated. As a result, either the conflict-of-interest problem disappears entirely when regulation is introduced, or regulation plays no substantive role because the problem is insignificant.

Fig. 1 summarizes the timing of the model. At time 0, the investment bank offers an incentive scheme to the analyst. At time 1, the analyst accepts or rejects the contract. If the analyst accepts, he then decides how much effort to dedicate to producing information. At time 2, the research effort yields a signal about the client firm, and the analyst issues a research report on the client. Investors use the research report to update their beliefs about the client and competitively determine the client's stock price. The investment bank receives the return α if and only if the client's stock price has increased, and the analyst is paid according to the incentive scheme. Finally, at time 3, the

[10] Recent empirical evidence suggests that the labor market does reward analysts for accuracy. Hong and Kubik (2003) show, for example, that analysts who forecast earnings accurately are subsequently more likely to move to high-status brokerage firms. Stickel (1992) finds that analysts belonging to *Institutional Investor*'s All-American Research Team are more likely to lose their Team membership (and generally high levels of pay) after a period of relatively inaccurate earnings forecasts.

true value of the client firm is revealed to all participants, and the analyst incurs disutility if his report was inaccurate.

3. Incentives for information production

Our goal in this section is to characterize how the investment bank sets the analyst's incentives in an unregulated setting and how these incentives determine report quality and the extent of information production. Suppose that, in the absence of any regulatory barriers between equity research and other divisions, the investment bank can observe all of the analyst's time-2 information. Then the investment bank can offer a nonnegative wage scheme $w(s,\phi,R)$ that is contingent on the signal realization s, the signal quality ϕ, and the analyst's report R.[11] While the incentive payments can be seen as pure monetary transfers, they can also be more broadly interpreted as general rewards, e.g., promotions, prestigious assignments, or nonpecuniary benefits.

It is worthwhile to note two other aspects of feasible incentive schemes. First, although a wage scheme might plausibly depend on other information (e.g., the amount by which the client's share price rises at time 2), we can ignore such dependence because wages already depend on s and ϕ. Indeed, any wage dependence on variables beyond s, ϕ, and R would be extraneous. For example, while the wage scheme can influence the analyst's effort choice, the level of effort, being unobservable to investors, can only affect expected wages by altering the probability distribution of s and ϕ. Second, if w is a wage scheme that arises in equilibrium, then dependence of $w(.)$ on the report R will, except for out-of-equilibrium reporting, already be captured in the dependence of $w(.)$ on s and ϕ. Thus, whenever there is no ambiguity concerning the analyst's reporting behavior, we will suppress notation and simply write $w(s,\phi)$ for the wage scheme.

3.1. Benchmark analysis: absence of conflict

We first study the benchmark case in which there are no informational asymmetries between the securities firm and investors.[12] Clearly, stock reports in this case give no additional information to investors, and the securities firm cannot affect the probability of winning the client's business by altering the level of research effort. With probability 1/2 the information on the client will be favorable, in which case the securities firm earns investment banking profits α. Thus, expected profits for the securities firm can be written as

$$\Pi = \frac{1}{2}\alpha - E\big[w\big(s,\phi,R(s,\phi)\big) \mid e\big], \tag{2}$$

where $R(s,\phi)$ and e are the analyst's reporting strategy and research effort, respectively. The securities firm's profit maximization problem implies maximizing (2) with respect to the wage scheme w, subject to

$$E\big[w\big(s,\phi,R(s,\phi)\big) \mid e\big] - \frac{k}{2}e^2 - \underline{w}E\big[\big(R(s,\phi)-V\big)^2 \mid e\big] \geqslant \overline{U}, \tag{3}$$

$$e \in \arg\max_{\hat{e}\geqslant 0}\left(E\big[w\big(s,\phi,R(s,\phi)\big) \mid \hat{e}\big] - \frac{k}{2}\hat{e}^2 - \underline{w}E\big[\big(R(s,\phi)-V\big)^2 \mid \hat{e}\big]\right), \tag{4}$$

$$R(s,\phi) \in \arg\max_{\hat{R}\in\{V^G,V^B\}}\big(w(s,\phi,\hat{R}) - \underline{w}E\big[(\hat{R}-V)^2 \mid e\big]\big) \quad \forall s\in\{G,B\},\ \phi\in\left\{\phi^H,\frac{1}{2}\right\}. \tag{5}$$

[11] Observe that this framework is more general than it may initially appear. For example, conditioning payments on s, ϕ, or R does not necessarily require explicit contracting. Indeed, the investment bank will be able to offer contingent payments provided that reputational considerations are sufficiently strong that the parties can engage in implicit contracting (see Laffont and Tirole, 1993, for discussion).

[12] An alternative benchmark (which would lead us to the same qualitative conclusions) is one where investors do not observe the produced information but where no substantive conflict of interest exists between the investment bank and the analyst. For example, if the bank could impose large penalties on the analyst, it could easily overcome the analyst's career concerns and come close to maximizing profits. This fact underscores the importance of the analyst's limited liability in constraining the investment bank's profits.

The first constraint is a standard individual rationality (IR) constraint that ensures the analyst's expected utility is at least $\overline{U}$, his opportunity cost or reservation utility. The second and third constraints are incentive compatibility (IC) constraints that ensure the analyst chooses his utility-maximizing effort level at time 1 and utility-maximizing report at time 2.

To gain intuition, it is useful to first consider the analyst's decisions in a "stand-alone" setting, where he does not receive any incentive pay from the investment bank. In this case, the analyst reports in a straightforward manner to minimize the inaccuracy penalty: he issues a favorable report whenever he receives a good signal, and he issues an unfavorable report upon receiving a bad signal. Under this straightforward reporting strategy, the conditional probability of reporting incorrectly upon receiving a high-precision signal is $1 - \phi^H$, and it is $\frac{1}{2}$ upon receiving a low-precision signal. Thus, upon exerting effort e, the analyst will have an expected inaccuracy penalty of $[p(\frac{1}{2} - \phi^H) + \frac{1}{2}]\underline{w}(V^G - V^B)^2$, and his total expected utility will be $-[p(\frac{1}{2} - \phi^H) + \frac{1}{2}]\underline{w}(V^G - V^B)^2 - \frac{k}{2}e^2$, where $p = \frac{1}{2} + e$. Maximization of the analyst's utility yields a stand-alone effort level $e_{SA} \equiv \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}(V^G - V^B)^2$. We can therefore compute the analyst's *stand-alone utility level* by substituting the expression for e_{SA} into the analyst's objective function:

$$U_{\mathrm{SA}} \equiv \left(\frac{1}{2k}\left(\phi^H - \frac{1}{2}\right)^2 - \left[\frac{3}{4} - \frac{\phi^H}{2}\right]\right)\underline{w}\big(V^G - V^B\big)^2. \tag{6}$$

Henceforth, we will assume that the analyst's reservation utility cannot be below this stand-alone level U_{SA}.

We now turn to equilibrium in the benchmark case and show that, in the absence of information asymmetries, the bank chooses a wage scheme that leads to unbiased reporting.

Proposition 1. *If investors fully observe the securities firm's information, the bank induces the analyst to use a straightforward reporting strategy $R_F(s, \phi)$ in which $R_F(s, \phi) = V^s$ for $s = G, B$ and $\phi = \phi^H, \frac{1}{2}$. The analyst's research effort is given by $e_{\mathrm{SA}} = \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}(V^G - V^B)^2$.*

The comparative statics are intuitive. The greater the market penalty for inaccuracy ($\underline{w}(V^G - V^B)^2$) or the greater the returns to effort in terms of improving the signal precision ($\phi^H - \frac{1}{2}$), the greater will be the equilibrium level of effort toward producing information. On the other hand, the higher the cost of devoting effort to research (k), the lower will be the equilibrium level of information production.

3.2. Unobservability of information

We next consider the more realistic case where investors do not have direct access to the analyst's information and must rely on the stock report to learn about the client firm. The client's interim stock price will now hinge on whether or not the analyst's report is favorable and on how credible investors perceive it to be. For his own part, the analyst selects his research effort and reporting behavior to maximize expected utility. The investment bank's problem is to solve

$$\max_{w(s,\phi,R)\geqslant 0} \alpha \Pr\big(E\big[V \mid e, R(s,\phi)\big] > E[V]\big) - E\big[w\big(s,\phi,R(s,\phi)\big) \mid e\big] \tag{7}$$

subject to constraints (3), (4), and (5) discussed earlier, which guarantee that the problem is consistent with utility maximization and rational participation by the analyst. The above objective function makes it clear that the bank cares fundamentally about three things: the payoff (α) conditional on winning the client's business, the probability that investors revalue the client's stock upwards after seeing the analyst's report, and the expected wage cost.

Since we are interested in making qualitative comparisons of information production across regulatory regimes, it is necessary to make cross-regime comparisons of research effort given different values of $\overline{U}$, the analyst's outside opportunity. We therefore characterize the analyst's equilibrium reporting behavior and establish key properties of how equilibrium effort varies with $\overline{U}$.

Proposition 2. *In equilibrium, the securities firm chooses a wage scheme that induces optimistically-biased reporting behavior $R_N(s, \phi)$ in which $R_N(s, \phi) = V^B$ if and only if $(s, \phi) = (B, \phi^H)$, and is otherwise equal* *to V^G. The equilibrium level of research effort, e_N, is a continuous function of the reservation utility $\overline{U}$ that satisfies the following properties*:

1. *If $\overline{U} = U_{SA}$, then $e_N = \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}(V^G - V^B)^2$.*
2. *If $U_{SA} < \overline{U} < (\phi^H - 1)\underline{w}(V^G - V^B)^2$, e_N is strictly decreasing.*
3. *If $\overline{U} \geqslant (\phi^H - 1)\underline{w}(V^G - V^B)^2$, $e_N = 0$.*

Proposition 2 demonstrates that, when investors do not directly observe the information produced by the analyst's research, a conflict-of-interest problem arises: the investment bank will induce an optimistic bias in the analyst's reporting behavior. The unique equilibrium reporting strategy can be understood as follows. There are four possible states of the world, determined by whether precision is high or low and whether the signal is good or bad. The investment bank chooses to allow an unfavorable analyst report in only one state, i.e., when precision is high and the signal is bad. In the other three states, the bank induces a favorable report. Since investors can only observe the report (and not the underlying state), they will bid up the stock price after a favorable report but will revalue the stock price downwards after an unfavorable report. Thus, the ex ante probability that the investment bank fails to win the client's business α is equal to $\frac{1}{2}p$, the probability that a highly precise, bad signal arrives.

The intuition for why effort decreases monotonically in the reservation utility is straightforward. As the reservation utility increases above $\overline{U}$ and the individual rationality constraint begins to bind more tightly, retaining the analyst requires the bank to pay a progressively higher wage. Since information production acts as a complement to the analyst's career-based incentives to report truthfully, the bank can induce lying more easily if less information is produced. Therefore, the bank will choose to penalize research effort by offering higher wage payments in low-precision states and nothing in high-precision states. When the analyst's outside opportunities exceed a certain level, the investment bank finds it optimal to offer a compensation scheme that eliminates research effort completely (see Appendix A for a full characterization of the compensation scheme).

Although Proposition 2 is stated in terms of research effort, the relevant consideration for investors is the informativeness of the report. Consistent with recent related literature (e.g., Morgan and Stocken, 2003), we define the informativeness Φ of the stock report in terms of the expected squared difference between the market's interim valuation of the client firm ($\hat{V}$) and the realized value of the client firm (V):

$$\Phi = -E\big[(V - \hat{V})^2\big]. \tag{8}$$

In general, report informativeness will depend on the analyst's equilibrium reporting behavior, the level of research effort, and on any information available to investors at time 2. Appendix B contains explicit expressions for Φ under each of the scenarios considered in the paper.

Corollary 1. *The quality of the analyst's stock report is strictly lower when the investment bank is privately informed than when its information is fully observable to investors.*

This result highlights the fact that the conflict-of-interest problem and the attendant reduction in report quality stem largely from the informational asymmetry between the investment bank and public investors. The result also sheds light on an important question: if investors are rational, can they not anticipate the conflict of interest and thereby protect themselves against the analyst's bias? Empirical research shows that investors do appear to rationally perceive and compensate for conflicts of interest on the part of analysts and other financial intermediaries (see, e.g., Agrawal and Chen, 2007; Kroszner and Rajan, 1994; Puri, 1996). In our model, although investors can perfectly infer the analyst's incentives and bias, they cannot perfectly back out his actual information. This is so because not only is the investment bank inducing the analyst to be overoptimistic, it is also providing incentives for some information to be hidden. To the extent that the investment bank lacks the incentive and the means to credibly disclose its superior information to investors, regulatory policies aimed at governing internal and external information flows may help improve the quality of stock reports.

4. The effects of regulation

4.1. Regulations imposing information barriers

In this section, we examine the effects of regulations that address the conflict-of-interest problem by restricting the flow of information to and from analysts within securities firms (e.g., by prohibiting analysts from participating in marketing or roadshow activities, preventing investment bankers from supervising analysts, and physically separating equity research offices from other offices).[13]

The investment bank, being unable to directly observe the analyst's information under such regulation, will now design the analyst's incentives to not only determine research effort and reporting behavior, but also to *extract* the analyst's information about the client. (As we show in Proposition 3 and its proof in Appendix A, extracting this information is necessary in order to profitably induce an optimistic bias in reporting.) We can assume without loss of generality that the investment bank solves this incentive design problem by offering the analyst a compensation scheme in which (1) after obtaining private information about the client, the analyst announces privately to the bank a signal s^* and precision ϕ^*, and he is given incentives to announce truthfully; and (2) based upon the announcements s^* and ϕ^*, the analyst is paid $w(s^*, \phi^*)$ and obligingly issues a public report $R(s^*, \phi^*)$. The investment bank's problem is therefore to choose a wage scheme $w(s, \phi)$ and reporting behavior $R(s, \phi)$ to solve

$$\max_{\substack{w(s,\phi)\geqslant 0,\\ R:\{G,B\}\times\{\phi^H,\frac{1}{2}\}\to\{V^G,V^B\}}} \alpha \Pr\big(E\big[V \mid e, R(s^*, \phi^*)\big] > E[V]\big) - E\big[w(s^*, \phi^*) \mid e\big] \tag{9}$$

subject to constraints (3) and (4), as well as the constraint that

$$\textit{The analyst finds it optimal to convey } s^* \textit{ and } \phi^* \textit{ truthfully}. \tag{10}$$

Although the investment bank's objective function is unchanged from the no-regulation case with private information, the overall incentive design problem changes considerably. Indeed, constraint (10) now captures the additional incentive compatibility requirement that the analyst always find it optimal to convey the state truthfully to the investment bank. The exact form of this constraint will depend on which reporting strategy the investment bank chooses to implement.

We can now describe the key features of equilibrium in the case of information barriers.

Proposition 3. *With information barriers, the securities firm chooses a wage scheme $w_W(s, \phi)$ and optimistically-biased reporting behavior $R_W(s, \phi)$ in which $R_W(s, \phi) = V^B$ if and only if $(s, \phi) = (B, \phi^H)$, and is otherwise equal to V^G. Define $U_S \equiv (2\phi^H - \frac{3}{2})\underline{w}(V^G - V^B)^2$. Then the equilibrium level of research effort, e_W, is a continuous function of the reservation utility $\overline{U}$ that satisfies the following properties:*

1. *If $\overline{U} = U_{SA}$, then $e_W = \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}(V^G - V^B)^2$.*
2. *If $U_{SA} < \overline{U} < U_S$, then e_W is strictly decreasing.*
3. *If $\overline{U} \geqslant U_S$, then $e_W = 0$.*

Moreover, $e_W \geqslant e_N$, with the inequality strict for $\overline{U} \in (U_{SA}, U_S)$.

Proposition 3 shows that, as in the case with no regulation, stock reports exhibit an optimistic bias even when communication is restricted, and research effort is a decreasing and continuous function

[13] While the sort of regulations we consider here restrict communication within the firm, they do not necessarily ensure that analyst compensation will be unrelated to investment banking profits. As a practical matter, it may be difficult for internal remedies to remove all linkages between investment banking and analyst pay since many securities firms derive a substantial fraction of their revenues from investment banking operations. For example, in the midst of the New York Attorney General's efforts to craft a settlement with Merrill Lynch & Co. in 2003, the president of NASD Regulation, Inc. expressed concern over "how, operationally, analyst compensation would be severed completely from investment-banking revenue, [on which all employee pay] is based" (Cohen and Kelly, 2003).

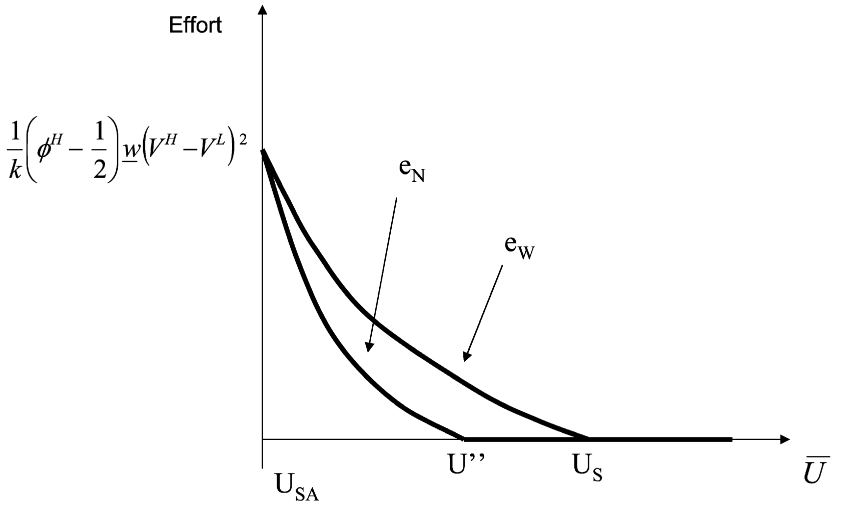

Fig. 2. Equilibrium effort provision with and without information barriers. Without regulation, effort e_N is strictly decreasing for values of the reservation utility above U_{SA} and zero for reservation utilities above $U'' = (\phi^H - 1)\underline{w}(V^H - V^L)^2$. With information barriers, effort e_W is always higher, and it is strictly higher for reservation utilities between U_{SA} and $U_S = (2\phi^H - \frac{3}{2})\underline{w}(V^H - V^L)^2$.

of the analyst's reservation utility level. Fig. 2 presents a comparison of equilibrium levels of research effort under the two regimes. As the figure shows, research effort is always as high—and often strictly higher—with information barriers than with no regulation. The intuition for this is as follows. In general, the bank would like to induce a low level of information production so that it can more easily distort reporting behavior. However, information barriers give rise to additional constraints in the incentive design problem: the bank, no longer able to observe the analyst's information directly, must compensate the analyst to elicit his information about the underlying state. The additional constraints make it more difficult for the bank to inhibit effort by rewarding low-precision states relative to high-precision states. As a result, research effort is higher in equilibrium.

Note that information barriers force the bank to tailor the analyst's incentives to extract two separate pieces of private information: signal level and signal precision. Thus, the bank's incentive design problem becomes one of multidimensional screening. As has been established in the literature on multidimensional screening with discrete type spaces (see, e.g., Armstrong and Rochet, 1999, for a general treatment), the solution typically involves a "bunching" or "pooling" across types. Proposition 3 shows that information barriers do lead to a pooling-type equilibrium in our model: the analyst's compensation is the same in three of the four states. In essence, the bank is able to resolve the design problem by offering a compensation scheme that penalizes high-precision states relative to low-precision states, but not to such a degree that the analyst would lie to the bank about the true state.

We can extend Proposition 3 to a comparison of report qualities.

Corollary 2. *If $\overline{U} \in (U_{SA}, U_S)$, then report quality under information barriers is strictly higher than under no regulation. Otherwise, quality is the same across the two regimes.*

A natural question to ask is whether the conclusions of Proposition 3 and Corollary 2 rely on the assumption that, absent any regulation, the bank can freely observe ϕ and condition wage payments upon it. Put differently, if the bank could observe s but not ϕ in the no-regulation regime, would information barriers still have the same effect? It can be shown (results available from the authors) that our conclusions would not change in this case since if the bank can observe s, it can in fact extract ϕ from the analyst at no additional expected cost given its equilibrium strategy.

Finally, note that while information barriers do not eliminate bias, in many cases they do reduce the extent of bias. Indeed, the probability of issuing a biased report is lower with information barriers than with no regulation because the greater research effort in the former regime ensures that the analyst has a higher chance of getting a high-precision signal.

4.2. Disclosure regulation

We turn now to an analysis of regulation that focuses on imposing disclosure requirements rather than on erecting barriers within the firm. As discussed in the introduction, one natural form of disclosure regulation is the requirement that securities firms publicly reveal, ex post, any incentive payments made to analysts.[14] For concreteness, we assume that the securities firm must disclose these wage payments at the time that the analyst issues his stock report. Thus, the set of all information observed by investors at time 2 now includes both the disclosed wage payment $w(s,\phi)$ and the analyst's report $R(s,\phi)$.[15] Note that it is not immediately obvious a priori whether disclosure regulation will succeed at improving equilibrium report quality. For example, disclosure requirements might cause the investment bank to limit investors' information by using a flattened wage scheme to pool information across some states. Nevertheless, as the following proposition demonstrates, disclosure regulation in fact always increases report quality relative to the status quo of no regulation.

Proposition 4. *Research effort under disclosure regulation, e_D, is at least as high as effort under no regulation, e_N. Since observability of the wage provides additional information to investors, price informativeness is always strictly higher with disclosure regulation than without.*

Under disclosure regulation, reporting will again be biased upward in equilibrium: the analyst will issue a favorable report in all states except the one in which he receives a bad, high-precision signal. However, disclosure regulation will cause the investment bank to use a wage scheme that is quite different from that used under information barriers. In particular, the bank will choose to pool wage payments across only two states ($(s,\phi)=(B,\frac{1}{2})$ and $(s,\phi)=(G,\phi^H)$) rather than across three states. Thus, the disclosed wage payment itself conveys some (but not all) information about the underlying state to investors. Note that, by offering such a wage scheme, the bank is still able to credibly bias reports upward because investors cannot fully uncover the false optimism. Nevertheless, because disclosure makes it more difficult for the bank to offer greatly different compensation across precision levels, the analyst's incentives to generate information are greater than in the absence of regulation.

4.3. Information barriers versus disclosure regulation

We now proceed to compare directly the informational quality of reporting under the two regulatory regimes. The following result establishes an unequivocal ranking of the two types of regulation.

Proposition 5. *Price informativeness and report quality are strictly higher under disclosure regulation than under information barriers.*

Note that Proposition 5 does not say that research effort is higher under disclosure than under information barriers; in fact, it can be shown that equilibrium research effort is sometimes lower under the former regime. Nonetheless, Proposition 5 guarantees that, of the two types of regulation,

[14] Disclosure of the ex ante wage scheme has no effect in our model since investors already anticipate the optimal scheme. Recently, other forms of disclosure regulation have been adopted in practice. For example, NASD Rule 2711 includes a provision that requires analyst research reports to display the total percentages of the employing firm's stock recommendations that are buys, holds, or sells. This kind of regulation would also have little effect in our model since investors already anticipate the likelihood of a negative report. See Barber et al. (2006) for an empirical study of the impact of this type of regulation.

[15] The main qualitative results of this section would continue to hold if complete disclosure could not be perfectly enforced, so that investors observe the wage payment only with some positive probability.

disclosure will always lead to more total information in prices. This is due to the fact that wage disclosures provide investors with valuable state-relevant information beyond what is simply in the analyst's report. From the standpoint of overall report quality and informational efficiency, then, disclosure appears to be a superior form of regulation compared to information barriers.

5. Direct benefits from information production

In this section, we extend our framework to incorporate a direct concern on the part of the securities firm for information production. There are a number of reasons why the securities firm might derive direct benefits from the analyst's production of information. For example, researching the client firm might allow the analyst to improve his general knowledge about the industry, making it easier to research and attract other clients in the future. More generally, the bank itself may be concerned with developing a reputation for providing clients and customers with high-quality information and accurate deal pricing.[16] In addition, the production of timely investment information could increase profits from trading, asset management, market-making, and retail brokerage operations. We capture these benefits in the model by assuming that they can be represented as an additional term in the investment bank's objective function. Thus, the bank's expected profits are equal to

$$\alpha \Pr\big(E\big[V \mid e, R(s,\phi)\big] > E[V]\big) - E\big[w\big(s,\phi,R(s,\phi)\big) \mid e\big] + \alpha_2(e), \tag{11}$$

where the earlier parameter assumptions continue to hold and where $\alpha_2(e), \alpha_2'(e) > 0$, and $\alpha_2''(e) \leqslant 0$ for all $e \in [0, \frac{1}{2}]$. Since we are primarily interested in studying the case where direct benefits are secondary in importance to incentives created by the conflict-of-interest problem, we further assume that $\alpha_2(e) \leqslant \alpha/2$, so that direct benefits are smaller than the maximum amount by which distortion of the analyst's reporting can increase expected investment banking revenues.

With this setup, we show that informational barriers may no longer be effective at increasing report informativeness. Provided that the bank finds it profitable to employ the analyst, we have:

Proposition 6. *If $\alpha_2'(e_{SA}) > \alpha$, then report informativeness is strictly lower under information barriers than in the absence of regulation, for $\overline{U} > U_{SA}$. If $\alpha_2'(e_{SA}) \leqslant \alpha$, then informativeness is higher under information barriers.*

The somewhat surprising message of Proposition 6 is that, if the investment bank can benefit directly from the analyst's research, then information barriers can actually decrease report quality. The reasoning underlying this result is that, when the marginal direct benefit of information production is large, the investment bank would, in the absence of regulation, choose a high level of research effort. Under information barriers, the bank faces additional constraints that limit its ability to reward information generation via high payments in high-precision states. In other words, the bank is unable to both extract the analyst's information and at the same time strongly reward high-precision states. As a result, information barriers limit the possible wage differential between high-precision states and low-precision states, effectively capping effort below the level that the bank would prefer to implement under no regulation.

What effect does disclosure regulation have in the presence of informational benefits $\alpha_2(e)$? Recall from Proposition 4 that, in the baseline model, such regulation does not reduce informativeness relative to the status quo. It can in fact be shown (using an argument parallel to the one in the proof of Proposition 4) that, even when the bank derives informational benefits from research activity, imposing a disclosure requirement leads to greater production of information and higher report informativeness for all levels of reservation utility. This is depicted in Fig. 3, along with relative levels of report informativeness under information barriers and no regulation.

[16] For a model in which reputational concerns can lead investment banks to act as credible producers of information, see Chemmanur and Fulghieri (1994).

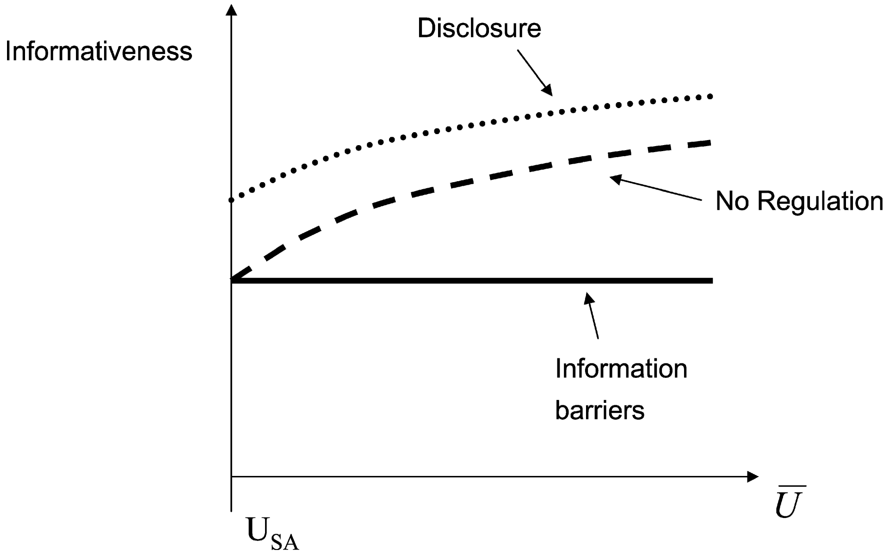

Fig. 3. Equilibrium levels of informativeness when direct informational benefits are high. The figure depicts informativeness levels versus the analyst's reservation utility for each of the three regulatory regimes (disclosure, information barriers, and no regulation).

To summarize, Proposition 6 establishes a significant drawback to information barriers: they can lead to a reduction in research effort and report informativeness when the analyst's research is directly valuable to the securities firm. Disclosure regulation, in contrast, never reduces research effort relative to the status quo, whether or not the research yields intrinsic benefits. From a public policy perspective, then, disclosure regulation becomes especially advantageous compared to information barriers if a key regulatory objective is to minimize the chance of worsening the situation for investors.

Note also that, compared to informational barriers, disclosure regulation leads to greater production of information. Thus, the investment bank may prefer disclosure regulation to information barriers–even though the barriers in and of themselves do not prevent the bank from enjoying the direct benefits of the analyst's research. Furthermore, disclosure may result in greater societal benefits, especially if analyst employers use research for specific, value-creating purposes (e.g., the accurate pricing of securities offerings) that ultimately enhance the informational and allocational role of financial markets.

While we have analyzed each form of regulation in isolation, a natural question that arises is whether imposing both types of regulation together would yield a better outcome than imposing just one. It can be shown that the answer is negative, as imposing information barriers when disclosure regulation is in place negates the beneficial effect obtained through the disclosure of analyst compensation. The simple reason for this is that the incentive constraints that must be satisfied under information barriers subsume those that must hold for disclosure regulation. Consequently, with both types of regulation in place, the bank chooses the same incentive scheme that it chooses under information barriers alone, and since this scheme pools wages across three states, the wage disclosure does not provide any incremental information to investors.

Finally, we note that similar results hold under an alternative model in which the informational benefits that arise from the analyst's research are conditional on winning the client's business. For instance, the information gathered by the analyst could complement the due diligence that occurs after winning an investment banking deal, thus making the deal pricing more accurate and reducing the chance of a failed merger or initial public offering. Incorporating such contingent benefits into the model yields qualitatively similar results to those of Proposition 6.

6. Empirical implications and evidence

The results of our model provide a number of empirical implications concerning the impact of regulation on analyst optimism and the stock price effects of analyst research. First, the model predicts that analyst regulation should most often lead to intensified research effort, resulting in less upward distortion in analyst reports. This prediction is consistent with the empirical finding of Barber et al. (2006) that, surrounding the introduction of new disclosure requirements under NASD Rule 2711, the percentage of "buy" ratings in a large sample of analyst recommendations decreased from 60 percent to 45 percent, whereas the percentage of "sell" ratings increased from 5 to 14 percent. Likewise, Cliff (2007), Ertimur et al. (2007), Fang and Yasuda (2005), and Kadan et al. (2007) document that the frequency of buy recommendations decreased significantly after the adoption of the Global Settlement and the NASD and NYSE reforms.

Our analysis further implies that disclosure requirements should increase the price impact and information content of stock reports. (Information barriers should have a similar effect, provided that direct informational benefits are not too large.) In line with this prediction, Cliff (2007) and Kadan et al. (2007) report that the average short-term stock price reaction to buy or strong buy recommendations became significantly more positive after implementation of Rule 2711 and the NYSE's amendment to Rule 472. In addition, Cliff (2007) and Fang and Yasuda (2005) find that the average medium-term profitability of following leading investment bank analysts' buy recommendations rose after the 2002 reforms. Finally, consistent with the view that the reforms improved the information content of analyst reports, Ertimur et al. (2007) find that the profitability of individual analysts' buy recommendations became more tightly linked to the analysts' earnings forecasting accuracy in the post-reform era.

The analysis also yields some yet-to-be-tested cross-sectional implications about the effectiveness of regulation. For example, the effect of regulatory change on equilibrium research effort should increase in the variability of the client firm's value, $V^G - V^B$. This implies that regulation should have the most significant impact on analyst credibility for firms with highly uncertain prospects. Such uncertainty might be present for small, young, rapidly-growing firms within such industries as biotechnology or computer software. Likewise, we should expect regulation to play a larger role for industries and firms with relatively few tangible assets. Regulation should have a larger impact on credibility for analysts facing powerful career concerns (i.e., a high $\underline{w}$), such as mid-career analysts with established reputations and with large future earnings at stake.

7. Conclusion

The analysis presented here has focused on one important dimension of the conflict-of-interest problem: how investment banking concerns and information asymmetries between securities firms and investors can lead to biases in analyst research. Our analysis indicates that this kind of problem is best addressed by disclosure-based regulations designed to increase the amount of information available to all parties. Disclosure-based regulations, in our model, unambiguously lead to more informative prices and report quality compared to regulations that restrict communication within the firm. This perspective emerges from a modeling framework in which a securities firm (i.e., investment bank) can respond to changes in the regulatory regime by adjusting the type of incentive contract used to influence an analyst's research effort and reporting behavior. Thus, our approach recognizes the endogenous nature of costly information production within securities firms and enables us to investigate how regulatory changes are likely to affect the quality of analysts' forecasts and recommendations via the amount of underlying information that is produced.

We conclude by noting that our attempt to understand the role of analysts' incentives in the generation and transmission of information has led us to take a simplified view towards a number of potentially important issues. An example is the extent to which competition, either among investment banks for analyst services or among analysts for employment opportunities, affects the relevant outside option for an analyst. Moreover, we have limited our analysis to two specific types of regulation on the premise that they represent the best-known and most widely-discussed regulatory approaches. The broader issue of optimal regulatory design is left for future research.

Acknowledgments

We thank Tim Brennan, Armando Gomes, Vojislav Maksimovic, Roni Michaely, Donald Morgan, and seminar participants at Cornell University, the University of Maryland, and the 2004 FIRS Conference in Capri, Italy for helpful comments. We are also grateful to two anonymous referees and to the editor, Elu von Thadden, for valuable suggestions that significantly improved the paper. All remaining errors are our own.

Appendix A. Proofs

To simplify notation throughout this appendix, we define $\Delta_v \equiv (V^G - V^B)^2$.

Proof of Proposition 1. We first note that equilibrium reporting is straightforward. Suppose to the contrary. Clearly, the analyst must receive a payment in the state (s,ϕ) in which he issues a biased report. The bank can reduce the payment in state (s,ϕ) by a small positive amount and allow the analyst to report straightforwardly. The probability of winning the deal is unchanged since the brokerage firm's information is public, and the analyst's expected utility is at least as high as before. Hence, it cannot be profit-maximizing to induce a bias.

Next, let $w^*(s,\phi)$ be the optimal contract chosen by the investment bank. Let $W^H \equiv w^*(G,\phi^H) + w^*(B,\phi^H)$ denote the sum of wage payments in high-precision states, and let $W^L \equiv w^*(G,\frac{1}{2}) + w^*(B,\frac{1}{2})$ denote that sum in low-precision states. As discussed earlier in the text, straightforward reporting implies that an effort level of e results in an expected inaccuracy penalty of $[p(\frac{1}{2}-\phi^H)+\frac{1}{2}]\underline{w}\Delta_v$ and total expected utility of $\frac{1}{2}pW^H + \frac{1}{2}(1-p)W^L - [p(\frac{1}{2}-\phi^H)+\frac{1}{2}]\underline{w}\Delta_v - \frac{k}{2}e^2$, where $p = \frac{1}{2}+e$. We now argue that $W^L = W^H$. Suppose without loss of generality that $W^L > W^H$. Then the individual rationality (IR) constraint must bind: if it were slack, the firm could increase profits by lowering W^L slightly and causing the analyst to exert more effort, reducing expected wage costs. Maximization of the analyst's expected utility implies that either $e=0$ or

$$e = \frac{1}{2k}W^H - \frac{1}{2k}W^L - \frac{1}{k}\left(\frac{1}{2}-\phi^H\right)\underline{w}\Delta_v. \tag{A.1}$$

Suppose that the latter is true. Then, given that the IR constraint binds, the bank's profits are $\Pi = \frac{1}{2}\alpha - E[w(s,\phi,R(s,\phi)) \mid e] = \frac{1}{2}\alpha - [p(\frac{1}{2}-\phi^H)+\frac{1}{2}]\underline{w}\Delta_v - \frac{k}{2}e^2 - \overline{U}$. Using (A.1) to substitute out for p and e in this last expression, we obtain an expression for Π in terms of W^H and W^L. Differentiating the resulting expression with respect to W^H and W^L, we have that a necessary condition for maximal profits is that $W^L = W^H$, contradicting the assumption that $W^L > W^H$. Thus, (A.1) implies that $e_{SA} = \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}\Delta_v$. Finally, it is straightforward to check that inducing the corner solution $e=0$ does not maximize profits. □

We now establish a simple but useful result.

Lemma 1. *Suppose that $w(s,\phi)$ and $\hat{w}(s,\phi)$ are two contracts that induce the same reporting strategy and that satisfy the following conditions*:

1. $\hat{w}(G,\phi^H) + \hat{w}(B,\phi^H) = w(G,\phi^H) + w(B,\phi^H)$; *and*
2. $\hat{w}(G,\frac{1}{2}) + \hat{w}(B,\frac{1}{2}) = w(G,\frac{1}{2}) + w(B,\frac{1}{2})$.
   Then $w(s,\phi)$ and $\hat{w}(s,\phi)$ induce the same level of research effort from the analyst.

Proof of Lemma 1. Observe that $\Pr\binom{s=G}{\phi=\phi^H} = \Pr\binom{s=B}{\phi=\phi^H} = \frac{1}{2}p$ and $\Pr\binom{s=G}{\phi=\frac{1}{2}} = \Pr\binom{s=B}{\phi=\frac{1}{2}} = \frac{1}{2}(1-p)$. Hence, the expected wage payment received by the analyst under $w(s,\phi)$ is given by $\frac{1}{2}p(w(G,\phi^H) + w(B,\phi^H)) + \frac{1}{2}(1-p)(w(G,\frac{1}{2}) + w(B,\frac{1}{2}))$. Similarly, the expected wage payment received by the analyst under $\hat{w}(s,\phi)$ is $\frac{1}{2}p(\hat{w}(G,\phi^H) + \hat{w}(B,\phi^H)) + \frac{1}{2}(1-p)(\hat{w}(G,\frac{1}{2}) + \hat{w}(B,\frac{1}{2}))$. For a given level of effort, these two expected wages are equal if the conditions in the lemma are satisfied. Therefore, the analyst's marginal incentives to exert research effort are the same under the two contracts. □

Proof of Proposition 2. We will characterize the optimal contract and equilibrium effort level assuming that the investment bank induces the optimistically-biased reporting strategy $R_N(s,\phi)$. The proof will be completed by verifying that other reporting strategies lead to lower profits for the firm. We first calculate the analyst's expected utility under the biased reporting strategy. Observe that $\Pr(R_N(s,\phi)\text{ is incorrect}|^{s=G}_{\phi=\phi^H}) = \Pr(R_N(s,\phi)\text{ is incorrect}|^{s=B}_{\phi=\phi^H}) = 1-\phi^H$. Also, $\Pr(R_N(s,\phi)\text{ is incorrect}|^{s=G}_{\phi=\frac{1}{2}}) = \Pr(R_N(s,\phi)\text{ is incorrect}|^{s=B}_{\phi=\frac{1}{2}}) = \frac{1}{2}$. Taking the weighted sum of these four conditional probabilities, the total probability of being incorrect is $p(\frac{1}{2}-\phi^H)+\frac{1}{2}$. Therefore, the analyst's expected utility under wage contract $w(s,\phi)$ is given by $\frac{1}{2}pW^H + \frac{1}{2}(1-p)W^L - [p(\frac{1}{2}-\phi^H)+\frac{1}{2}]\underline{w}\Delta_v - \frac{k}{2}e^2$ where $W^H \equiv w(G,\phi^H) + w(B,\phi^H)$ and $W^L \equiv w(G,\frac{1}{2}) + w(B,\frac{1}{2})$. Maximization implies that the analyst chooses effort according to (A.1), and this level of effort is nonnegative provided that $W^L - W^H \leqslant (2\phi^H - 1)\underline{w}\Delta_v$ (this inequality will be satisfied if the wage scheme is profit-maximizing). Now note that, under the biased reporting strategy, the stock price will decline when the analyst receives a bad and highly precise signal, which occurs with probability $\frac{1}{2}p$. In all other states, the stock price will rise, and the investment bank will obtain α from winning the client firm's business. Therefore, the wage contract $w(s,\phi)$ solves the investment bank's profit maximization problem only if W^H, W^L solve the following problem:

$$\max_{W^H,W^L} \Pi = \alpha\left(1-\frac{1}{2}p\right) - \frac{1}{2}pW^H - \frac{1}{2}(1-p)W^L$$

$$\text{s.t.}\quad p = \frac{1}{2} + \frac{1}{2k}W^H - \frac{1}{2k}W^L - \frac{1}{k}\left(\frac{1}{2}-\phi^H\right)\underline{w}\Delta_v, \tag{A.2}$$

$$\frac{1}{2}pW^H + \frac{1}{2}(1-p)W^L - \frac{k}{2}\left(p-\frac{1}{2}\right)^2 - \left[p\left(\frac{1}{2}-\phi^H\right)+\frac{1}{2}\right]\underline{w}\Delta_v \geqslant \bar{U}, \tag{A.3}$$

$$W^L \geqslant 0. \tag{A.4}$$

(A.2) can be used to eliminate p from the optimization problem. Then, letting $\mathcal{L}$ denote the Lagrangian and letting λ and μ denote the Lagrange multipliers for the IR constraint (A.3) and the IC constraint (A.4), respectively, we have the f.o.c.'s

$$\begin{aligned}\frac{\partial\mathcal{L}}{\partial W^H} &= -\frac{\alpha}{4k} - \frac{1}{4} + \frac{(\frac{1}{2}-\phi^H)}{2k}\underline{w}\Delta_v - \frac{W^H}{2k} + \frac{W^L}{2k}\\ &\quad - \lambda\left[-\frac{1}{4} - \frac{W^H}{4k} + \frac{W^L}{4k} + \frac{(\frac{1}{2}-\phi^H)}{2k}\underline{w}\Delta_v\right] \leqslant 0,\end{aligned} \tag{A.5}$$

$$\begin{aligned}\frac{\partial\mathcal{L}}{\partial W^L} &= \frac{\alpha}{4k} - \frac{1}{4} - \frac{(\frac{1}{2}-\phi^H)}{2k}\underline{w}\Delta_v + \frac{W^H}{2k} - \frac{W^L}{2k}\\ &\quad - \lambda\left[-\frac{1}{4} + \frac{W^H}{4k} - \frac{W^L}{4k} - \frac{(\frac{1}{2}-\phi^H)}{2k}\underline{w}\Delta_v\right] + \mu \leqslant 0.\end{aligned} \tag{A.6}$$

There are four possibilities:

Case 1: $W^H > 0$ and $W^L > 0$. In this case, the Kuhn–Tucker conditions imply that $\frac{\partial\mathcal{L}}{\partial W^H} = 0$ and $\frac{\partial\mathcal{L}}{\partial W^L} = 0$, and so $\lambda = 1 - 2\mu$. Then, since complementary slackness implies that $\mu = 0$, we have $\lambda = 1$. Therefore, the f.o.c.'s imply that $W^L = W^H + \alpha$, and the IR constraint binds.

Case 2: $W^H > 0$ and $W^L = 0$. This case cannot hold, as we now show. Suppose to the contrary that this case did hold and that the IR constraint were satisfied by an expected utility of $U^* = \frac{1}{2}pW^H + \frac{1}{2}(1-p)W^L - \frac{k}{2}(p-\frac{1}{2})^2 - [p(\frac{1}{2}-\phi^H)+\frac{1}{2}]\underline{w}\Delta_v$. Substituting (A.2) into this equation eliminates

p, yielding an implicit function in W^H and W^L. Holding the analyst's expected utility constant and implicitly differentiating, we obtain that $\frac{\partial W^H}{\partial W^L} = (-k + W^H - W^L - (1-2\phi^H)\underline{w}\Delta_v)/(k + W^H - W^L - (1-2\phi^H)\underline{w}\Delta_v)$. Then, computing the total derivative of profits with respect to W^L and using the preceding equality, we have $\frac{d\Pi}{dW^L} = (W^H - W^L + \alpha)/(2k + 2W^H - 2W^L + (4\phi^H - 2)\underline{w}\Delta_v)$. This last quantity is positive by our parameter assumption on α and by the fact that $W^L = 0$. In other words, the firm could increase profits by raising W^L and lowering W^H slightly in such a way that the IR constraint continues to be satisfied by the same level of analyst utility, a contradiction.

Case 3: $W^H = 0$ and $W^L > 0$. By complementary slackness, $\mu = 0$. If $\lambda = 0$, then the second f.o.c. implies that $W^L = \frac{\alpha}{2} - \frac{k}{2} - (\frac{1}{2} - \phi^H)\underline{w}\Delta_v < 0$, contradicting the nonnegativity constraint. Therefore $\lambda > 0$, and the individual rationality constraint binds.

Case 4: $W^H = 0$ and $W^L = 0$.

Based on the above four cases, we proceed to characterize the optimal choices of W^H and W^L as functions of $\overline{U}$. First, note that the analyst's equilibrium expected utility is increasing separately in W^H and W^L. Now, for Case 4, all wage payments are zero, and so clearly this gives the analyst his stand-alone utility, U_{SA}. For intermediate values of $\overline{U}$ greater than U_{SA} but less than $(\phi^H - 1)\underline{w}\Delta_v$, $W^L - W^H < (2\phi^H - 1)\underline{w}\Delta_v < \alpha$. Case 3 is then the only possibility, and the IR constraint binds. Next, when $\overline{U}$ equals $(\phi^H - 1)\underline{w}\Delta_v$, according to Case 3 $W^H = 0$, $W^L = (2\phi^H - 1)\underline{w}\Delta_v$, and hence (A.1) implies effort is zero. Finally, consider values of $\overline{U}$ above $(\phi^H - 1)\underline{w}\Delta_v$. We argue that the firm can do no better than by setting $W^L - W^H = (2\phi^H - 1)\underline{w}\Delta_v$. First, the probability of receiving a high-precision signal is $\frac{1}{2}$ so long as the analyst exerts zero effort, and so the investment bank cannot gain by setting $W^L - W^H > (2\phi^H - 1)\underline{w}\Delta_v$ while maintaining the same level of analyst utility. Second, if the firm were to set $W^L - W^H < (2\phi^H - 1)\underline{w}\Delta_v$, then maintaining the same level of analyst utility would require $W^H > 0$. But then the argument used in Case 2 above implies that the firm could strictly increase expected profits by increasing W^L and decreasing W^H. Taken together, the preceding arguments characterize the optimal choice of $W^H$and W^L as in the proposition. Given this optimal wage scheme, (A.1) then characterizes equilibrium effort as a function of $\overline{U}$ in accordance with the proposition.

To complete the proof, we verify that the investment bank indeed maximizes profits by inducing the biased reporting strategy considered above. There are four cases to consider. First, inducing favorable reporting in all states would make the analyst's report completely uninformative, resulting in zero investment banking profits. Second, any strategy inducing a downward bias in a given state would be suboptimal as both the analyst and the investment bank would be better off with the wage payment in that state assigned instead to the favorable report.

Third, it would also not be profit maximizing to induce a reporting strategy $\hat{R}(s,\phi)$ in which $\hat{R} = V^B$ if and only if $(s,\phi) = (B, \frac{1}{2})$. Suppose to the contrary that, for a given reservation utility $\hat{U}$, there exists a wage scheme $\hat{w}(s,\phi)$ that induces $\hat{R}(s,\phi)$ and yields maximal profits $\hat{\Pi}$ to the bank. Using arguments similar to those used in analyzing $R_N(s,\phi)$ above, it can be shown that the optimal contract $\hat{w}(s,\phi)$ associated with $\hat{R}(s,\phi)$ has the following characteristics: (1) for $\overline{U} = U_{\mathrm{SA}}$, $\hat{W}^L \equiv \hat{w}(G, \frac{1}{2}) + \hat{w}(B, \frac{1}{2}) = 0$ and $\hat{W}^H \equiv \hat{w}(G, \phi^H) + \hat{w}(B, \phi^H) = (2\phi^H - 1)\underline{w}\Delta_v$; (2) for $\overline{U} > U_{\mathrm{SA}}$, $\hat{W}^L = 0$ and $\hat{W}^H$ is strictly increasing until $\hat{W}^H - \hat{W}^L = \alpha$, beyond which $\hat{W}^H - \hat{W}^L$ ceases to vary with $\overline{U}$. Let Π denote maximized profits under $R_N(s,\phi)$, and let $\hat{\Pi}$ denote maximized profits under $\hat{R}(s,\phi)$, and compare Π to $\hat{\Pi}$. First, direct computations show that, for $\overline{U} = U_{\mathrm{SA}}$, $\Pi - \hat{\Pi} = \frac{1}{2}(\phi^H - \frac{1}{2})\underline{w}\Delta_v - \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}^2\Delta_v + \frac{1}{k}(\phi^H - \frac{1}{2})^2\underline{w}^2\Delta_v - \frac{\alpha}{k}(\phi^H - \frac{1}{2})\underline{w}\Delta_v > 0$. Second, consider intermediate levels of $\overline{U} > U_{\mathrm{SA}}$ for which equilibrium effort is positive under $R_N(s,\phi)$. Calculating $\frac{\partial \Pi}{\partial W^L}$ and $\frac{\partial W^L}{\partial \overline{U}}$ and using the Chain Rule, we have that

$$\left.\frac{\partial \Pi}{\partial \overline{U}}\right|_{W^H=0} = \frac{-k + (2\phi^H - 1)\underline{w}\Delta_v + \alpha - 2W^L}{k - (2\phi^H - 1)\underline{w}\Delta_v + W^L}. \tag{A.7}$$

Likewise, we can calculate that

$$\left.\frac{\partial \hat{\Pi}}{\partial \overline{U}}\right|_{\hat{W}^L=0} = \frac{-k+\alpha-2\hat{W}^H}{k+\hat{W}^H}. \tag{A.8}$$

Since effort under $R_N(s,\phi)$ is positive, we have that $W^L < (2\phi^H-1)\underline{w}\Delta_v < \hat{W}^H$. Therefore, simple calculations show that $\frac{\partial \Pi}{\partial \overline{U}}|_{W^H=0} > \frac{\partial \hat{\Pi}}{\partial \overline{U}}|_{\hat{W}^L=0}$. Thus we have that $\Pi > \hat{\Pi}$. Third, consider high levels of $\overline{U} > U_{\mathrm{SA}}$ such that effort under $R_N(s,\phi)$ is zero and such that $\hat{W}^H - \hat{W}^L = \alpha$. Direct computations show that, for these cases, $\Pi - \hat{\Pi} = -\frac{\alpha^2}{8k} + [\frac{\phi^H}{2} - \frac{1}{4}]\underline{w}\Delta_v$, which is positive from our assumptions on k. Furthermore, for these cases we have $\frac{\partial \Pi}{\partial \overline{U}} \geqslant -1$ and $\frac{\partial \hat{\Pi}}{\partial \overline{U}} = -1$. Thus we have that $\Pi > \hat{\Pi}$ for all levels of reservation utility.

Fourth, allowing straightforward reporting would not be profit maximizing, as we now show. By the reasoning used in the proof of Proposition 1, profits under straightforward reporting are maximized by a flat wage scheme. Let $\widetilde{\Pi}$ denote these maximized profits, and let $\widetilde{W}$ denote the wage level. Suppose that $\overline{U} = U_{\mathrm{SA}}$. Direct computations show that $\Pi - \widetilde{\Pi} = (\frac{1}{2} - e_{\mathrm{SA}})\frac{\alpha}{2} > 0$. Next, consider intermediate levels of $\overline{U} > U_{\mathrm{SA}}$ for which equilibrium effort is positive under $R_N(s,\phi)$. As before, $\frac{\partial \Pi}{\partial \overline{U}}|_{W^H=0} > -1$. However, $\frac{\partial \widetilde{\Pi}}{\partial \overline{U}}|_{\widetilde{W}>0} = -1$. Finally, consider high levels of $\overline{U} > U_{\mathrm{SA}}$ such that effort under $R_N(s,\phi)$ is zero. Then $\frac{\partial \Pi}{\partial \overline{U}} = \frac{\partial \widetilde{\Pi}}{\partial \overline{U}}|_{\widetilde{W}>0} = -1$. Thus we have shown that $\Pi > \widetilde{\Pi}$. □

Proof of Corollary 1. From Appendix B below, we have expressions for report informativeness in the symmetric information case ($\Phi_F(p)$) and in the biased reporting case ($\Phi_B(p)$). Using these expressions, we can calculate that $\Phi_F(1) = \Phi_B(1) = -(\phi^H - (\phi^H)^2)\Delta_v$. Moreover, direct computations show that $\Phi_B'(1) > \Phi_F'(1)$ and that $\Phi_B''(p) > \Phi_F''(p)$ for all $p \in (\frac{1}{2}, 1)$. Therefore, $\Phi_F(p) > \Phi_B(p)$ for all $p \in [\frac{1}{2}, 1)$. Finally, $\Phi_F(p)$ and $\Phi_B(p)$ are strictly increasing, and we know from Proposition 2 that equilibrium effort under private information and no regulation, e_N, is always weakly lower than under symmetric information, $e_{\mathrm{SA}} = \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}\Delta_v$. □

We now state and prove a lemma that will be useful for the proof of Proposition 3. The lemma describes how the IC requirements in (10) constrain the form of the optimal contract.

Lemma 2. *Suppose that $w(s,\phi)$ and $R(s,\phi)$ are a wage scheme and reporting strategy that solve the optimal design problem under restricted communication, and suppose that $R(s,\phi) = V^B$ if and only if $(s,\phi) = (B,\phi^H)$. Then $w(s,\phi)$ satisfies the following properties*:

1. $w(G,\phi^H) = w(G,\frac{1}{2}) = w(B,\frac{1}{2})$;
2. $w(G,\phi^H) - (2\phi^H-1)\underline{w}\Delta_v \leqslant w(B,\phi^H) \leqslant w(G,\phi^H)$.

Proof of Lemma 2. Since $w(s,\phi)$ and $R(s,\phi)$ solve (9), the analyst must find it optimal to declare the signal and precision truthfully and issue the report dictated by $R(s,\phi)$. In other words, for each $s^* \in \{G,B\}$ and $\phi^* \in \{\phi^H, \frac{1}{2}\}$, the following truthtelling constraints must be satisfied:

$$w(s^*,\phi^*) - \Pr\big(R(s^*,\phi^*) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v \geqslant w(s^*,\hat{\phi}) - \Pr\big(R(s^*,\hat{\phi}) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v, \tag{A.9}$$

$$w(s^*,\phi^*) - \Pr\big(R(s^*,\phi^*) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v \geqslant w(\hat{s},\phi^*) - \Pr\big(R(\hat{s},\phi^*) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v, \tag{A.10}$$

$$w(s^*,\phi^*) - \Pr\big(R(s^*,\phi^*) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v \geqslant w(\hat{s},\hat{\phi}) - \Pr\big(R(\hat{s},\hat{\phi}) \text{ is wrong}|^{s=s^*}_{\phi=\phi^*}\big)\underline{w}\Delta_v, \tag{A.11}$$

where $\hat{s} \neq s^*$ and $\hat{\phi} \neq \phi^*$. It is straightforward to verify that these constraints are satisfied if and only if the conclusions of the lemma hold. □

Proof of Proposition 3. We first characterize the optimal contract assuming that the investment bank's profits are maximized if it induces the optimistically biased strategy $R_W(s,\phi)$. The proof will be completed by showing that this is in fact the case. Using Lemma 2 and an argument similar to that in the proof of Proposition 2, we have that a wage scheme $w(s,\phi)$ solves the investment bank's problem if and only if $W^H \equiv w(G,\phi^H)+w(B,\phi^H) \geqslant 0$ and $W^L \equiv w(G,\frac{1}{2})+w(B,\frac{1}{2}) \geqslant 0$ solve:

$$\max_{W^H,W^L} \Pi = \alpha\left(1-\frac{1}{2}p\right)-\frac{1}{2}pW^H-\frac{1}{2}(1-p)W^L$$

$$\text{subject to } p = \frac{1}{2}+\frac{1}{2k}W^H-\frac{1}{2k}W^L-\frac{1}{k}\left(\frac{1}{2}-\phi^H\right)\underline{w}\Delta_v, \tag{A.12}$$

$$\frac{1}{2}pW^H+\frac{1}{2}(1-p)W^L-\frac{k}{2}\left(p-\frac{1}{2}\right)^2-\left[p\left(\frac{1}{2}-\phi^H\right)+\frac{1}{2}\right]\underline{w}\Delta_v \geqslant \bar{U}, \tag{A.13}$$

$$W^H \geqslant W^L-(2\phi^H-1)\underline{w}\Delta_v, \tag{A.14}$$

$$W^H \leqslant W^L, \tag{A.15}$$

$$W^H \geqslant W^L/2. \tag{A.16}$$

We use (A.12) to eliminate p from the above problem. Then, letting λ, μ_1, μ_2, and μ_3 denote the Lagrange multipliers for constraints (A.13), (A.14), (A.15), and (A.16), respectively, we can derive the necessary first-order conditions for optimization as was done in the proof of Proposition 2. The standard Kuhn–Tucker conditions, combined with the facts that $W^H > 0$ and $W^L \geqslant W^H$, lead to the following three possibilities:

Case 1: The IR constraint is slack. The f.o.c.'s imply that $\frac{\lambda}{2}+\frac{\mu_3}{2}=\frac{1}{2}$. Since the IR constraint (A.13) is slack, $\lambda=0$, implying that $\mu_3=1$ and that the associated constraint binds. Therefore, the f.o.c. for W^L implies that $\frac{\alpha}{4k}-\frac{3}{4}+\frac{(\phi^H-\frac{1}{2})}{2k}\underline{w}\Delta_v+\frac{W^H}{2k}=\frac{W^L}{2k}+\mu_1-\mu_2$. If the constraint for μ_2 is slack, then $W^L<W^H$, a contradiction. Therefore, $W^L=0$ and $W^H=\frac{1}{2}W^L$.

Case 2: The IR constraint binds and $W^H > W^L/2$. Since $\mu_3=0$, $\lambda=1$ and the first-order conditions imply that $W^L=W^H+\alpha-4k\mu_1+4k\mu_2$. If constraint (A.14) is slack, then $W^L \geqslant W^H+\alpha$, a contradiction. Therefore, $W^H=W^L-(2\phi^H-1)\underline{w}\Delta_v$.

Case 3: The IR constraint binds and $W^H = W^L/2$. In this case, W^L is determined by the binding IR constraint.

Combining the results from the above three cases and using arguments similar to those used in the proof of Proposition 2, it is straightforward to characterize the equilibrium wage scheme and research effort as functions of the analyst's reservation utility $\bar{U}$. Finally, observe that we have established that $e_W=e_N=\frac{1}{k}(\phi^H-\frac{1}{2})\underline{w}\Delta_v$ for $\bar{U}=U_{\text{SA}}$ and $e_W=e_N=0$ for $\bar{U} \geqslant (2\phi^H-\frac{3}{2})\underline{w}\Delta_v$. Hence, to complete the proof we only need to show that $e_W > e_N$ for the remaining values of $\bar{U}$. Let U_N denote the analyst's expected utility in the no-regulation case. Substitute (A.2) into the expression for U_N and differentiate to obtain that $\frac{\partial U_N}{\partial W^L}=\frac{k+(1-2\phi^H)\underline{w}\Delta_v+W^L}{4k}$. Also, calculate from (A.2) that $\frac{\partial e}{\partial W^L}=-\frac{1}{2k}$. Therefore, $\frac{\partial e}{\partial U_N}=\frac{\partial e}{\partial W^L}\frac{\partial W^L}{\partial U_N}=-\frac{2}{k+(1-2\phi^H)\underline{w}\Delta_v+W^L}$. In similar fashion, if U_W denotes expected utility in the information barriers case, then we can calculate that $\frac{\partial e}{\partial U_W}=-\frac{2}{3k+(1-2\phi^H)\underline{w}\Delta_v+W^L}$. Thus, whenever $U_W=U_N$, $\frac{\partial e}{\partial U_N}<\frac{\partial e}{\partial U_W}$. In other words, effort under information barriers decreases less rapidly than effort under no regulation. But the IR constraint binds in both regimes whenever $\bar{U} \in (U_{\text{SA}}, (2\phi^H-\frac{3}{2})\underline{w}\Delta_v)$, so we automatically have that $U_W=U_N$ over this range.

We now complete the proof by arguing that, with information barriers, the bank's profits are indeed maximized by inducing optimistically-biased reporting $R_W(s,\phi)$. First, a downward-biased reporting strategy or a strategy of always issuing a favorable report are not profit-maximizing for the same reasons as in the proof of Proposition 2. Second, consider the overoptimistic reporting strategy in which an unfavorable report is issued if and only if the signal is unfavorable with *low* precision. It can be shown that inducing this strategy would not be feasible because two or more of the analyst's truthtelling constraints contained in (10) would be logically incompatible. Third, consider the straightforward reporting strategy. Let $\widetilde{\Pi}$ denote maximized profits under this strategy, which, by an argument similar to that used in the proof of Proposition 1, are equivalent to the profits from a flat wage scheme. Also, let Π denote maximized profits under the optimistically-biased reporting strategy $R_W(s,\phi)$. By direct calculation, when $\overline{U} = U_{\mathrm{SA}}$, then $\Pi - \widetilde{\Pi} = (\frac{1}{2} - e_{\mathrm{SA}})\frac{\alpha}{2}$, which is positive by our parameter assumptions. Furthermore, reasoning similar to that in Proposition 2 shows that $\frac{\partial \Pi}{\partial \overline{U}} \geqslant \frac{\partial \widetilde{\Pi}}{\partial \overline{U}} = -1$ for all $\overline{U} \geqslant U_{\mathrm{SA}}$. Thus, $\Pi > \widetilde{\Pi}$. □

Proof of Corollary 2. The investment bank induces the same optimistically-biased reporting strategy under information barriers as under no regulation. Since report quality under this reporting strategy, $\Phi_B(p)$, is strictly increasing in p (see the expression in Section B.2 of Appendix B), report quality is strictly increasing in research effort. From Proposition 3, if $\overline{U} \in (U_{\mathrm{SA}}, (2\phi^H - \frac{3}{2})\underline{w}\Delta_v)$, then research effort is strictly higher under information barriers regulation than under no regulation. For other values of $\overline{U}$, effort is equal in the two regulatory regimes. □

Proof of Proposition 4. As argued in the proof of Proposition 2 for no regulation, under disclosure regulation the firm will induce the biased reporting strategy $R(s,\phi)$ in which $R = V^B$ if and only if $(s,\phi) = (B,\phi^H)$. To maximize profits, the firm will choose an optimal wage scheme $w(s,\phi)$ that "pools" information across states. Specifically, the firm will set $w(B,\frac{1}{2}) = w(G,\phi^H)$, thereby preventing investors from using the wage disclosure to learn perfectly whether upward distortion has occurred. Under this wage scheme, the interim stock price increases whenever $(s,\phi) \in \{(B,\frac{1}{2}),(G,\phi^H),(G,\frac{1}{2})\}$, and so the investment bank still obtains profits in three out of four states.

To simplify the characterization, we assume without loss of generality that $w(B,\frac{1}{2}) = w(G,\phi^H) = 0$. To see why this simplification is valid, suppose that $w(B,\frac{1}{2}) = w(G,\phi^H) = \delta$ where $\delta > 0$. Consider a wage scheme $\hat{w}(s,\phi)$ with $\hat{w}(B,\frac{1}{2}) = \hat{w}(G,\phi^H) = 0$, $\hat{w}(B,\phi^H) = w(B,\phi^H) + \delta$, and $\hat{w}(G,\frac{1}{2}) = w(G,\frac{1}{2}) + \delta$. By Lemma 1, $w(s,\phi)$ and $\hat{w}(s,\phi)$ induce the same level of effort from the analyst. Also, the expected wages under $w(s,\phi)$ and $\hat{w}(s,\phi)$ are equal. Hence, $w(s,\phi)$ and $\hat{w}(s,\phi)$ lead to the same economic outcomes for the bank and the analyst.

To characterize the optimal scheme $w(s,\phi)$, we first note that profits are maximized only if $w^H \equiv w(B,\phi^H) \geqslant 0$ and $w^L \equiv w(G,\frac{1}{2}) \geqslant 0$ solve the following optimization program:

$$\max_{w^H,w^L} \Pi = \alpha\left(1 - \frac{1}{2}p\right) - \frac{1}{2}pw^H - \frac{1}{2}(1-p)w^L$$

$$\text{subject to} \quad p = \frac{1}{2} + \max\left[0, \frac{1}{2k}w^H - \frac{1}{2k}w^L - \frac{1}{k}\left(\frac{1}{2} - \phi^H\right)\underline{w}\Delta_v\right], \tag{A.17}$$

$$\frac{1}{2}pw^H + \frac{1}{2}(1-p)w^L - \frac{k}{2}\left(p - \frac{1}{2}\right)^2 - \left[p\left(\frac{1}{2} - \phi^H\right) + \frac{1}{2}\right]\underline{w}\Delta_v \geqslant \overline{U}. \tag{A.18}$$

Assuming that $w^L - w^H \leqslant (2\phi^H - 1)\underline{w}\Delta_v$ (it can be shown that this is optimal for the investment bank), we can derive, as in the proof of Proposition 2, the f.o.c.'s necessary for optimization. Straightforward application of the Kuhn–Tucker conditions implies that if the IR constraint is slack, then we must have $w^H = w^L = 0$. On the other hand, if the IR constraint binds, then the investment bank will find it optimal to choose $w^H = 0$ and to set w^L in accordance with the binding constraint.

Applying Lemma 1 and directly comparing the wage scheme implied by Cases 1 and 2 to the wage scheme characterized in Proposition 2 (the no-regulation case), we see that, for a given reservation utility $\overline{U}$, effort is always higher under wage disclosure. The final step of the proof is to show that, for any given level of effort e, informativeness under the optimistically-biased reporting strategy is higher with wage disclosure ($\Phi_{BW}(p)$) than with no wage disclosure ($\Phi_B(p)$). This fact follows directly from the expressions for $\Phi_{BW}(p)$ and $\Phi_B(p)$ derived in Appendix B. □

Proof of Proposition 5. We proceed to characterize, in terms of $\overline{U}$, the equilibrium probabilities p_{walls} and p_{disc} of obtaining high-precision signals in the information barriers and mandatory disclosure regimes. Consider first the information barriers regime. We know from Lemma 2 and the proof of Proposition 3 that, if $U_{\text{SA}} \leqslant \overline{U} \leqslant (2\phi^H - \frac{3}{2})\underline{w}\Delta_v$, the equilibrium wage scheme is given by $w(B, \phi^H) = 0$ and $w(G, \phi^H) = w(G, \frac{1}{2}) = w(B, \frac{1}{2}) = C$ for some positive C. Thus, let $W_C \equiv -w(G, \phi^H) - w(B, \phi^H) = \frac{1}{2}(-w(G, \frac{1}{2}) - w(B, \frac{1}{2}))$. If the IR constraint is binding, it follows from the analyst's expected utility function that

$$\overline{U} = \frac{1}{2} p_{\text{walls}}(-W_C) + \frac{1}{2}(1 - p_{\text{walls}})(-2W_C) - \frac{k}{2}\left(p_{\text{walls}} - \frac{1}{2}\right)^2 - \left[p_{\text{walls}}\left(\frac{1}{2} - \phi^H\right) + \frac{1}{2}\right]\underline{w}\Delta_v. \tag{A.19}$$

In addition, from direct computations the analyst's optimal effort choice implies that

$$p_{\text{walls}} = \frac{1}{2} + \frac{1}{2k} W_C - \frac{1}{k}\left(\frac{1}{2} - \phi^H\right)\underline{w}\Delta v. \tag{A.20}$$

Solving (A.20) for W_C, substituting the resulting expression into (A.19), and simplifying, we have that, for $U_{\text{SA}} \leqslant \overline{U} \leqslant (2\phi^H - \frac{3}{2})\underline{w}\Delta_v$,

$$\overline{U} = \frac{k}{2} p_{\text{walls}}^2 - 2k p_{\text{walls}} + \left(2\phi^H - \frac{3}{2}\right)\underline{w}\Delta_v + \frac{7}{8}k. \tag{A.21}$$

A similar argument can be used for the disclosure regime to show that, if $U_{\text{SA}} \leqslant \overline{U} \leqslant (\phi^H - 1)\underline{w}\Delta_v$,

$$\overline{U} = \frac{k}{2} p_{\text{disc}}^2 - k p_{\text{disc}} + (\phi^H - 1)\underline{w}\Delta_v + \frac{3}{8}k. \tag{A.22}$$

From (A.21) and (A.22), we therefore have the following expressions for the equilibrium probabilities of obtaining high-precision signals in the two regimes:

$$p_{\text{walls}}(\overline{U}, \phi^H) = 2 - \sqrt{\frac{9}{4} + \frac{2\overline{U} - (4\phi^H - 3)\underline{w}}{k}} \quad \text{for } \overline{U} \in \left[U_{\text{SA}}, \left(2\phi^H - \frac{3}{2}\right)\underline{w}\Delta_v\right], \tag{A.23}$$

$$p_{\text{disc}}(\overline{U}, \phi^H) = 1 - \sqrt{\frac{1}{4} + \frac{2\overline{U} - (2\phi^H - 2)\underline{w}}{k}} \quad \text{for } \overline{U} \in \left[U_{\text{SA}}, (\phi^H - 1)\underline{w}\Delta_v\right]. \tag{A.24}$$

Now note the following facts. First, $p_{\text{disc}} = \frac{1}{2}$ if $\overline{U} \geqslant (\phi^H - 1)\underline{w}\Delta_v$, while $p_{\text{disc}} > \frac{1}{2}$ if $\overline{U} < (\phi^H - 1) \times \underline{w}\Delta_v$. Furthermore, at $\overline{U} = (\phi^H - 1)\underline{w}\Delta_v$, $p_{\text{walls}} = p_{\text{disc}} + D$, where $D \equiv \frac{3}{2} - \sqrt{\frac{9}{4} - \frac{(2\phi^H - 1)\underline{w}\Delta_v}{k}}$. Also note that, over the domain $\overline{U} \in (U_{\text{SA}}, (\phi^H - 1)\underline{w}\Delta_v)$,

$$\frac{\partial p_{\text{walls}}}{\partial \overline{U}} - \frac{\partial p_{\text{disc}}}{\partial \overline{U}} = \frac{1}{k\sqrt{\frac{1}{4} + \frac{2\overline{U} - (2\phi^H - 3)\underline{w}\Delta_v}{k}}} - \frac{1}{k\sqrt{\frac{9}{4} + \frac{2\overline{U} - (4\phi^H - 3)\underline{w}\Delta_v}{k}}} > 0. \tag{A.25}$$

The above facts imply that the distance $p_{\text{walls}} - p_{\text{disc}}$ is maximized at $\overline{U} = (\phi^H - 1)\underline{w}\Delta_v$, and the maximal difference is equal to D.

Now consider report informativeness in the two regulatory regimes. Under equilibrium reporting strategies, the report quality equals $\Phi_B(\cdot, \phi^H)$ in the information barriers regime and $\Phi_{BW}(\cdot, \phi^H)$ in the disclosure regime (see Appendix B for the relevant expressions). We will therefore be done if we can show that $\Phi_{BW}(p, \phi^H) > \Phi_B(p + D, \phi^H)$ for all $p \in (\frac{1}{2}, \frac{1}{2} + e_{\text{SA}})$.

Direct calculations reveal that, for all $p \in (\frac{1}{2}, \frac{1}{2} + e_{\text{SA}})$,

$$\frac{\partial \Phi_{\text{BW}}(p, \phi^H)}{\partial p} - \frac{\partial \Phi_B(p + D, \phi^H)}{\partial p} = \left[1 + 2p - \frac{4}{(p - \sqrt{\frac{9}{4} - \frac{(2\phi^H - \frac{1}{2})\underline{w}\Delta_v}{k}})^2}\right]\left(\frac{1}{8} - \frac{\phi^H}{2} + \frac{(\phi^H)^2}{2}\right).$$

The first factor (in brackets) is negative, while the second factor (in parentheses) is zero at $\phi^H = \frac{1}{2}$ and positive elsewhere. Hence, $\Phi_{\text{BW}}(p, \phi^H) - \Phi_B(p + D, \phi^H)$ is minimized when p is maximized over the relevant domain, i.e., when $p = \frac{1}{2} + e_{\text{SA}}$. Also, we can calculate that, for $p \in (\frac{1}{2}, \frac{1}{2} + e_{\text{SA}})$,

$$\frac{\partial \Phi_{\text{BW}}(p, \phi^H)}{\partial \phi^H} - \frac{\partial \Phi_B(p + D, \phi^H)}{\partial \phi^H} = -\frac{1}{2}(p + p^2) + \phi^H(p + p^2) + (2\phi^H - 1)\left(\frac{p + D}{p + D - 2}\right) > 0.$$

Thus, $\Phi_{\text{BW}}(p, \phi^H) - \Phi_B(p + D, \phi^H)$ is minimized at $(p, \phi^H) = (\frac{1}{2} + e_{\text{SA}}, \frac{1}{2})$. Direct calculations show that $\Phi_{\text{BW}}(\frac{1}{2} + e_{\text{SA}}, \frac{1}{2}) - \Phi_B(\frac{1}{2} + e_{\text{SA}} + D, \frac{1}{2})$ is in fact nonnegative. Thus we have shown that $\Phi_{\text{BW}}(p, \phi^H) > \Phi_B(p + D, \phi^H)$ for all $p \in (\frac{1}{2}, \frac{1}{2} + e_{\text{SA}})$. □

Proof of Proposition 6. Consider first the no-regulation case. Observe that the only effect of the intrinsic research benefits is to alter the investment bank's profit function. Assume that the investment bank will still choose to induce an optimistic bias exactly when the analyst receives an unfavorable signal with low precision (the proof will be concluded by showing that this is indeed the case). Hence, the optimization problem is the same as in the proof of Proposition 2, with the exception that firm profits are now given by $\Pi = \alpha(1 - \frac{1}{2}p) - \frac{1}{2}pW^H - \frac{1}{2}(1 - p)W^L + \alpha_2(e)$. Letting λ denote the Lagrange multiplier for the IR constraint (A.3) and letting μ denote the Lagrange multiplier for the IC constraint (A.4), we have the first-order conditions

$$\frac{\partial \mathcal{L}}{\partial W^H} = -\frac{\alpha}{4k} - \frac{1}{4} + \frac{(\frac{1}{2} - \phi^H)}{2k}\underline{w}\Delta_v - \frac{W^H}{2k} + \frac{W^L}{2k} + \frac{\alpha_2'(e)}{2k}$$
$$- \lambda\left[-\frac{1}{4} - \frac{W^H}{4k} + \frac{W^L}{4k} + \frac{(\frac{1}{2} - \phi^H)}{2k}\underline{w}\Delta_v\right] \leqslant 0, \tag{A.26}$$
$$\frac{\partial \mathcal{L}}{\partial W^L} = \frac{\alpha}{4k} - \frac{1}{4} - \frac{(\frac{1}{2} - \phi^H)}{2k}\underline{w}\Delta_v + \frac{W^H}{2k} - \frac{W^L}{2k} - \frac{\alpha_2'(e)}{2k}$$
$$- \lambda\left[-\frac{1}{4} + \frac{W^H}{4k} - \frac{W^L}{4k} - \frac{(\frac{1}{2} - \phi^H)}{2k}\underline{w}\Delta_v\right] + \mu = 0. \tag{A.27}$$

Arguments similar to those used in the proof of Proposition 2 give rise to four distinct candidate solutions, depending on whether $W^H > 0$ and whether the IC constraint binds. To analyze these cases, we calculate, as in the proof of Proposition 2, the total derivative of firm profits with respect to W^L for a fixed level of the analyst's expected utility:

$$\frac{d\Pi}{dW^L} = \frac{W^H - W^L + \alpha - 2\alpha_2'(e)}{2k + 2W^H - 2W^L + (4\phi^H - 2)\underline{w}\Delta_v}. \tag{A.28}$$

Using the fact that $W^L - W^H \leqslant (2\phi^H - 1)\underline{w}\Delta_v$ over the range of interest, it follows from (A.28) that if $\alpha_2'(e_{\text{SA}}) < \frac{\alpha}{2}$, then the sign of $\frac{d\Pi}{dW^L}$ is positive when the IC constraint binds and $\overline{U} = U_{\text{SA}}$. Therefore, $W^L - W^H$ will always be positive as $\overline{U}$ increases. Hence, it cannot be the case that $W^H > 0$ at the same time that the IC constraint binds, and equilibrium effort will always be below e_{SA} for $\overline{U} > U_{\text{SA}}$. Likewise, if $\alpha_2'(e_{\text{SA}}) = \frac{\alpha}{2}$, then equilibrium effort will be e_{SA} for all $\overline{U} > U_{\text{SA}}$. However, if $\alpha_2'(e_{\text{SA}}) > \frac{\alpha}{2}$ then the IC constraint must bind. This implies that effort is strictly increasing in $\overline{U}$ for all $\overline{U} \geqslant U_{\text{SA}}$.

Next, consider equilibrium under information barriers. We assume that the investment bank will choose to induce an optimistic bias exactly when the analyst receives an unfavorable signal with low precision (the proof will be completed by showing that this is the case). The optimization is the same as in the proof of Proposition 3, except that $\Pi = \alpha(1 - \frac{1}{2}p) - \frac{1}{2}pW^H - \frac{1}{2}(1 - p)W^L + \alpha_2(e)$. Arguments similar to those used in the proof of Proposition 3 identify four distinct cases, depending on whether or not the IR constraint binds and whether or not $W^H > W^L/2$. To analyze these cases, one can calculate $d\Pi/dW^L$, the total derivative of profits for increases in W^L and decreases in W^H that together leave the analyst as well off as before. Then, one can show that if $\alpha_2'(e_{\text{SA}}) \leqslant \frac{\alpha}{2}$, then it is only possible to have a binding IR constraint and $W^H > W^L/2$ if the constraint for μ_1 binds.

This case is qualitatively similar to the case with no direct benefits in that W^L increases steadily and effort decreases steadily as $\overline{U}$ increases. If instead $\alpha_2'(e_{\text{SA}}) > \frac{\alpha}{2}$, then the only possibilities involve a binding constraint associated with μ_2. Therefore, the level of effort must be constant and equal to the stand-alone effort level, e_{SA}. To summarize, if $\alpha_2'(e_{\text{SA}}) \leqslant \frac{\alpha}{2}$, then optimal effort levels under no regulation and under information barriers bear the same qualitative relationship as in the absence of intrinsic benefits. However, consider the case with $\alpha_2'(e_{\text{SA}}) > \frac{\alpha}{2}$. In the absence of regulation, effort is strictly increasing in $\overline{U}$ (for $\overline{U} > U_{\text{SA}}$), but under information barriers effort is constant for all $\overline{U}$.

Since the informativeness measure $\Phi_B(p)$ is strictly increasing in effort (see Section B.2 in Appendix B), to complete the proof we need only show that the bank will choose to distort upwards exactly when the state is $(s, \phi) = (B, \frac{1}{2})$. Consider first the no-regulation regime. As argued before in Proposition 2, a downward-biased reporting strategy or a strategy of always issuing a favorable report are not profit maximizing. Also observe that, in the presence of direct benefits, maximized profits under straightforward reporting are lower than maximized profits under the strategy of distorting in state $(s, \phi) = (B, \phi^H)$. Let $\widetilde{\Pi}$ and $\widetilde{e}$ denote maximal profits and equilibrium effort associated with distorting in $(s, \phi) = (B, \phi^H)$, and let Π and e denote maximal profits and equilibrium effort associated with distorting in $(s, \phi) = (B, \frac{1}{2})$. Direct calculations show that when $\overline{U} = U_{\text{SA}}$, $\Pi - \widetilde{\Pi} = \frac{1}{2}(\phi^H - \frac{1}{2})\underline{w}\Delta_v - \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}^2\Delta_v + \frac{1}{k}(\phi^H - \frac{1}{2})^2\underline{w}^2\Delta_v - \frac{\alpha}{k}(\phi^H - \frac{1}{2})\underline{w}\Delta_v > 0$. When $\overline{U} \geqslant U_{\text{SA}}$, $\Pi - \widetilde{\Pi} \geqslant \frac{1}{2}(\phi^H - \frac{1}{2})\underline{w}\Delta_v - \frac{1}{k}(\phi^H - \frac{1}{2})\underline{w}^2\Delta_v + \frac{1}{k}(\phi^H - \frac{1}{2})^2\underline{w}^2\Delta_v - \frac{\alpha}{k}(\phi^H - \frac{1}{2})\underline{w}\Delta_v - A_1(\overline{U}) - A_2(\overline{U}) \geqslant \frac{3}{8}(\phi^H - \frac{1}{2})\underline{w}\Delta_v - A_1(\overline{U}) - A_2(\overline{U})$, where $A_1(\overline{U})$ and $A_2(\overline{U})$ correspond to the additional profit differential due to smaller direct benefits and a smaller probability of winning the client's business, respectively. Note that expected wage payments must be less than the expected benefits from employing the analyst. In other words, if the bank distorts in $(s, \phi) = (B, \frac{1}{2})$, then $(\frac{1}{4} + \frac{e}{2})W^H \leqslant (\frac{1}{4} - \frac{e}{2})\alpha + \alpha_2$, where W^H is the sum of payments in high-precision states. Since $\alpha_2 \leqslant \alpha/2$, we therefore have that $W^H \leqslant 3\alpha$ and $e \leqslant \frac{3\alpha}{2k}$. A similar argument shows that if the bank distorts in $(s, \phi) = (B, \phi^H)$, then $\widetilde{e} \leqslant \frac{3\alpha}{2k}$. Now, there are two cases to consider. First, if $\widetilde{e} = e = \frac{3\alpha}{2k}$, then $A_1(\overline{U}) = 0$ and $A_2(\overline{U}) \leqslant \frac{\alpha}{2}[\widetilde{e} - \frac{\alpha}{2k}] + \frac{\alpha}{2}[e] = \frac{5\alpha^2}{4k}$. Second, if $\widetilde{e} \leqslant \frac{3\alpha}{2k}$ and $e < \frac{3\alpha}{2k}$, then $A_1(\overline{U}) \leqslant \alpha_2'(e)(\widetilde{e} - e) \leqslant \alpha_2'(e)(\frac{3\alpha}{2k} - \frac{2\alpha_2'(e) - \alpha}{2k})$. This quantity is maximized when $\alpha_2' = \alpha$. Therefore, $A_1(\overline{U}) \leqslant \frac{\alpha^2}{k}$. Moreover, $A_2(\overline{U}) \leqslant \frac{\alpha}{2}[\widetilde{e} - \frac{\alpha}{2k}] + \frac{\alpha}{2}[e] = \frac{5\alpha^2}{4k}$. In either case, $A_1(\overline{U}) + A_2(\overline{U}) < \frac{3}{8}(\phi^H - \frac{1}{2})\underline{w}\Delta_v$. We have thus shown that $\Pi - \widetilde{\Pi} > 0$ for all $\overline{U}$.

Now consider the information barriers regime. As argued previously, a downward-biased reporting strategy or the strategy of always issuing a favorable report are not profit maximizing. Under straightforward reporting, profits are maximized by a flat wage scheme (recall that the bank cannot observe the analyst's information). However, it was already shown in Proposition 3 that, even without informational benefits, biased reporting leads to higher profits than straightforward reporting. Finally, overoptimistic reporting that distorts in state $(s, \phi) = (B, \phi^H)$ cannot be induced by the bank because two or more of the analyst's truthtelling constraints contained in condition (10) would be logically incompatible. $\square$

Appendix B. Reporting strategies and informativeness levels

To simplify calculation of informativeness levels for the different reporting strategies considered in the text, we will use the fact that $-E[(V - \hat{V})^2] = -E[\text{var}(V \mid \Omega)]$, where Ω is the set of all information available to investors at time 2 upon observing the analyst's report. To see why this equality holds, simply note that $-E[(V - \hat{V})^2] = -E[E[(V - \hat{V})^2 \mid \Omega]] = -E[E[(V^2 - 2V\hat{V} + \hat{V}^2) \mid \Omega]] = -E[E[(V^2 - E[V \mid \Omega]^2) \mid \Omega]] = -E[\text{var}(V \mid \Omega)]$.

B.1. Symmetric information (Φ_F)

When all information is observable by investors, investors can distinguish among all four states. Therefore, we have that

$$\begin{aligned}\Phi_F(p) &= -\frac{1}{2}p * \mathrm{var}\big(V\big|^{s=G,}_{\phi=\phi^H}\big) - \frac{1}{2}(1-p) * \mathrm{var}\big(V\big|^{s=G,}_{\phi=\frac{1}{2}}\big) - \frac{1}{2}p * \mathrm{var}\big(V\big|^{s=B,}_{\phi=\phi^H}\big) \\ &\quad - \frac{1}{2}(1-p) * \mathrm{var}\big(V\big|^{s=B,}_{\phi=\frac{1}{2}}\big) \\ &= -\big[p\phi^H\big(1-\phi^H\big) + (1-p)/4\big] * \big(V^G - V^B\big)^2. \end{aligned} \tag{B.1}$$

B.2. Optimistically-biased reporting (Φ_B)

Under the optimistically-biased reporting strategy considered in the text, $R(s,\phi) = V^B$ if $s = B$ and $\phi = \phi^H$; otherwise, $R(s,\phi) = V^G$. This implies that investors can distinguish between the two possibilities $(s,\phi) = (B,\phi^H)$ and $(s,\phi) \in \{(G,\phi^H), (G,\frac{1}{2}), (B,\frac{1}{2})\}$. Thus, we have that

$$\begin{aligned}\Phi_B(p) &= -\Pr\big(R = V^G\big) * \mathrm{var}\big(V \mid R = V^G\big) - \Pr\big(R = V^B\big) * \mathrm{var}\big(V \mid R = V^B\big) \\ &= \frac{\frac{1}{2} - \frac{p}{2} + p\phi^H - p(\phi^H)^2}{p-2} * \big(V^G - V^B\big)^2. \end{aligned} \tag{B.2}$$

B.3. Optimistically-biased reporting with wage disclosure (Φ_{BW})

Here, investors learn the ex post wage paid in addition to the information they learn in Section B.2. As shown in the proof of Proposition 4, the investment bank pools information by setting $w(G,\phi^H) = w(B,\frac{1}{2})$. Therefore, investors can distinguish among the following three possibilities: $(s,\phi) = (G,\frac{1}{2})$, $(s,\phi) = (B,\phi^H)$, or $(s,\phi) \in \{(G,\phi^H), (B,\frac{1}{2})\}$. We can calculate that

$$\begin{aligned}\Phi_{\mathrm{BW}}(p) &= -\Pr\big(^{s=G,}_{\phi=\frac{1}{2}}\big) * \mathrm{var}\big(V\big|^{s=G,}_{\phi=\frac{1}{2}}\big) - \Pr\big(\big(^{s=G,}_{\phi=\phi^H}\big) \text{ or } \big(^{s=B,}_{\phi=\frac{1}{2}}\big)\big) * \mathrm{var}\big(V \mid \big(^{s=G,}_{\phi=\phi^H}\big) \text{ or } \big(^{s=B,}_{\phi=\frac{1}{2}}\big)\big) \\ &\quad - \Pr\big(^{s=B,}_{\phi=\phi^H}\big) * \mathrm{var}\big(V\big|^{s=B,}_{\phi=\phi^H}\big) \\ &= -\frac{1}{2}\left[\frac{1}{2} - \frac{1}{4}p - \frac{1}{4}p^2 + \big(p+p^2\big)\phi^H\big(1-\phi^H\big)\right] * \big(V^G - V^B\big)^2. \end{aligned} \tag{B.3}$$

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