

STRATEGIC DISCLOSURE OF MEANINGFUL INFORMATION TO RIVAL

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I study a model of strategic disclosure of a private signal to a rival in the presence of a payoff externality. In the model, two agents forecast the unknown true state of a future period. Specifically, the quality of the signal is also private information. Hence, which quality of signal is revealed for which incentive is the main question of interest. I show that, even when disclosure is costly, the revealing equilibrium, where an agent voluntarily reveals his signal, can exist and it should be a monotone equilibrium. Asymmetry between the penalty for an incorrect forecast and the reward for a correct forecast is a necessary condition for the existence of this revealing equilibrium. If the penalty is larger than the reward, the unique revealing equilibrium is a separating equilibrium, where only the low quality signal is disclosed in order to induce the rival's imitation. On the other hand, if the reward is much larger than the penalty, the unique revealing equilibrium is a pooling equilibrium, where the signal is always revealed in order to induce the rival's deviation. If the reward is not much larger than the penalty, no revealing equilibrium is robust to a costly disclosure. (JEL D81, D82)

I. INTRODUCTION

It is common for agents or firms in the competitive environment to disclose private information to competitors. For example, rating agencies such as Standard & Poor's, Moody's, and Fitch, which compete with one another in the sovereign credit rating market, announce their own ratings to which investors refer. If one agency publicly announces his rating, competitors can also see it and infer how that agency is evaluating the subject. The competitors can then use it as another source of information for their own ratings. How each agency evaluates the subject is private information because competitors

cannot see it if no announcement is made. That is, the announcement of a rating discloses the agency's private information. Similar behavior can also be observed in the product market. Firms in competitive industries often preannounce a new product well in advance of its actual market availability. Firms investing in R&D for technology make announcements about their upcoming innovations or intermediate achievements well in advance of actual success. This type of preannouncement gives competitors some sense about the direction of future competition. If a firm hides what it is doing, competitors may remain uninformed. In that sense, the preannouncement can be interpreted as another way of disclosing private information.

In the above examples, the rating announcement and the preannouncement of a new product necessarily cause a spillover of private information. Moreover, such disclosure of private information can be intentional. Firms are not required to preannounce a product, so their decision to do so may be strategic. Although credit rating agencies must announce their rating, they can decide when to announce it. That is, they can decide whether to disclose private information or prevent its spillover to competitors by controlling the timing of the announcement. If they would like to disclose private information, they can announce before competitors. If not,

*I thank the Editor, and two anonymous referees for helpful comments and suggestions. I am also grateful to Talia Bar, Jay Pil Choi, Luke Froeb, Thomas Jeitschko, Li Way Lee, Jae Nahm, Marco Ottaviani, Eric Rasmusen, Michael Waldman, the conference participants at International Industrial Organization Conference, Midwest Economic Theory Meeting, Asian Meeting of Econometric Society, Conference on Tournaments, Contests and Relative Performance Evaluation, and the seminar participants at University of Windsor, University of Seoul, IUPUI, University of Guelph, Michigan State University, Sogang University, City University of Hong Kong, SUNY Buffalo, Lehigh University, Wayne State University, International University of Japan, and Yonsei University for their helpful discussions.

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they can delay the announcement as long as possible to prevent competitors from observing the announcement. Ample examples of pre-announcement of products and the sequential announcements by rating agencies suggest that the disclosure of private information is common and can be strategic. Then, it is natural to ask what incentives induce them to disclose private information voluntarily, and what message they want to send to competitors.

In this article, I focus on the role of the information quality in motivating agents to disclose information voluntarily. Although someone has meaningful information, they should consider the possibility that the information may be wrong. The agent may have different attitudes toward disclosing information depending on his confidence in the information, or as I call it, the information quality. Previous literature focuses on the phenomenon of information disclosure itself, the amount of information disclosed, or the effect of the realization of information (such as whether it is good news or bad news) on the disclosure of information.¹ In those models, the information is assumed to be always correct or, if imperfect information is considered, its quality is assumed to be public information. The assumptions in this article, that the information is imperfect and that its precision is private information, are more realistic than the assumptions in those models. Thus, this article contributes to the existing literature by studying the effect of the realization of the quality of information on information disclosure.² Specifically, as the information quality is assumed to be private information, the question as to which quality type of information would be revealed for which incentive can be addressed.

I am also concerned about the effect of the payoff structure on the incentive to disclose information. In a competitive environment, what usually matters is how agents perform relative to

their competitors.³ Given the relative evaluation system, the reward for satisfactory performance and the penalty for poor performance are affected by the performance of competitors. For example, in completing a task, an agent's success is more positively evaluated if his peers did not also succeed. On the other hand, if an agent fails in a task, it is not bad news if his peers also fail because it results in a less negative evaluation than if he alone failed. Thus, it is interesting to ask how the incentive to disclose information is affected by this type of competitive payoff structure. Specifically, this article attempts to investigate how the payoff structure affects the quality of disclosed information, which was not addressed in previous works.

Based on these motivations, I consider the following model. There are two managers of two independent firms, and each manager selects one of two business projects. Which project would be more profitable is not known. One manager (henceforth M) observes an imperfect, but informative, signal regarding which project would be more profitable, but the other manager (henceforth U) does not observe an informative signal. M's signal and its precision are private information. The more profitable project is revealed after each manager chooses a project. The managers compete with each other in that their payoffs depend on the accuracy of both agents' choices. The payoff structure is characterized by the reward earned when an agent is the only one who chose correctly and the penalty faced when an agent is the only one who was wrong. The reward or penalty is shared if the two managers' choices are identical. Thus, the concept of relative evaluation is incorporated in this payoff structure. In this set-up, M decides whether or not to follow his signal when choosing a project and also decides whether or not to disclose his signal to U. Also, since the precision of his signal is private information, M should decide which signal quality type to reveal if he decides to do so.

The main results can be summarized as follows. I am interested in a revealing equilibrium, where M reveals his signal voluntarily to his rival

1. In the field of accounting, there is a large literature on how the realization of information (i.e., whether it is good news or bad news) affects the disclosure of private information in various settings. For example, see Darrrough and Stoughton (1990), Dye (1985), Jung and Kwon (1988), Lanen and Verrecchia (1987), Langberg and Sivaramakrishnan (2008), and Wagenhofer (1990).

2. Verrecchia (1990) is an exception in that it also studies how the signal quality influences the decision to disclose information. However, Verrecchia's model considers this topic in a different context from the current model. The signal is about the liquidating value of the risky asset and the informed manager's objective is to maximize the market price of the risky asset, in the presence of market traders who have rational expectations about his motivation to withhold unfavorable reports.

3. Aggarwal and Samwick (1999), Antle and Smith (1986), Gibbons and Murphy (1990), Janakiraman, Lambert, and Larcker (1992) provide evidence that the relative evaluation is widely used in the market. In particular, according to Mikhail, Walther, and Willis (1999), analysts who are inferior to their peers are more likely to be fired. However, the absolute accuracy of the forecast has little effect on the probability of layoff.

when he is not required to do so. *M*'s equilibrium strategy regarding which signal-quality type he reveals for which incentive is contingent on the payoff structure. If the reward and the penalty are symmetric, *M* never discloses his signal, implying that asymmetry in reward and penalty is necessary for the disclosure of a signal. If the penalty is larger than the reward, *M* reveals his signal only if it is of low quality in order to induce imitation by *U*. By inducing *U*'s imitation when he has weak confidence in his information, *M* avoids the worst case scenario of being penalized alone. On the other hand, if the reward is greater than the penalty, the size of the reward matters. If the reward is not great enough, the incentive to differentiate is not strong, and *M* reveals his signal only if it is of low quality. However, if the reward is sufficiently large, the incentive to differentiate would be well-motivated even for *U*. In this case, *M* reveals his signal only if it is of high quality. Given that *U* is willing to deviate from the disclosed signal, if the revealed signal is of low quality, *U*'s choice is more likely to be correct than when the revealed signal is of high quality. Hence, if *M* intends to reveal his signal expecting *U*'s deviation, it is better to do so when his signal is of high quality. When the reward is sufficiently large, there also exists another equilibrium where *M* always discloses his signal regardless of its precision. In both equilibria, the disclosure of the signal is meant to induce *U*'s alternative choice by giving *U* an opportunity for deviation, which is necessary for earning the reward alone.

Even when the disclosure of the signal is assumed to be costly, *M* is willing to reveal his signal if (1) the penalty is larger than the reward, or (2) the reward is sufficiently larger than the penalty. In the former case, *M* discloses his signal only if it is of low quality in order to be imitated. In the latter case, *M* always does so regardless of the precision in order to induce differentiation. If the reward is not much larger than the penalty, no revealing equilibrium is robust to costly disclosure. This result indicates that asymmetry between reward and penalty affects the incentive to disclose information in different ways. If the penalty is larger than the reward, the incentive to share blame high enough to admit costly disclosure is always motivated. On the other hand, the payoff structure should be strongly biased toward the reward for the incentive to differentiate, high enough to admit a costly disclosure, to be motivated. In this way, depending on whether it is biased toward penalty or reward, the signal of different precision will be revealed for different

incentives and so the disclosure of a private signal can be qualitatively different.

Conner (1995), Conner and Rumelt (1991), and Gallini (1984) are closely related with the present paper in that they explicitly deal with the topic of the strategic advantage from being imitated by competitors. Gallini (1984) suggests that licensing can be used as a tool to allow imitation to prevent rivals from engaging in R&D activity which can lead to better technology. Conner (1995) and Conner and Rumelt (1991) propose that allowing other firms' imitation can be a dominant strategy if a positive network externality is present.⁴ In the above models, there is no process of inference of information quality, and so the question of which information quality type is revealed for which incentive is not addressed. My model also proposes an alternative equilibrium not addressed in those models, where information is revealed to induce the rival's deviation.

There is a large literature on the topic of information disclosure related to the process of unraveling which was first proposed in Grossman (1981), Grossman and Hart (1980), and Milgrom (1981).⁵ Here, the unraveling is derived because an agent's choice of hiding private information reveals what he wants to hide (namely, others can infer what he wants to hide from his action of hiding), so his attempt should fail. The main question asked is whether the mandatory disclosure requirement is necessary or not. Most papers propose that if there is a credible and costless way of delivering private information, it is fully revealed and so the mandatory disclosure requirement is unnecessary.⁶ The current model considers a setting where there is no such unraveling process. Voluntary information disclosure is derived when others remain uninformed if the informed agent does not reveal his private signal.

4. In their models, the network externality is positive in that other firms' imitation can increase the size of the market; that is, although the pie must be shared, if the pie itself grows and so increases each firm's slice, imitation can be advantageous. The positive externality present in my model is different in that encouraging others' imitation is intended to secure a minimum portion of the pie rather than to enlarge the size of the pie.

5. The recent papers, Celik (2014) and Hotz and Xiao (2013) provide good summaries of this literature.

6. Hotz and Xiao (2013) provide a model where information is not fully revealed even when firms can credibly disclose private information at zero cost. The intuition is that when providing consumers with more information results in more elastic demand, it can result in more intensive price competition and lower profits for competing firms. Hence, revealing information is not an optimal choice.

The topic of strategic information disclosure (or information sharing) between firms has been covered in different contexts of industrial organization.⁷ For example, De Fraja (1993) proposes a model in which a firm may intend to reveal knowledge to its rival during a patent race if there are benefits to be gained in the long term, even though the rival's success may be unfavorable in the short term. Clark, Foros, and Sand (2011) propose the idea that the competitive knowledge can be transferred only to a subset of potential rivals, driving out the remaining rivals, with whom the knowledge is not shared. A recent paper by Jansen (2010) considers the effects of the degree of protection of property right on information disclosure. In cases of extreme protection parameters, full disclosure emerges, but for an intermediate value, either partial disclosure or full concealment emerges.⁸ In contrast, the key factor in my model which induces the information disclosure is the trade-off between securing the minimum payoff through risk-sharing and seeking the maximum payoff while taking a risk of being in the worst case scenario, which in turn affects the quality of information disclosed.

Finally, this article is related with the literature of herding and antiherding which analyzes how the agent responds to the information disclosed by the predecessor. In this literature, the analysis of how the information is generated by the predecessor is absent. Some papers only consider an informational externality without a payoff externality, so the predecessor does not need to consider the follower's response to the revealed information. Even in papers that consider a payoff externality, the predecessor is forced to reveal his choice, so there is no strategic decision of revealing information. This article studies both aspects of information generation and the response to the revealed information by considering the predecessor's strategic disclosure of his private information even when he is not forced to do so.

The rest of this article is organized as follows. Section II introduces the model. Section III

provides preliminary results. Section IV considers a benchmark case where the precision of M's signal is public information. Section V characterizes the revealing equilibrium when the precision of M's signal is private information. Section VI considers the case where the disclosure of information is costly. Section VII concludes.

II. MODEL

Suppose that there are two risk-neutral managers of two independent firms. Each manager selects one business project out of two possible projects, h and l . Only one project is profitable in the next period, and which project is profitable is not known. Each manager can only pursue one project due to a practical reason such as budget constraint. The true state is $w \in \{H, L\}$, and these two states are mutually exclusive. If $w = H$ ($w = L$), it means that project h (l) is profitable. Each manager's prior belief for each state is $\Pr(w = H) = \Pr(w = L) = \frac{1}{2}$.⁹ Before making a choice, one manager can observe an informative signal $\theta \in \{h, l\}$, which is correlated with the true state. The other manager has no opportunity to observe an informative signal regarding the true state.¹⁰ Henceforth, I denote by M the informed manager who observes a signal θ , and by U the other uninformed manager who cannot observe a signal.

The signal θ partially reveals information about the true state in the following manner: $\Pr(\theta = h|w = H) = \Pr(\theta = l|w = L) = p$ and $\Pr(\theta = h|w = L) = \Pr(\theta = l|w = H) = 1 - p$ where $p \in (\frac{1}{2}, 1)$. Given the true state, the probability that the signal θ is correct is p . Hence, p measures the precision of M's signal θ and represents the quality of information. As $p > \frac{1}{2}$, θ is an informative signal in that it delivers information about the unknown true state. However, as $p < 1$, it is imperfect. I assume that it is drawn from the uniform distribution $Z(p)$ where $p \in (\frac{1}{2}, 1) = P$.

7. See Anton and Yao (2003, 2004), Bhattacharya, Glazer, and Sappington (1990, 1992), Bhattacharya and Guriev (2006), Gill (2008), and Rosenkranz (2001).

8. In his model, the type of firm (private information) determines whether he has good news or bad news. Also, in his model, full disclosure of information emerges because the competing firm infers perfectly the information he wants to hide, so attempts to conceal information do not succeed. In my model, the type which really matters is the precision of the private signal and an agent's disclosure of signal is derived even when others cannot infer it if no disclosure is made.

9. I am interested in the equilibrium in which M reveals his choice due to the payoff effects, even though he is not required to do so. The assumption of an unbiased prior belief for each state is important for this motivation. If the prior belief for the true state is biased toward one state, then M's decision of not showing his choice reveals some information about his private signal. (See Mailath 1993 which deals with this case.) Then, M's decision of revealing his signal can be nonvoluntary in that the disclosure of his signal stems from this concern.

10. This can be justified by assuming that one manager has begun collecting information before the other, or one manager has more experience in this business than the other.

TABLE 1
Ex-Post Payoff Structure

ω	$a_u = \omega$	$a_u \neq \omega$
$a_m^1 = \omega$	1, 1	$\gamma, -\phi$
$a_m^1 \neq \omega$	$-\phi, \gamma$	$-1, -1$

M's signal $\theta \in \{h, l\}$ and its precision $p \in \left(\frac{1}{2}, 1\right)$ are private information. I also assume that both managers have no opportunity to communicate directly with each other about M's signal and its precision. Hence, U faces uncertainty not only over the realization of the signal and the true state but also the precision of M's signal.

M's action set is denoted by $\{a_m^1, a_m^2\}$. Here, $a_m^1 \in \{h, l\}$ denotes M's choice of a project. If $a_m^1 = h$ ($a_m^1 = l$), it means that M chooses project h (l). Since M's signal θ is private information, M can make a strategic decision of whether to follow or deviate from θ in choosing his project. He also decides whether or not to reveal his choice to U. I denote this decision by $a_m^2 \in \{R, N\}$. If $a_m^2 = R$ ($a_m^2 = N$), it means that M reveals his choice (does not reveal his choice). If M reveals his choice, it must be truthful in that what he announces as his choice should be what he really chooses. The action set of U is represented by $a_u \in \{h, l\}$.

After the true state w is realized, each manager earns his ex-post payoff, conditional on the accuracy of both managers' choices (Table 1). This model adopts the framework of a forecasting contest model in which the market commits ex-ante to a particular payoff structure.¹¹ Each manager's payoff can be interpreted as either a pecuniary gain such as a bonus or a gain in reputation regarding their foresight. This payoff structure is designed to represent the basic feature of the evaluation of a competitive environment: If an agent is successful, the competitor's success is bad news. If an agent is not successful, the competitor's failure is good news. In what follows, I assume that $\gamma > 1$ and $\phi > 1$.

Suppose that both managers' choices are identical. If their identical choices turn out to be right, both earn +1 and, if not, both are penalized by earning a payoff of -1 . On the other hand, if both managers' choices are different, the manager who made a correct choice gets $\gamma > 1$ and

the manager who made an incorrect choice gets $-\phi < -1$. In other words, if a manager's choice turns out to be correct, the other manager's identical choice causes a negative payoff externality because the reward is shared. Conversely, if a manager's choice turns out to be wrong, the other manager's identical choice causes a positive payoff externality because the penalty is shared. As the true state is revealed after both managers' decisions are made, whether the other manager's identical choice causes a positive or a negative payoff externality is uncertain.

The timing of game is as follows:

(T1) Nature chooses $w \in \{H, L\}$, $\theta \in \{h, l\}$, and $p \in \left(\frac{1}{2}, 1\right)$.

(T2) Both managers observe the ex-post payoff structure.

(T3) M observes $\theta \in \{h, l\}$ and $p \in \left(\frac{1}{2}, 1\right)$ which are private information. M decides (1) which project to choose and (2) whether or not to announce his choice to U. He announces his choice if he decides to do so.

(T4) U chooses his project. If M announced his choice in (T3), U observes M's choice before he chooses his own project.

(T5) The true state w is revealed. Each manager earns his payoff according to the ex-post payoff structure.

The model described above is relevant to situations where (1) an agent who has private incomplete information of the unknown true state makes a choice relevant to the true state before it is realized, and (2) a competitor who acts in the same way may or may not be favorable, depending on the agent's own performance. As this setting is of general economic interest, this model can be applied to various economic situations. The market of credit rating agencies or professional forecasters is a good example. The forecasting agent's job is to provide information regarding future economic trends with incomplete information. The reward γ can be interpreted as the improved reputation or bonus for successful performance, and the penalty ϕ can be interpreted as the ruined reputation or reduced salary due to poor performance. Firms' competition in acquiring the global standard of new technology is another good example.¹² If two incompatible technologies are introduced to

11. This approach enables me to see the effects of payoff structure on the players' strategic behaviors clearly. For a more detailed discussion regarding this approach, see Ottaviani and Sørensen (2006).

12. The competitions between Sony's BETA and JVC's VHS, Sony's Blu-ray and Toshiba's HD-DVD, and NAND flash and NOR flash in the flash memory market are famous examples.

the market, only one technology can ultimately survive. Both firms should make a choice with incomplete information about which technology is superior and will be preferred by the market. When firms' choices are different, the reward γ (ϕ) can be interpreted as a winner's gain (loser's cost) from winning (losing) the competition. If both firms make the same choice, both firms may share the market. Here, it would be reasonable to assume that, when both firms adopt a superior technology, each firm earns a larger market-sharing profit than the case where both adopt another one because there can be a potential increase in demand when superior technology is introduced.

A point of clarification regarding a restriction on the equilibrium strategy is in order. In this article, M's strategy uses the same threshold of p for $\theta \in \{h, l\}$ in his decision to reveal his choice. In other words, regardless of the state indicated by the signal, the precision threshold used to determine whether or not to reveal his choice is the same.

ASSUMPTION 1. *M uses the same threshold of p for $\theta \in \{h, l\}$ in his decision to reveal his choice. Thus, both cases of $\theta = h$ and $\theta = l$ are ex-ante symmetric.*

In this article, I mainly want to explore M's strategic incentive to reveal his private signal to the rival when his rival remains uninformed if M's does not reveal it. Given that M uses the same threshold of p for $\theta \in \{h, l\}$ in revealing his choice, if M does not disclose his signal, U has no updated information about M's private signal because in that case $\Pr(\theta = h) = \Pr(\theta = l)$. This fits the scenario I am interested in and, in this sense, the restriction can be justified.

This model uses the Perfect Bayesian equilibrium concept. M has two types of private information, $\theta \in \{h, l\}$ and $p \in (\frac{1}{2}, 1)$. U can infer θ only if M reveals his choice. On the other hand, U can always partially infer p because M's decision of whether or not to disclose his choice reveals some information about the precision of M's signal p . That is, M's action of revealing his choice can work as a channel to signal the precision of his private signal. Let $\lambda = \lambda(\theta, a_m^2)$ be U's belief regarding that M follows θ in his choice of a project and $Z(p|a_m^2)$ be U's posterior belief over p , given M's decision to reveal his choice. Then, each manager's strategy and the beliefs, λ and $Z(p|a_m^2)$, constitute a Perfect Bayesian equilibrium if each manager's expected payoff

is maximized, given beliefs and the other manager's strategy. In equilibrium, the beliefs λ and $Z(p|a_m^2)$ should be consistent with M's strategy.

III. PRELIMINARY RESULTS

A. M's Belief for U's Choice When M Does Not Reveal His Choice

If M does not reveal his choice, that is, $a_m^2 = N$, U cannot infer any information about θ . In this case, U's expected payoff from selecting each project should be based on beliefs about both the true state and M's private signal, that is, $\Pr(w, \theta)$. Then, it can be checked that

$$\begin{aligned} E\pi_u(a_u = h) &= \sum_{w \in \{H, L\}} \sum_{\theta \in \{h, l\}} (\Pr(w, \theta) \pi_u(a_u = h)) \\ &= \sum_{w \in \{H, L\}} \sum_{\theta \in \{h, l\}} (\Pr(w, \theta) \pi_u(a_u = l)) \\ &= E\pi_u(a_u = l) \end{aligned}$$

for all $p \in (\frac{1}{2}, 1)$ and all $\lambda \in [0, 1]$. That is, U earns the same expected payoff from $a_u = h$, $a_u = l$, and any mixed strategy. Denote M's belief for $a_u = h$ when $a_m^2 = N$ by $q \in [0, 1]$. M's belief q does not affect U's expected payoff. It matters, however, in M's decision of whether to follow his signal or not in his choice when $a_m^2 = N$ because, for given $\theta \in \{h, l\}$, whether $a_u = a_m^1$ or $a_u \neq a_m^1$, which depends on q , determines M's expected payoff.¹³ Many different equilibria may exist depending on q , so how $q \in [0, 1]$ is set matters in the analysis.

ASSUMPTION 2. *When $a_m^2 = N$, M believes that $q = \Pr(a_u = h) = \frac{1}{2}$.*

I assume that M has uniform belief for U's choice $a_u \in \{h, l\}$ when $a_m^2 = N$. Given that $a_m^2 = N$ does not reveal any information about θ , the only information U has about the true state is just a prior belief that each state occurs with equal probability. Then, M, who knows this, has no

13. For example, when $\gamma > \phi$, if $\theta = h$, always $a_m^1 = \theta$ for $q < \frac{1}{2}$. If $q > \frac{1}{2}$, there exists a critical value of p below which $a_m^1 \neq \theta$ and above which $a_m^1 = \theta$. On the other hand, if $\theta = l$, always $a_m^1 = \theta$ for $q > \frac{1}{2}$. If $q < \frac{1}{2}$, there exists a critical value of p below which $a_m^1 \neq \theta$ and above which $a_m^1 = \theta$. In this way, M's decision on whether to follow his signal or not depends on q and $\theta \in \{h, l\}$.

specific reason to have a biased belief that $q \neq \frac{1}{2}$. In this sense, M's belief that $q = \frac{1}{2}$ when $a_m^2 = N$ would be reasonable.

B. Decision on the Choice of a Project

M's signal $\theta \in \{h, l\}$ is private information. Thus, M can decide whether to follow or deviate from θ in his choice of a project.

LEMMA 1. *M follows his signal θ in his choice of a project for all $p \in (\frac{1}{2}, 1)$ whether or not he discloses his choice to U.*

Proof of Lemma 1

See the Appendix. ■

Lemma 1 implies that U can infer θ perfectly if he can observe M's choice. Then, M's decision to reveal his choice is no more than a decision to disclose his private signal θ to U. If M reveals his choice, it is in order to reveal θ intentionally to U. If not, it is to prevent θ from being revealed.

IV. BENCHMARK CASE: WHEN THE INFORMATION QUALITY IS PUBLIC INFORMATION

In this section, as a benchmark, I consider the case in which the precision of M's signal p is public information.

PROPOSITION 1. *Suppose that p is public information.*

(1) *Suppose $\gamma < \phi$. If $p \in (\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2))$, $a_m^2 = R$ and if $p \in ((\phi - 1)/(\gamma + \phi - 2), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U imitates a_m^1 for all $p \in (\frac{1}{2}, 1)$.*

(2) *Suppose $\gamma > \phi$. If $p \in (\frac{1}{2}, (\gamma + 1)/(\gamma + \phi + 2))$, $a_m^2 = R$ and if $p \in ((\gamma + 1)/(\gamma + \phi + 2), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U deviates from a_m^1 for $p \in (\frac{1}{2}, (\gamma + 1)/(\gamma + \phi + 2))$ and U imitates a_m^1 for $p \in ((\gamma + 1)/(\gamma + \phi + 2), 1)$.*

(3) *Suppose $\gamma = \phi$. Then, $a_m^2 = N$ for all $p \in (\frac{1}{2}, 1)$. If $a_m^2 = R$, U imitates a_m^1 for all $p \in (\frac{1}{2}, 1)$.*

Proof of Proposition 1

See the Appendix. ■

If the reward and the penalty are symmetric, M does not reveal his signal. In fact, asymmetry

in reward and penalty is a necessary condition for M to reveal his choice. If the payoff structure is biased toward the penalty, that is, $\gamma < \phi$, U's main concern is to avoid being penalized alone. Hence, U always imitates M's choice if M discloses it. By making an identical choice, U can avoid the worst case scenario of earning the lowest payoff, $\pi_u = -\phi$, although he has to give up the best case scenario of earning $\pi_u = \gamma$. As θ is correlated with the true state, it seems reasonable for U to rely on it. However, it should be noted that the bias of the payoff structure toward the penalty plays an important role in inducing U's strategic behavior of imitating M's choice. As shown below, U has a different response when the payoff structure is biased toward the reward; therefore, the payoff structure affects U's strategic response against M's revealed signal.

Despite his informative signal, M is not completely free from the concern of being penalized because his signal is not perfectly informative. Therefore, the precision of his signal matters. If the information quality is relatively high, that is, $p \in (\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2))$, M gives more weight to the possibility that his signal is correct. If M's choice turns out to be correct, U's identical choice causes a negative payoff externality, because the reward must be shared. Thus, M regards U's identical choice as a strategic substitute and therefore wants to keep his signal private when it is of high quality. On the other hand, if the information quality is relatively low, that is, $p \in ((\phi - 1)/(\gamma + \phi - 2), 1)$, M has weak confidence in his signal, and he is more concerned about the possibility of being penalized alone. If M chooses the wrong project, U's identical choice would cause a positive payoff externality, because the penalty would be shared. In this case, M regards U's identical choice as a strategic complement. Therefore, M wants to induce U's imitation by voluntarily revealing his signal, if his signal is of low quality.

If the reward is greater than the penalty, that is, $\gamma > \phi$, earning the reward alone becomes more attractive and requires both managers' choices to be different. Thus, even the uninformed U has an incentive to differentiate himself. However, if θ is of high quality, that is, $p \in ((\gamma + 1)/(\gamma + \phi + 2), 1)$, the incentive to differentiate himself is dominated because ignoring the very precise signal is not beneficial. Hence, U imitates M's choice if it is observable. At the same time, M also desires to differentiate himself and wants U to choose the other project. M knows that if the high quality

signal is revealed, U will make the same choice and the reward γ must be shared. Hence, M does not reveal his choice if his signal is of high quality. Meanwhile, if the quality of his signal is relatively low, that is, $p \in \left(\frac{1}{2}, (\gamma + 1)/(\gamma + \phi - 2)\right)$, U does not give much credit to the accuracy of M's signal. Therefore, the incentive to differentiate dominates and U diverges from M's choice, if observable, even though he knows that M's choice is based on the informative signal. Then, it is better for M to reveal his signal to U in order to induce $a_m^1 \neq a_u$, a necessary condition for earning γ . Thus, M reveals his signal if it is low quality.

COROLLARY 1. *Suppose that p is public information.*

(1) *When $\gamma < \phi$, as the penalty ϕ increases, the parameter set of p for which M reveals his signal increases.*

(2) *When $\gamma > \phi$, as the reward γ increases, the parameter set of p for which M reveals his signal increases.*

Note that $\frac{\partial\left(\frac{\phi-1}{\gamma+\phi-2}\right)}{\partial\phi} = (\gamma - 1)/(\gamma + \phi - 2)^2 > 0$, implying that when the penalty is greater than the reward, the parameter set of p for which M reveals his signal increases as the penalty increases. Intuitively, as the penalty increases, the incentive to avoid being penalized alone increases and M is more likely to reveal his choice. Also, $\frac{\partial\left(\frac{\gamma+1}{\gamma+\phi+2}\right)}{\partial\gamma} = (\phi + 1)/(\gamma + \phi - 2)^2 > 0$, implying that if $\gamma > \phi$, the parameter set of p for which M reveals his signal increases as the reward increases. The incentive to differentiate himself increases with the reward, so the parameter set of p for which U deviates from a_m^1 and M reveals his signal increases.

REMARK 1. *If p is public information, M does not reveal his high-quality signal.*

Proposition 1 says that M reveals his signal only if it is of low quality. If the penalty is greater than the reward, he reveals his signal in order to induce U's imitation. If the reward is greater than the penalty, he reveals his signal to induce U's deviation. M's very precise signal is never revealed because U always imitates it.

V. EQUILIBRIUM WHEN P IS PRIVATE INFORMATION

Now, I consider the case in which the precision of M's signal is private information. I consider the

existence of (1) separating equilibrium and (2) pooling equilibrium where M's private signal θ is revealed, which I call a revealing equilibrium. I first focus on the existence of a monotone separating equilibrium where there is one threshold of p in M's decision to reveal his signal.¹⁴ In following, the notion that the decision to disclose a private signal reveals information as to the quality of the signal plays an important role in the analysis.

A. Monotone Separating Equilibrium

I start my analysis by considering two monotone strategies.

DEFINITION 1. (1) *Strategy 1 (S1):* $\exists x \in \left(\frac{1}{2}, 1\right)$ s.t. for $p \in \left(\frac{1}{2}, x\right)$, $a_m^2 = R$, and for $p \in (x, 1)$, $a_m^2 = N$.

(2) *Strategy 2 (S2):* $\exists y \in \left(\frac{1}{2}, 1\right)$ s.t. for $p \in \left(\frac{1}{2}, y\right)$, $a_m^2 = N$, and for $p \in (y, 1)$, $a_m^2 = R$.

If M reveals his choice, that is, $a_m^2 = R$, U can infer θ by observing a_m^1 from Lemma 1 since M follows the signal. Hence, the concern is U's posterior belief over p inferred from observing that $a_m^2 = R$. Given (S1), M reveals his signal when it is of low quality. Given (S2), M reveals his signal when it is of high quality. The goal is to check whether or not each strategy can be an equilibrium strategy by finding the conditions under which the critical values $x \in \left(\frac{1}{2}, 1\right)$ and $y \in \left(\frac{1}{2}, 1\right)$ exist. Given that each strategy can be an equilibrium strategy, if M reveals his signal, U infers that the precision of M's signal is relatively low in (S1) and high in (S2).

PROPOSITION 2. (MONOTONE SEPARATING EQUILIBRIUM) (1) *Suppose that $\gamma < \phi$. Then, there exists a unique monotone separating equilibrium where if $p \in \left(\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2)\right)$, $a_m^2 = R$ and if $p \in ((\phi - 1)/(\gamma + \phi - 2), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U imitates a_m^1 always.*

(2) *Suppose that $\phi < \gamma < 3\phi + 2$. Then, there exists a unique monotone separating equilibrium where if $p \in \left(\frac{1}{2}, (3\gamma - \phi + 2)/(2\gamma + 2\phi + 4)\right)$, $a_m^2 = R$ and if $p \in ((3\gamma - \phi + 2)/(2\gamma + 2\phi + 4), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U imitates a_m^1 with probability $\frac{1}{2}$.*

14. The discussion on the existence of nonmonotone separating equilibrium is presented in Section V.D.

(3) Suppose that $\gamma > 3\phi + 2$. Then, there exists a unique monotone separating equilibrium where if $p \in \left(\frac{1}{2}, (\gamma - \phi)/(\gamma + \phi + 2)\right)$, $a_m^2 = N$ and if $p \in ((\gamma - \phi)/(\gamma + \phi + 2), 1)$, $a_m^2 = R$. If $a_m^2 = R$, U imitates a_m^1 with probability $\frac{1}{2}$.

Proof of Proposition 2

See the Appendix. ■

If the payoff structure is biased toward the penalty, that is, $\gamma < \phi$, the equilibrium is the same as the case in which p is public information. Recall that, when p is public information, U 's best response against $a_m^2 = R$ is to imitate M 's choice for all $p \in \left(\frac{1}{2}, 1\right)$. Then, even when p is private information, U should have the same best response because $\tilde{p} \in \left(\frac{1}{2}, 1\right)$, where $\tilde{p}$ is the inferred precision of M 's signal from observing that $a_m^2 = R$. Then, M should also use the same cutoff strategy, which can be explained by the same intuition as before.

However, if the payoff structure is biased toward the reward, $\gamma > \phi$, then p being private information leads to different outcomes from the case in which p is public information. M 's decision to disclose the signal depends on the size of the reward and the signal's precision. I highlight that, for U 's same best response against the revealed signal, which is to use the same mixed strategy, the precision of the signal disclosed depends on the size of the reward. If the reward is not large enough, the incentive to differentiate is not well motivated and M reveals his signal only if it is of low quality. On the contrary, if the reward is sufficiently larger than the penalty, M reveals his signal only if it is of high quality. Given that U is expected to deviate from the revealed signal because of the incentive to differentiate, U 's choice is more likely to be correct if the revealed signal is of low quality than if the revealed signal is of high quality. Hence, if M intends to reveal his signal expecting U 's deviation, it is better to do so when his signal is of high quality. If the signal is relatively imprecise, it is better to conceal it. That is, the intent of the disclosure of signal in this case is to induce U 's alternative choice by providing an opportunity for deviation, which is necessary for earning the reward alone.

As to U 's equilibrium strategy when $\gamma > \phi$, it should be noted that, unlike the case in which $\gamma < \phi$, U deviates from M 's choice with a positive probability, even though he knows that

M 's choice follows an informative signal. This happens because the bias of the payoff structure toward the reward gives even the uninformed U an incentive to differentiate.

B. Pooling Equilibrium

Next, I check the existence of a revealing pooling equilibrium. I start my analysis by considering following pooling strategy where M always reveals his signal: $a_m^2 = R$ for all $p \in \left(\frac{1}{2}, 1\right)$. The goal is to find conditions under which this strategy can be an equilibrium strategy.

PROPOSITION 3. (POOLING EQUILIBRIUM) (1) Suppose that $\gamma > 3\phi + 2$. Then there exists a pooling equilibrium. If $a_m^2 = R$, U deviates from a_m .

(2) Suppose that $\gamma = 3\phi + 2$. Then there exists a pooling equilibrium. If $a_m^2 = R$, then $z \leq \frac{1}{2}$ where $z = \Pr(a_u = a_m^1)$.

Proof of Proposition 3

See the Appendix. ■

Proposition 3 indicates that for M to reveal his signal for all $p \in \left(\frac{1}{2}, 1\right)$: (1) the reward should be sufficiently larger than the penalty, and (2) U deviates, or is more likely to deviate, from M 's choice when it is observable. If the reward is sufficiently larger than the penalty, U may intend to deviate from M 's choice because his choice must be different from M 's to earn the sufficiently large reward alone. This in turn affects M . If it is expected that U deviates (or is more likely to deviate) from M 's choice, it is better for M to reveal his signal because it guarantees different choices. If M does not reveal his signal, U uses a mixed strategy which can lead to both agents choosing the same project under which M cannot earn the reward γ . This explains why M reveals his signal to U for all $p \in \left(\frac{1}{2}, 1\right)$.

C. Summary of the Monotone Revealing Equilibrium

The revealing equilibrium derived above can be summarized in Table 2.

COROLLARY 2. No monotone revealing equilibrium violates the intuitive criterion.

Proof of Corollary 2

See the Appendix. ■

TABLE 2
Monotone Revealing Equilibrium

	$\gamma < \phi$	$\phi < \gamma < 3\phi + 2$	$\gamma = 3\phi + 2$	$\gamma > 3\phi + 2$
Separating equilibrium				
Disclosure	Low p	Low p		High p
Pooling equilibrium				
Disclosure			All p	All p

If $\gamma < \phi$ or $\phi < \gamma < 3\phi + 2$, a separating equilibrium where M's low quality signal is revealed is the unique monotone revealing equilibrium.¹⁵ If $\gamma = 3\phi + 2$, a pooling equilibrium is the unique monotone revealing equilibrium. If $\gamma > 3\phi + 2$, multiple revealing equilibria exist: one separating equilibrium where M reveals a high-quality signal and one pooling equilibrium.

In addition, the case of $\gamma < \phi$ can be interpreted as the one in which a positive payoff externality is present because the worst case scenario can be avoided by the other manager's same choice. On the other hand, the case of $\gamma > \phi$ can be interpreted as the one in which a negative payoff externality is present because the two managers' different choice is necessary for earning the reward alone. This result indicates that if there is a positive- ($\gamma < \phi$) or a weak negative payoff ($\phi < \gamma < 3\phi + 2$) externality, M's signal is revealed only if it is of low quality. On the other hand, if there is a strong negative payoff externality ($\gamma \geq 3\phi + 2$), M's high-quality signal is always revealed.

Compared with a benchmark case where p is public information, the most distinctive result is that M's signal of high quality is always revealed when the reward is sufficiently larger than the penalty, that is, $\gamma \geq 3\phi + 2$.

REMARK 2. *Incomplete information about p is a necessary condition for the disclosure of M's signal of high quality.*

This result is due to the fact that U cannot infer p perfectly from observing M's discrete binary choice of whether or not to reveal his signal. That is, given that M's type p is continuous, M's binary choice is not fine enough to allow U to infer M's type perfectly. The inferred quality of signal is not high enough to outweigh U's incentive to differentiate and trigger U's imitation.¹⁶ Therefore, U deviates from M's

choice if observable with a positive probability in a separating equilibrium and he always does so in a pooling equilibrium. This reasoning explains the disclosure of M's signal even when it is of high quality. This reasoning also explains the existence of multiple equilibria when $\gamma > 3\phi + 2$. In a separating equilibrium, U intends to deviate with a positive probability from the revealed signal even though the inferred quality of signal is relatively high. As the inferred quality of signal should be lower in a pooling equilibrium than a separating equilibrium, it is reasonable for U to always deviate from the revealed signal in a pooling equilibrium. In other words, by using a pooling strategy, M can make U infer that his signal is of low quality. This can be a good strategy for M, especially when he wants to induce U's deviation because U is more likely to deviate from the revealed signal as it is less credible.

Further analysis on the separating equilibrium sheds light on the effect of payoff structure on the probability of signal disclosure and the average quality of the disclosed signal (Figures 1 and 2).

If $\gamma < \phi$ and $\phi < \gamma < 3\phi + 2$, as the difference between the reward and the penalty increases, the probability of information disclosure increases. Specifically, as $\phi \rightarrow \infty$ or $\gamma \rightarrow 3\phi + 2$, the probability of information disclosure converges to 1 because each equilibrium approaches a pooling equilibrium. Meanwhile, when $\gamma > 3\phi + 2$, as the difference between the reward and the penalty increases, the probability of information disclosure decreases. As $\gamma \rightarrow \infty$, equilibrium approaches a nonrevealing equilibrium. The average quality of signal disclosed in each separating equilibrium is described in Figure 2.

Finally, according to Table 2, if the reward and the penalty are symmetric (i.e., $\gamma = \phi$), the revealing equilibrium does not exist. It can be explicitly shown that the nonrevealing equilibrium is the unique equilibrium when $\gamma = \phi$ by considering the following pooling strategy for M: " $a_m^2 = N$ for all $p \in \left(\frac{1}{2}, 1\right)$ " when $\gamma = \phi$.

This implies that when p is private information, the inferred precision of the signal has to be strictly greater than $p = (\gamma + 1)/(\gamma + \phi + 2)$ to trigger U to imitate M's choice when it is observable. In the separating equilibrium derived when $\gamma > 3\phi + 2$, M's signal is revealed if $p \in ((\gamma - \phi)/(\gamma + \phi + 2), 1)$. Then, U's inference of p is that $E(p | a_m^2 = R) = (\gamma + 1)/(\gamma + \phi + 2)$. In the pooling equilibrium derived when $\gamma \geq 3\phi + 2$, U's inference of p is $E(p | a_m^2 = R) = \frac{3}{4}$ which is less than the critical value $p = (\gamma + 1)/(\gamma + \phi + 2)$. That is, $E(p | a_m^2 = R) \neq (\gamma + 1)/(\gamma + \phi + 2)$ in both equilibria.

15. The thresholds of p below which M's signal is revealed are different in both cases.

16. In Proposition 1, when $\gamma > \phi$, the critical value of p above which U imitates M's choice is $p = (\gamma + 1)/(\gamma + \phi + 2)$.

FIGURE 1
Probability of Information Disclosure in Separating Equilibrium

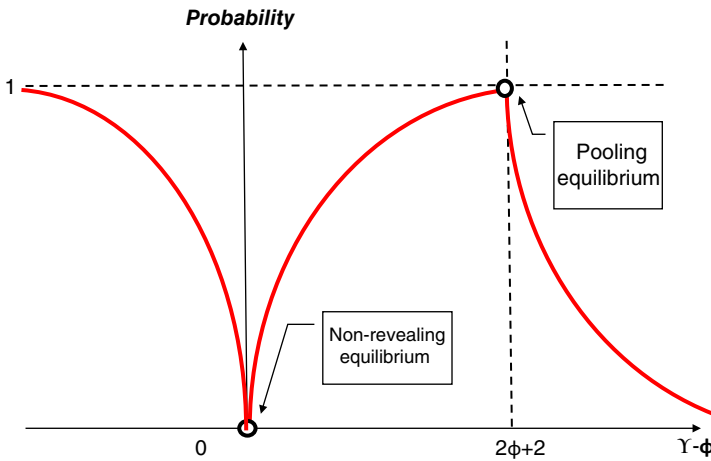
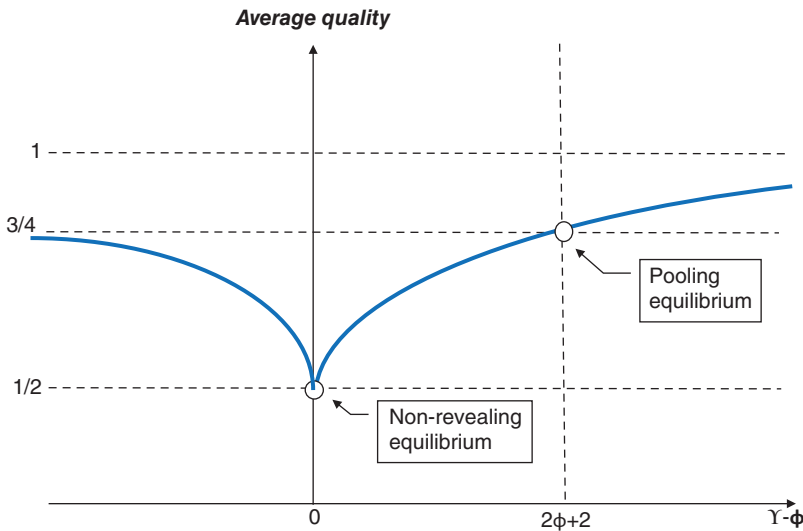


FIGURE 2
Average Quality of Revealed Information in Separating Equilibrium



PROPOSITION 4. Suppose that the reward and the penalty are symmetric, that is, $\gamma = \phi$. Then, the unique equilibrium is a nonrevealing pooling equilibrium in which M does not disclose his signal for all $p \in (\frac{1}{2}, 1)$.

Proof of Proposition 4
See the Appendix. ■

Proposition 4 confirms that asymmetry in reward and penalty is a necessary condition for the strategic disclosure of the informative signal.

D. Nonmonotone Separating Equilibrium

In this section, I explore the existence of a nonmonotone revealing equilibrium. If a nonmonotone equilibrium exists, the strategy with at least two or more thresholds of p in M 's decision to

disclose his signal can be an equilibrium strategy. It is not hard to show that there does not exist a nonmonotone equilibrium if U uses a pure strategy of either imitating or deviating from M's signal.¹⁷ In either case, from (A11) and (A13), there exists at most one threshold of p for M's disclosure of signal. That is, if a separating equilibrium exists, it should be a monotone equilibrium due to the condition of consistency which requires that U should have a correct belief over p . Hence, if U uses a pure strategy, no nonmonotone strategy can be an equilibrium strategy.

However, if U is indifferent between imitating and deviating from M's choice, a nonmonotone equilibrium can exist. If U uses a mixed strategy which makes M indifferent between $a_m^2 = R$ and $a_m^2 = N$, the condition of consistency allows that any belief over p for which U is indifferent between imitating and deviating from M's choice can be a rational belief. As many nonmonotone separating strategies can be considered, many corresponding nonmonotone separating equilibria may exist. However, every nonmonotone separating equilibrium that exists is a mixed strategy equilibrium. Thus, in that equilibrium, M attains the same expected payoff whether or not he reveals his signal.

VI. REVEALING EQUILIBRIUM WHEN DISCLOSURE IS COSTLY

So far, the revealing equilibrium is based on the assumption that the cost of revealing M's choice is zero. What would be the outcome if the action of disclosure is costly?

REMARK 3. *No nonmonotone revealing equilibrium is robust to costly disclosure.*

Every nonmonotone equilibrium is a mixed strategy equilibrium where M's expected payoffs are the same regardless of his choice of $a_m^2 = R$ and $a_m^2 = N$. This equilibrium is vulnerable to costly disclosure. Each type who is willing to reveal his signal has less to gain from revealing his signal than not revealing, given that disclosure is costly. Thus, not revealing a signal is the optimal choice and no nonmonotone revealing equilibrium is robust to costly disclosure.

17. Given any nonmonotone strategy, after considering the p suggested in that strategy, U's expected payoffs when U uses two pure strategies of imitating and deviating from a_m^1 can be calculated respectively. The comparison of these two expected payoffs determines U's best response.

COROLLARY 3. *Each separating revealing equilibrium of the cases where $\phi < \gamma < 3\phi + 2$ and $\gamma > 3\phi + 2$ is not robust to costly disclosure.*

Each separating revealing equilibrium of the case in which $\phi < \gamma < 3\phi + 2$ and $\gamma > 3\phi + 2$ is also a mixed strategy equilibrium, where M's expected payoffs are the same regardless of his choice of $a_m^2 = R$ and $a_m^2 = N$. Thus, neither equilibrium is robust to costly disclosure. In particular, when $\phi < \gamma < 3\phi + 2$, the separating revealing equilibrium is the unique monotone revealing equilibrium. This implies that when $\phi < \gamma < 3\phi + 2$, a nonrevealing equilibrium is the unique equilibrium if disclosure is costly.

COROLLARY 4. *The separating revealing equilibrium of the case where $\phi > \gamma$ and the pooling revealing equilibrium of the case where $\gamma \geq 3\phi + 2$ are robust to costly disclosure if the cost is arbitrarily small.*

On the other hand, the separating equilibrium derived when $\phi > \gamma$ and the pooling equilibrium derived when $\gamma \geq 3\phi + 2$ can be robust to costly disclosure. In a separating equilibrium derived when $\phi > \gamma$, for $p \in \left(\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2)\right)$, the gains from disclosing his signal are given by $G = E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) = \frac{1}{2}(2p + \phi - p\gamma - p\phi - 1) > 0$. In a pooling equilibrium derived when $\gamma \geq 3\phi + 2$, every $p \in \left(\frac{1}{2}, 1\right)$ leads to gains from disclosing the signal given by $G = E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) = \frac{1}{2}(-2p - \phi + p\gamma + p\phi + 1) > 0$. Hence, for both cases, if a cost of disclosure is arbitrarily small, each revealing equilibrium is robust.

In a separating equilibrium under $\phi > \gamma$, the following holds: $\partial G/\partial p = -(\gamma + \phi - 2) < 0$. This implies that, as the quality of signal decreases, the gains from disclosure increase, and the cost of disclosure admissible for this revealing equilibrium to be sustained increases. On the other hand, for a pooling equilibrium under $\gamma \geq 3\phi + 2$, $\partial G/\partial p = \gamma + \phi - 2 > 0$, implying that, as the quality of signal increases, the cost of disclosure admissible for this revealing equilibrium to be sustained increases. These results are intuitive. When $\phi > \gamma$, given that M has weaker confidence in his signal as his signal is less precise, M should have greater incentive to reveal his signal in order to induce U's imitation, admitting the greater cost of disclosure. On the other hand, when $\gamma \geq 3\phi + 2$, given that M has stronger confidence in his signal as his signal is more precise, M

TABLE 3
Robust Revealing Equilibrium When the
Disclosure Is Costly

$\gamma < \phi$ Separating EQ (low p)	$\phi \leq \gamma < 3\phi + 2$ Nonrevealing EQ	$\gamma \geq 3\phi + 2$ Pooling EQ
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should have greater incentive to reveal his signal in order to induce U 's deviation, admitting the greater cost of disclosure.

In sum, the equilibrium when the disclosure is costly can be summarized as follows.

As Table 3 shows, even when disclosure is costly, a robust revealing equilibrium can exist when: (1) the penalty is larger than the reward, or (2) the reward is sufficiently larger than the penalty. In the former case, the revealing equilibrium is a separating equilibrium where only the signal of low quality is revealed. In the latter case, the revealing equilibrium is a pooling equilibrium where the signal is always revealed. If the reward is not much larger than the penalty, no revealing equilibrium is robust to costly disclosure and so the nonrevealing equilibrium is the unique equilibrium.

Since M is a risk-neutral agent, this result also indicates that the asymmetry between reward and penalty affects the incentive to reveal the signal in different ways. M is more sensitive to the payoff structure biased toward the penalty than not in revealing his signal. A revealing equilibrium always exists when the penalty is larger than the reward, implying that the incentive to share blame, high enough to admit a costly disclosure, is always motivated. On the other hand, no revealing equilibrium robust to costly disclosure exists if the reward is not sufficiently larger than the penalty, implying that the payoff structure should be strongly biased toward the reward for the incentive to differentiate to be triggered.

VII. CONCLUDING REMARKS

In this article, I explore an agent's strategic incentive to intentionally reveal meaningful information to a competing agent. I consider this question in the model where the informed agent's signal and its precision are private information. The key issue is that the informed agent's decision to reveal his signal works as a channel through which information about the quality of his signal is revealed.

I show that asymmetry in the reward and penalty for the accuracy of their performance

is a necessary condition for the disclosure of information. This asymmetry plays an important role in the informed agent's decision regarding which quality type of signal he reveals for a given incentive. If the penalty is greater than the reward, his signal is revealed only if it is of low quality. This disclosure reflects the desire to be imitated for avoiding the worst case scenario of being punished alone. On the other hand, if the reward is greater than the penalty, the quality type of signal he reveals is contingent upon how large the reward is. In particular, if the reward is sufficiently large, both a separating and a pooling equilibrium exist in which the signal of high quality is always revealed. This occurs so as to induce the competing agent's alternative choice by giving him a chance for deviation. My result also indicates that incomplete information about the precision of the informed player's signal is a necessary condition for the disclosure of a high-quality signal. If the informed agent's information quality is public information, although the reward is sufficiently large, precise information is not revealed because it outweighs the competing agent's incentive to differentiate. If it is private information, the precision of the signal, imperfectly inferred through observing the informed agent's discrete choice, is not high enough to outweigh the competing agent's incentive to differentiate. Even when disclosure is costly, both the separating equilibrium of the case where the penalty is greater than the reward and the pooling equilibrium of the case where the reward is sufficiently larger than the penalty are robust. If the reward is weakly larger than the penalty, the nonrevealing equilibrium is the unique equilibrium.

I conclude by presenting possible extensions of the current model. First, my model assumes that each player has an unbiased prior belief that each state can be a true state with equal probability. This may preclude the analysis of how the initial bias of prior belief toward one state affects the information disclosure. For example, if the informed player goes against the biased prior, such an action may signal that he has accurate information enough to dominate the prior bias. Then, the uninformed player may be able to infer the precision of the informed player's signal from the revealed signal itself, in addition to the decision of disclosure. Moreover, the decision of not revealing his choice can also reveal information about the signal itself and its precision. In this way, if the biased prior belief for the

true state is allowed, other equilibria may exist.¹⁸ Second, in this model, only one player is partially informed. A possible extension would be the case in which both players observe the informative signals and the information quality is private information. As is well known, the case of two sided private information is difficult to analyze, because each player's belief about the other player's information quality has to be considered interactively. Finally, the results of this article can be interpreted as testable propositions. I believe experiments would be the most effective way to test the proposed results because factors such as the information quality and the payoff structure can be controlled and how people behave can be observed. However, as far as I know, such experiments have not been carried out and reported. I intend to explore these issues in the future.

APPENDIX

PROOF OF LEMMA 1

Case 1: When $a_m^2 = R$ (When M reveals his choice)

In this case, U observes a_m^1 . As θ is private information, U is not sure about whether $a_m^1 = \theta$ or not. Let $\lambda \in [0, 1]$ be U's belief for that $a_m^1 = \theta$. Then, according to λ , U imitates a_m^1 , deviates from a_m^1 , or is indifferent between imitating and deviating from a_m^1 . (I do not describe the condition of λ in detail because what I am interested in is not U's best response but M's best response.) Without loss of generality, assume that $\theta = h$. In the following, $E\pi_m(a_m^1 = \theta)$ is M's expected payoff when he follows θ and $E\pi_m(a_m^1 \neq \theta)$ is the expected payoff when he deviates from θ .

Consider the case where U imitates a_m^1 for given some condition of λ . Then,

$$E\pi_m(a_m^1 = \theta) = \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ \pi_m(a_m^1 = \theta, a_u = a_m^1, w) = 2p - 1$$

$$E\pi_m(a_m^1 \neq \theta) = \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ \pi_m(a_m^1 \neq \theta, a_u = a_m^1, w) = 1 - 2p$$

and $E\pi_m(a_m^1 = \theta) > E\pi_m(a_m^1 \neq \theta)$ for all $p \in (\frac{1}{2}, 1)$.

Consider the case where U deviates from a_m^1 for given some condition of λ . Then,

$$E\pi_m(a_m^1 = \theta) = \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ \pi_m(a_m^1 = \theta, a_u \neq a_m^1, w) = p\gamma - (1 - p)\phi$$

18. Mailath (1993) considers the case where the prior belief for the true state is biased toward one state. In his model, however, the signal by the informed agent reveals the true state perfectly. Hence, the analysis regarding the inference of information quality is ruled out.

$$E\pi_m(a_m^1 \neq \theta) = \sum_{w \in \{H, L\}} \Pr(w|\theta = h)$$

$$\pi_m(a_m^1 \neq \theta, a_u \neq a_m^1, w) = -p\phi + (1 - p)\gamma$$

and $E\pi_m(a_m^1 = \theta) - E\pi_m(a_m^1 \neq \theta) = (2p - 1)(\gamma + \phi) > 0$ for all $p \in (\frac{1}{2}, 1)$.

Consider the case where U is indifferent between imitating and deviating from a_m^1 under some condition of λ . Let $\mu \in [0, 1]$ be the probability that U imitates a_m^1 . Then,

$$E\pi_m(a_m^1 = \theta) - E\pi_m(a_m^1 \neq \theta) \\ = -(\gamma\mu - 2\mu - \phi - \gamma + \mu\phi)(2p - 1) > 0$$

for all $p \in (\frac{1}{2}, 1)$ because $\gamma\mu - 2\mu - \phi - \gamma + \mu\phi < 0$ for all $\mu \in [0, 1]$.

Therefore, if $a_m^2 = R$, M's best response is $a_m^1 = \theta$ for all $\lambda \in [0, 1]$.

Case 2: When $a_m^2 = N$ (When M does not reveal his choice)

From Assumption 2, for $\theta \in \{h, l\}$,

$$E\pi_m(a_m^1 = \theta) - E\pi_m(a_m^1 \neq \theta) \\ = \frac{1}{2} \left(\sum_{a_u \in \{h, l\}} \sum_{w \in \{H, L\}} \Pr(w|\theta) \pi_m(a_m^1 = \theta, a_u) \right) \\ - \frac{1}{2} \left(\sum_{a_u \in \{h, l\}} \sum_{w \in \{H, L\}} \Pr(w|\theta) \pi_m(a_m^1 \neq \theta, a_u) \right) \\ = \frac{1}{4} (\gamma + \phi + 2)(2p - 1) > 0$$

for all $p \in (\frac{1}{2}, 1)$. So, M's best response is $a_m^1 = \theta$.

Finally, whether $a_m^2 = R$ or $a_m^2 = N$, M follows θ in his choice of a project.

PROOF OF PROPOSITION 1

(Step 1) U's best response when $a_m^2 = R$.

Suppose that $a_m^2 = R$. Then, U observes a_m^1 and infers θ . Then,

$$(A1) \quad E\pi_u(a_u = a_m^1) = \sum_{w \in \{H, L\}} \Pr(w|\theta) \pi_u(a_u = a_m^1, w) = 2p - 1$$

$$(A2) \quad E\pi_u(a_u \neq a_m^1) = \sum_{w \in \{H, L\}} \Pr(w|\theta = h)$$

$$\pi_u(a_u \neq a_m^1, w) = -p\phi + (1 - p)\gamma$$

where (A1) is U's expected payoff when he imitates a_m^1 and (A2) is the one when U deviates from a_m^1 . Then,

$$E\pi_u(a_u = a_m^1) - E\pi_u(a_u \neq a_m^1) = p(\gamma + \phi + 2) - \gamma - 1.$$

So, if $\gamma > \phi$, for $p \in (\frac{1}{2}, ((\gamma + 1)/(\gamma + \phi + 2)))$, U deviates from a_m^1 , for $p \in (((\gamma + 1)/(\gamma + \phi + 2)), 1)$, U imitates a_m^1 , and if $p = (\gamma + 1)/(\gamma + \phi + 2)$, U is indifferent between imitating and deviating from a_m^1 . On the other hand, if $\gamma \leq \phi$, U imitates a_m^1 for all $p \in (\frac{1}{2}, 1)$.

(Step 2) M's best response

If $a_m^2 = N$, for $\theta \in \{h, l\}$,

$$\begin{aligned} E\pi_m(a_m^2 = N) &= \frac{1}{2} \sum_{a_u \in \{h, l\}} \sum_{w \in \{H, L\}} \Pr(w|\theta) \pi_m(a_m^1, a_u, w) \\ (A3) \quad &= \frac{1}{2} (2p - \phi + p\gamma + p\phi - 1). \end{aligned}$$

First, suppose that $\gamma \leq \phi$. In this case, if $a_m^2 = R$, U imitates a_m^1 for $p \in (\frac{1}{2}, 1)$. Then,

$$\begin{aligned} (A4) \quad E\pi_m(a_m^2 = R) &= \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ &\quad \pi_m(a_m^1, a_u = a_m^1, w) = 2p - 1. \end{aligned}$$

From (A3) and (A4),

$$\begin{aligned} (A5) \quad E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) &= -\frac{1}{2} (-2p - \phi + p\gamma + p\phi + 1). \end{aligned}$$

If $\gamma < \phi$, for $p \in (\frac{1}{2}, ((\phi - 1)/(\gamma + \phi - 2)))$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ and for $p \in (((\phi - 1)/(\gamma + \phi - 2), 1)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$. On the other hand, if $\gamma = \phi$, for $p \in (\frac{1}{2}, 1)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$.

Second, suppose that $\gamma > \phi$. For $p \in (\frac{1}{2}, ((\gamma + 1)/(\gamma + \phi + 2)))$, U deviates from a_m^1 if $a_m^2 = R$. Then,

$$\begin{aligned} (A6) \quad E\pi_m(a_m^2 = R) &= \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ &\quad \pi_m(a_m^1, a_u \neq a_m^1, w) = p\gamma - \phi + p\phi. \end{aligned}$$

From (A3) and (A6),

$$\begin{aligned} (A7) \quad E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) &= \frac{1}{2} (-2p - \phi + p\gamma + p\phi + 1). \end{aligned}$$

If $\gamma > \phi$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ for $p \in (\frac{1}{2}, (\gamma + 1)/(\gamma + \phi + 2))$. On the other hand, for $p \in (((\gamma + 1)/(\gamma + \phi + 2), 1)$, U imitates a_m^1 if $a_m^2 = R$. Then, from (A5), if $\gamma > \phi$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$ for $p \in (((\gamma + 1)/(\gamma + \phi + 2), 1)$. Finally, if $p = (\gamma + 1)/(\gamma + \phi + 2)$, U is indifferent between imitating and deviating from a_m^1 . Now, let $z = \Pr(a_u = a_m^1)$ when a_m^1 is observable. Then, from (A4) and (A6),

$$E\pi_m(a_m^2 = R) = z(2p - 1) + (1 - z)(p\gamma - \phi + p\phi).$$

The comparison with (A3) yields that, when $p = (\gamma + 1)/(\gamma + \phi + 2)$, M is indifferent between $a_m^2 = R$ and $a_m^2 = N$ if $z = \frac{1}{2}$.

PROOF OF PROPOSITION 2

First, let's consider (S1). Without loss of generality, assume that $a_m^2 = R$ and $a_m^1 = h$. Then,

$$\begin{aligned} (A8) \quad E\pi_u(a_u = a_m^1) &= \int \left(\sum_{w \in \{H, L\}} \Pr(w|\theta = h) \pi_u(a_u = a_m^1, w) \right) \\ dZ(p|a_m^2 = R) &= \int_{p \in (\frac{1}{2}, x)} (p - (1 - p)) dZ(p) \\ &= \frac{1}{2} (2x - 1) \end{aligned}$$

$$\begin{aligned} (A9) \quad E\pi_u(a_u \neq a_m^1) &= \int \left(\sum_{w \in \{H, L\}} \Pr(w|\theta = h) \pi_u(a_u \neq a_m^1, w) \right) \\ dZ(p|a_m^2 = R) &= \int_{p \in (\frac{1}{2}, x)} (p(-\phi) + (1 - p)\gamma) dZ(p) \\ &= \left(-\frac{1}{4}\right) (\phi - 3\gamma + 2x\gamma + 2x\phi) \end{aligned}$$

where (A8) is the expected payoff when U imitates a_m^1 and (A9) is the expected payoff when U deviates from a_m^1 . Then,

$$\begin{aligned} E\pi_u(a_u = a_m^1) - E\pi_u(a_u \neq a_m^1) &= \frac{1}{4} (4x - 3\gamma + \phi + 2x\gamma + 2x\phi - 2). \end{aligned}$$

Let $f(x) = 4x - 3\gamma + \phi + 2x\gamma + 2x\phi - 2$. Then, U's best response when a_m^1 is observable can be described as follows: (1) $f(x) > 0 \Rightarrow U$ imitates a_m^1 , (2) $f(x) < 0 \Rightarrow U$ deviates from a_m^1 , and (3) $f(x) = 0 \Rightarrow U$ is indifferent between imitating and deviating from a_m^1 . In the following, I denote by $E\pi_m(a_m^2)$ M's expected payoff when $a_m^2 \in \{R, N\}$. Refer (A3) for M's expected payoff when $a_m^2 = N$.

Case 1: When $f(x) > 0$.

In this case, U imitates a_m^1 if $a_m^2 = R$. Then,

$$\begin{aligned} (A10) \quad E\pi_m(a_m^2 = R) &= \sum_{w \in \{H, L\}} \Pr(w|\theta = h) \\ &\quad \pi_m(a_m^1, a_u = a_m^1, w) = 2p - 1. \end{aligned}$$

From (A3) and (A10),

$$\begin{aligned} (A11) \quad E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) &= -\frac{1}{2} (-2p - \phi + p\gamma + p\phi + 1). \end{aligned}$$

From (A11), if $p \geq (\phi - 1)/(\gamma + \phi - 2)$, $E\pi_m(a_m^2 = R) \leq E\pi_m(a_m^2 = N)$. This satisfies the condition of (S1). The manipulation yields that (1) if $\gamma \geq \phi$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$ for all $p \in (\frac{1}{2}, 1)$, (2) if $\gamma < \phi$, for $p \in (\frac{1}{2}, ((\phi - 1)/(\gamma + \phi - 2)))$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ and for $p \in (((\phi - 1)/(\gamma + \phi - 2), 1)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$. Hence, the separating equilibrium is supported only if $\gamma < \phi$. In this case, $x = (\phi - 1)/(\gamma + \phi - 2)$ and $f(x) = (\phi - 1)/(\gamma + \phi - 2) = (3\gamma + 3\phi - 2)(\phi - \gamma)/(\gamma + \phi - 2) > 0$. So the condition that $f(x) > 0$ is satisfied.

LEMMA A1. Suppose that $\gamma < \phi$. If $p \in \left(\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2)\right)$, $a_m^2 = R$ and if $p \in ((\phi - 1)/(\gamma + \phi - 2), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U imitates a_m^1 .

Case 2: When $f(x) < 0$.

In this case, if $a_m^2 = R$, U deviates from a_m^1 . Then,

$$(A12) \quad E\pi_m(a_m^2 = R) = \sum_{w \in \{H, L\}} \Pr(w | \theta = h) \pi_m(a_m^1, a_u \neq a_m^1, w) = p\gamma - \phi + p\phi.$$

From (A3) and (A12),

$$(A13) \quad E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) = \frac{1}{2}(-2p - \phi + p\gamma + p\phi + 1).$$

Then, if $p \geq (\phi - 1)/(\gamma + \phi - 2)$, $E\pi_m(a_m^2 = R) \geq E\pi_m(a_m^2 = N)$. However, this does not satisfy the condition of (S1) that M reveals the signal of low quality. Hence, this case is excluded.

Case 3: When $f(x) = 0$.

In this case, if $a_m^2 = R$, U is indifferent between imitating and deviating from a_m^1 . Suppose that $z = \Pr(a_u = a_m^1)$ when a_m^1 is observable. Then

$$(A14) \quad E\pi_m(a_m^2 = R) = z(p - (1 - p)) + (1 - z)(p\gamma - (1 - p)\phi)$$

$$E\pi_m(a_m^2 = N) = \frac{1}{2}(p - (1 - p)) + \frac{1}{2}(p\gamma - (1 - p)\phi).$$

If $z \neq \frac{1}{2}$, the separating equilibrium is not derived. If $z = \frac{1}{2}$, M is indifferent between $a_m^2 = R$ and $a_m^2 = N$ for all $p \in \left(\frac{1}{2}, 1\right)$. Here, $f(x) = 0$ at $x = (3\gamma - \phi + 2)/(2\gamma + 2\phi + 4)$. So, for the condition of consistency, I only have to check whether $x = (3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \in \left(\frac{1}{2}, 1\right)$ is satisfied or not. If it is, (S1) can be sustained as an equilibrium strategy. Note that $((3\gamma - \phi + 2)/(\gamma + 2\phi + 4)) - \frac{1}{2} = -(\phi - \gamma)/(\gamma + \phi + 2)$ and $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) - 1 = -((3\phi - \gamma + 2)/2(\gamma + \phi + 2))$. So (1) if $\gamma > \phi$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) > \frac{1}{2}$ and if $\gamma \leq \phi$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \leq \frac{1}{2}$, (2) if $\gamma < 3\phi + 2$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) < 1$ and if $\gamma \geq 3\phi + 2$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \geq 1$. Hence, (1) if $\phi \geq \gamma$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \notin \left(\frac{1}{2}, 1\right)$, (2) if $\phi < \gamma < 3\phi + 2$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \in \left(\frac{1}{2}, 1\right)$, and (3) if $\gamma \geq 3\phi + 2$, $(3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \notin \left(\frac{1}{2}, 1\right)$. Therefore, $x = (3\gamma - \phi + 2)/(2\gamma + 2\phi + 4) \in \left(\frac{1}{2}, 1\right)$ is satisfied only if $\phi < \gamma < 3\phi + 2$.

LEMMA A2. Suppose that $\phi < \gamma < 3\phi + 2$. Then, for $p \in \left(\frac{1}{2}, (3\gamma - \phi + 2)/(2\gamma + 2\phi + 4)\right)$, $a_m^2 = R$ and for $p \in ((3\gamma - \phi + 2)/(2\gamma + 2\phi + 4), 1)$, $a_m^2 = N$. If $a_m^2 = R$, U imitates or deviates from a_m^1 with probability $\frac{1}{2}$.

Second, let's consider (S2). Without loss of generality, assume that $a_m^1 = h$. After observing that $a_m^1 = h$, U infers that $\theta = h$. Also, U 's posterior belief from observing that $a_m^2 = R$

is that $p \in (y, 1)$. Then

$$(A15) \quad E\pi_u(a_u = a_m^1, w) = \int \left(\sum_{w \in \{H, L\}} \Pr(w | \theta = h) \pi_u(a_u = a_m^1, w) \right) dZ(p | a_m^2 = R) = \int_{p \in (y, 1)} (p - (1 - p)) dZ(p) = y$$

$$(A16) \quad E\pi_u(a_u \neq a_m^1, w) = \int \left(\sum_{w \in \{H, L\}} \Pr(w | \theta = h) \pi_u(a_u \neq a_m^1, w) \right) dZ(p | a_m^2 = R) = \int_{p \in (y, 1)} (p(-\phi) + (1 - p)\gamma) dZ(p) = \left(-\frac{1}{2}\right)(\phi - \gamma + y\gamma + y\phi)$$

$$E\pi_u(a_u = a_m^1, w) - E\pi_u(a_u \neq a_m^1, w) = \frac{1}{2}(2y - \gamma + \phi + y\gamma + y\phi).$$

Let $g(y) \equiv 2y - \gamma + \phi + y\gamma + y\phi$. Then, U 's best response can be described as follows: (1) $g(y) > 0 \Rightarrow U$ imitates a_m^1 , (2) $g(y) < 0 \Rightarrow U$ deviates from a_m^1 , (3) $g(y) = 0 \Rightarrow U$ is indifferent between imitating and deviating from a_m^1 .

Case 1: When $g(y) > 0$

If $a_m^2 = R$, U imitates a_m^1 . Then from (A11), $p \geq (\phi - 1)/(\gamma + \phi - 2) \Rightarrow E\pi_m(a_m^2 = R) \leq E\pi_m(a_m^2 = N)$. However, this does not satisfy the condition of (S2) that M intends to reveal the signal of high quality. Hence, this case is excluded.

Case (2): When $g(y) < 0$

If $a_m^2 = R$, U deviates from a_m^1 . Then from (A13), $p \geq (\phi - 1)/(\gamma + \phi - 2) \Rightarrow E\pi_m(a_m^2 = R) \geq E\pi_m(a_m^2 = N)$. This satisfies the condition of (S2). The manipulation yields that, (1) if $\gamma \geq \phi$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ for all $p \in \left(\frac{1}{2}, 1\right)$, (2) if $\gamma < \phi$, for $p \in ((\phi - 1)/(\gamma + \phi - 2), 1)$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$, and for $p \in \left(\frac{1}{2}, (\phi - 1)/(\gamma + \phi - 2)\right)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$. Thus, a separating equilibrium exists only if $\gamma < \phi$. In this case, $y = (\phi - 1)/(\gamma + \phi - 2)$ and $g(y) = (\phi - 1)/(\gamma + \phi - 2) = (\gamma - \phi + \gamma\phi - \gamma^2 + 2\phi^2 - 2)/(\gamma + \phi - 2)$. Let $h(\phi) \equiv 2\phi^2 + \phi(\gamma - 1) + \gamma - \gamma^2 - 2$. Then (1) $h(\phi)$ is a convex function, (2) $h(\phi)$ attains the minimized value at $\phi = -\frac{\gamma-1}{4} < 0$, and (3) $h(\phi) = \gamma = 2(\gamma - 1)(\gamma + 1) > 0$. Hence, for ϕ such that $\gamma < \phi$, $h(\phi) > 0$. Then, $g(y) = (\phi - 1)/(\gamma + \phi - 2) > 0$ for $\gamma < \phi$. As this does not satisfy the condition that $g(y) < 0$, this case is excluded.

Case (3): When $g(y) = 0$

If $a_m^2 = R$, U is indifferent between imitating and deviating from a_m^1 . From (A14), if U imitates (or deviates from) a_m^1 with probability $\frac{1}{2}$, M is indifferent between $a_m^2 = R$ and $a_m^2 = N$ for all $p \in \left(\frac{1}{2}, 1\right)$. Note that $g(y) = (\gamma - \phi)/(\gamma + \phi + 2) = 0$. Then, due to the requirement that U 's posterior belief over p should be consistent, I

have to check whether $((\gamma - \phi) / (\gamma + \phi + 2)) \in (\frac{1}{2}, 1)$ is satisfied or not. Here, $((\gamma - \phi) / (\gamma + \phi + 2)) - \frac{1}{2} = -((3\phi - \gamma + 2) / (2(\gamma + \phi + 2)))$ and $((\gamma - \phi) / (\gamma + \phi + 2)) - 1 = -((2(\phi + 1)) / (\gamma + \phi + 2)) < 0$. So, if $\gamma \leq 3\phi + 2$, $((\gamma - \phi) / (\gamma + \phi + 2)) \notin (\frac{1}{2}, 1)$, and if $\gamma > 3\phi + 2$, $((\gamma - \phi) / (\gamma + \phi + 2)) \in (\frac{1}{2}, 1)$. Hence, a separating equilibrium exists only if $\gamma > 3\phi + 2$.

LEMMA A3. Suppose that $\gamma > 3\phi + 2$. Then, for $p \in ((\gamma - \phi) / (\gamma + \phi + 2), 1)$, $a_m^2 = R$ and for $p \in (\frac{1}{2}, ((\gamma - \phi) / (\gamma + \phi + 2)))$, $a_m^2 = N$. If $a_m^2 = R$, U imitates or deviates from a_m^1 with probability $\frac{1}{2}$.

Lemmas A1–A3 yield Proposition 3.

PROOF OF PROPOSITION 3

If U observes that $a_m^2 = R$, U's posterior belief over p is $p \in (\frac{1}{2}, 1)$. On the other hand, for $a_m^2 = N$ which never occurs on the equilibrium path, an arbitrary U's posterior belief over p can be assigned. It should be noted that, regardless of U's belief over p for the action off the equilibrium path and his choice of a project, U earns the same expected payoff because θ is not inferred. Hence, U's belief over p for the action off the equilibrium path does not affect M's expected payoff when $a_m^2 = N$. What actually affects M's expected payoff when $a_m^2 = N$ is M's own belief for $a_u = h$. Then, M only has to consider whether to (1) show θ in order to induce U's imitation or deviation, or (2) conceal θ and make U use a mixed strategy.

Suppose that U observes that $a_m^2 = R$. Without loss of generality, assume that $a_m^1 = h$. Then

$$\begin{aligned} (A17) \quad E\pi_u(a_u = a_m^1) &= \int \left(\sum_{w \in \{H, L\}} \Pr(w | \theta = h) \pi_u(a_u = a_m^1, w) \right) \\ dZ(p | a_m^2 = R) &= \int_{p \in (\frac{1}{2}, 1)} (p - (1 - p)) dZ(p) = \frac{1}{2} \end{aligned}$$

$$\begin{aligned} (A18) \quad E\pi_u(a_u \neq a_m^1) &= \int \left(\sum_{w \in \{H, L\}} \Pr(w | \theta = h) \pi_u(a_u \neq a_m^1, w) \right) \\ dZ(p | a_m^2 = R) &= \int_{p \in (\frac{1}{2}, 1)} (p(-\phi) + (1 - p)\gamma) dZ(p) \\ &= \left(-\frac{1}{4}\right)(3\phi - \gamma) \end{aligned}$$

$$E\pi_u(a_u = a_m^1, w) - E\pi_u(a_u \neq a_m^1, w) = \frac{1}{4}(3\phi - \gamma + 2).$$

Then, U's best response can be described as follows: (1) if $3\phi + 2 > \gamma$, U imitates a_m^1 , (2) if $3\phi + 2 < \gamma$, U deviates from a_m^1 , (3) if $3\phi + 2 = \gamma$, U is indifferent between imitating and deviating from a_m^1 .

Case (1): When $\gamma < 3\phi + 2$

If $a_m^2 = R$, U imitates a_m^1 . From (A11), (1) if $\gamma \geq \phi$, for all $p \in (\frac{1}{2}, 1)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$, (2) if $\gamma < \phi$, for $p \in ((\phi - 1) / (\gamma + \phi - 2), 1)$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$ and for $p \in (\frac{1}{2}, (\phi - 1) / (\gamma + \phi - 2))$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$. Therefore, there exists no condition for which a revealing pooling equilibrium exists.

Case (2): When $\gamma > 3\phi + 2$

If $a_m^2 = R$, U deviates from a_m^1 . Recall (A13). Then (1) if $\gamma \geq \phi$, for all $p \in (\frac{1}{2}, 1)$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$, (2) if $\gamma < \phi$, for $p \in ((\phi - 1) / (\gamma + \phi - 2), 1)$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ and for $p \in (\frac{1}{2}, (\phi - 1) / (\gamma + \phi - 2))$, $E\pi_m(a_m^2 = R) < E\pi_m(a_m^2 = N)$. Therefore, a revealing pooling equilibrium exists only if $\gamma \geq \phi$. The condition that $\gamma > 3\phi + 2$ satisfies the required condition that $\gamma \geq \phi$. Hence, if $\gamma > 3\phi + 2$, a revealing pooling equilibrium exists.

Case (3): When $\gamma = 3\phi + 2$

If $a_m^2 = R$, U is indifferent between imitating and deviating from a_m^1 . Then from (A14),

$$\begin{aligned} E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N) &= \left(z - \frac{1}{2}\right)(2p + \phi - p\gamma - p\phi - 1). \end{aligned}$$

Note that if $p \leq (\phi - 1) / (\gamma + \phi - 2)$, $2p + \phi - p\gamma - p\phi - 1 \geq 0$. Here, (1) if $\gamma \geq \phi$, for all $p \in (\frac{1}{2}, 1)$, $2p + \phi - p\gamma - p\phi - 1 < 0$ and (2) if $\gamma < \phi$, for $p \in (\frac{1}{2}, -(\phi - 1) / (2 - \phi - \gamma))$, $2p + \phi - p\gamma - p\phi - 1 > 0$ and for $p \in (-(\phi - 1) / (2 - \phi - \gamma), 1)$, $2p + \phi - p\gamma - p\phi - 1 < 0$. Hence, when $\gamma \geq \phi$, if $z \leq \frac{1}{2}$, $E\pi_m(a_m^2 = R) \geq E\pi_m(a_m^2 = N)$ for all $p \in (\frac{1}{2}, 1)$. On the other hand, if $\gamma < \phi$, M's pooling strategy cannot be an equilibrium strategy. Therefore, a revealing pooling equilibrium exists if $\gamma \geq \phi$ and $z \leq \frac{1}{2}$. The condition that $\gamma = 3\phi + 2$ satisfies the condition that $\gamma \geq \phi$.

PROOF OF COROLLARY 2

Now let's apply the intuitive criterion to each derived equilibrium to rule out an equilibrium based on an irrational belief arbitrarily assigned for the off-the-equilibrium action. In each of separating equilibrium, two separate types are derived endogenously as the monotone strategy and only two possible actions $a_m^2 \in \{R, N\}$ for each type are considered. Hence, there is no off-the-equilibrium action in a separating equilibrium and so no separating equilibrium should violate the intuitive criterion. As for the pooling equilibrium which exists when $\gamma \geq 3\phi + 2$,

$$\begin{aligned} E\pi_m(a_m^2 = R) &= \sum_{w \in \{H, L\}} \Pr(w | \theta) \\ \pi_m(a_m^1 = \theta, a_u \neq a_m^1, w) &= p\gamma - \phi + p\phi \end{aligned}$$

$$\begin{aligned} E\pi_m(a_m^2 = N) &= \frac{1}{2} \left(\sum_{a_u \in \{h, l\}} \sum_{w \in \{H, L\}} \Pr(w | \theta) \pi_m(a_m^1 = \theta, a_u, w) \right) \\ &= \frac{1}{2} (2p - \phi + p\gamma + p\phi - 1) \end{aligned}$$

where $E\pi_m(a_m^2 = R)$ is the expected payoff when M follows the equilibrium strategy and $E\pi_m(a_m^2 = N)$ is the one when M deviates from the equilibrium strategy. Given that $\gamma \geq 3\phi + 2$, $E\pi_m(a_m^2 = R) > E\pi_m(a_m^2 = N)$ for all $p \in (\frac{1}{2}, 1)$. No type has an incentive to deviate from the equilibrium strategy, so this pooling equilibrium does not violate the intuitive criterion. Thus, no monotone revealing equilibrium violates the intuitive criterion.

PROOF OF PROPOSITION 4

Given this pooling strategy, if U observes that $a_m^2 = N$, U's best response is to use a mixed strategy because θ cannot be inferred, although he correctly infers that $p \in (\frac{1}{2}, 1)$. On the other hand, for $a_m^2 = R$ which is off the equilibrium path, any arbitrary belief of U over p can be assigned. Unlike a revealing pooling strategy, U's arbitrary belief over p , in this case, matters in the analysis because U's best response against the revealed θ , and thus, M's expected payoff depend on it. In Proposition 4, however, I show that if $\gamma = \phi$, the given nonrevealing pooling strategy is an equilibrium strategy regardless of U's belief over p for $a_m^2 = R$.

First, suppose that, for $a_m^2 = R$ which is off the equilibrium path, U believes that M follows the following strategy: $\exists x \in (\frac{1}{2}, 1]$ such that if $p \in (\frac{1}{2}, x)$, $a_m^2 = R$ and if $p \in (x, 1)$, $a_m^2 = N$. Here, as the case in which U observes that $a_m^2 = R$ is considered, the case of $x = \frac{1}{2}$ is excluded. For $a_m^2 = R$, U's posterior belief is $p \in (\frac{1}{2}, x)$ where $x \in (\frac{1}{2}, 1]$. From (A8) and (A9),

$$\begin{aligned} E\pi_u(a_u = a_m^1, w) \\ &= \frac{1}{2}(2x - 1) > 0 \text{ and } E\pi_u(a_u \neq a_m^1, w)|_{\phi=\gamma} \\ &= \left(-\frac{1}{2}\right)\gamma(2x - 1) < 0. \end{aligned}$$

So, for all $x \in (\frac{1}{2}, 1]$, U's best response against $a_m^2 = R$ is to imitate a_m^1 if it is observable.

Second, suppose that, for $a_m^2 = R$ which is off the equilibrium path, U believes that M follows the following strategy: $\exists y \in [\frac{1}{2}, 1)$ such that if $p \in (y, 1)$, $a_m^2 = R$ and if $p \in (\frac{1}{2}, y)$, $a_m^2 = N$. As the case in which U observes that $a_m^2 = R$ is considered, the case of $y = 1$ is excluded. For $a_m^2 = R$, U's posterior belief is $p \in (y, 1)$ where $y \in [\frac{1}{2}, 1)$. Then, from (A15) and (A16),

$$\begin{aligned} E\pi_u(a_u = a_m^1, w) &= y > 0 \text{ and} \\ E\pi_u(a_u \neq a_m^1, w)|_{\phi=\gamma} &= -\gamma y < 0. \end{aligned}$$

So, for all $y \in [\frac{1}{2}, 1)$, U's best response against $a_m^2 = R$ is to imitate a_m^1 if it is observable.

Therefore, regardless of U's posterior belief for $a_m^2 = R$ which is the off the equilibrium path, if $\gamma = \phi$, U's best response is to imitate a_m^1 if it is observable. Then from (A10), M's expected payoff of deviating from the given pooling strategy is $E\pi_m(a_m^2 = R) = 2p - 1$. On the other hand, if he follows the given pooling strategy, from (A3),

$$\begin{aligned} E\pi_m(a_m^2 = N)|_{\phi=\gamma} &= \frac{1}{2}(2p - 1)(\gamma + 1). \text{ Then} \\ E\pi_m(a_m^2 = R) - E\pi_m(a_m^2 = N)|_{\phi=\gamma} \\ &= \left(-\frac{1}{2}\right)(2p - 1)(\gamma - 1) < 0. \end{aligned}$$

So, when $\phi = \gamma$, M has no incentive to deviate from a pooling strategy that $a_m^2 = N$ for all $p \in (\frac{1}{2}, 1)$. Finally, if $\phi = \gamma$, $a_m^2 = N$ for all $p \in (\frac{1}{2}, 1)$.

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