論　　　文　　　題　　　目

Essays on Economic Analysis on Heterogeneity in Organizations

[組織内の異質性についての経済分析]

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Essays on Economic Analysis on Heterogeneity in Organizations

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Contents

Chapter 1.

Introduction

This thesis consists of three essays on the economics analysis on heterogeneity in organizations. In chapter 2, the first essay shows when preference diversity is beneficial for organizations. In chapter 3 and 4, I examine effects of heterogeneous prior beliefs on an incentive contract and a feedback strategy, respectively.

Information Acquisition, Decision Making, and Implementation in Organizations

The first essay studies a decision process of a two-agent organization that consists of a decision-maker who selects a project and an implementer who implements and executes the selected project. Each of the decision-maker and the implementer has intrinsic and possibly divergent preferences over projects. Key features of the model are that (i) there is the separation of decision and implementation, and the implementer may choose to execute no project if the cost of implementation is high; and (ii) the implementer engages in both acquiring additional information and implementing the project. This study shows that the implementer's incentives to gather information and to implement the selected project interact with each other in a non-trivial way. This study in particular shows how this interaction affects the optimality of diversity of preferences in organizations as well as the implementer's strategic communication.

Optimal Contracts for Human Capital Acquisition and Organizational Beliefs

The second essay examines how organizational beliefs affect on incentives to acquire human capital. I consider a dynamic moral hazard model in which a principal hires an agent for two periods, who then implements an identical project in each period. The project's outcome depends on both the agent's effort and his ability level. In the second period, the agent can develop his ability level. A key feature of the model is that the principal and the agent openly disagree and have differing prior beliefs on the success probability of the ability development. I show that the agent's belief regarding learnability has two effects: (i) it increases his incentive to work and develop his ability after failure, but (ii) it is counterproductive in the first period. The principal's belief regarding learnability determines which effect dominates.

Optimality of Straight Talk: Information Feedback and Human Capital Acquisition

The third essay studies an interaction between information feedback and human capital acquisition in a principal-agent model. An agent implements a project, and its success probability depends on the agent's ability level which is uncertain. While a principal cannot offer any monetary incentive, she has superior information about the agent's ability level and can provide feedback. A key feature of the model is that the agent may develop his ability level after receiving feedback, but before the project implementation. If the principal observes bad news and tells it truthfully, then (i) it hurts the agent's incentive to implement the project, but (ii) it induces the agent to develop his ability. I derive the condition under which the principal tells bad news truthfully.

Organization of This Thesis

The organization of this dissertation is as follows. Chapter 2 studies the preference heterogeneity in organizations. In Chapter 3, I examine the effect of differing priors on incentives to acquire human capital. In Chapter 4, I show the optimal feedback strategy under differing prior assumption. Chapter 5 summarizes the results and discuss possible future extensions.

Chapter 2.

Information Acquisition, Decision Making, and Implementation in Organizations[1]

2.1. Introduction

It is now well known that at the time of making movie *The Godfather*, director Francis Ford Coppola and Paramount Pictures had a lot of disagreements, particularly about casting choices. Although Coppola thought Marlon Brando was the right actor for Don Vito Corleone,[2] Coppola was told by the Paramount president who had the decision right, “As long as I’m president of Paramount, Marlon Brando will not be in the picture.” Despite this refusal, Coppola continued to persuade the president and the executives, and finally succeeded in turning around their opinions by performing screen test and listing reasons why Brando was necessary for *The Godfather*.

The executives of Paramount also disagreed with Coppola about the casting of Michael Corleone. While the studio wanted to cast a young blond star as Michael, Coppola wanted the image of an Italian-American found in then unknown Al Pacino.[3] Although

[1] This chapter is a joint work with Hideshi Itoh.

[2] According to Lebo (2005, p.48), Coppola said “I listed the reasons (...), one of them being that he had an aura about him when he was surrounded by other actors, similar to that of Don Corleone with the people.”

[3] According to Lebo (2005, p.63), Coppola said “I always saw this face of Al Pacino in this Sicily section.”

Coppola tried to persuade the vice president in charge of the production of the movie, he did not accept Coppola's opinion. Furthermore, the producer of the movie got upset about Coppola's taking a lot of test films of Al Pacino. However, these test films helped the studio to alter the opinion.[4] While *The Godfather* without Marlon Brando and Al Pacino might have been a good film, we could not watch the classic film without Coppola's effort.

How did the initial divergence in preferences between Coppola and Paramount executives affect the outcome? Coppola probably worked hard to gather additional information about actors, exactly because of the disagreements, in order to convince the executives to follow his opinion. Paramount executives probably thought that it was Coppola who directed the film anyway,[5] and he probably knew more about what he was doing to make the film succeed, and hence they were probably more inclined to respond to his claim in order to motivate him to direct the film enthusiastically than when they had similar preferences.

More generally, two key features of this story apply naturally to decision processes in organizations, such as a new product development process. First, there is division of labor between decision and implementation: The studio made final decisions and Coppola implemented them as a director. As is summarized by Gibbons et al. (2012), a decision process of an organization is often described as moving from choice to execution (Mintzberg, 1979) or from ratification to implementation (Fama and Jensen, 1983). The development of a new car model is executed by a team of engineers often led by a product manager (Clark and Fujimoto, 1991), only after it is ratified by top management. A decision is rarely implemented by the same person, and the authority of the decision maker is often ineffective and the subordinate implementer has some freedom to choose whether or not to obey the decisions (Arrow, 1974; Barnard, 1938; Simon, 1947).

[4] Marlon Brando also saw the test films and recognized the ability of Al Pacino. The studio chief eventually allowed Al Pacino to be cast after talking to Brando (Lebo, 2005).

[5] It is said that he was almost replaced not once but several times. However, he was not fired, and we do not consider such a possibility in this study.

Takahashi (1997) argues, based on surveys of white-collar workers of Japanese firms, that they commonly avoid completing their tasks so long that they sometimes become unnecessary.

Second, the person who implements the decision is very often the one who is in a better position to access to information valuable for decision making by exerting effort. Coppola engaged in both gathering additional information related to the success of the film *and* expending effort to direct the film following the approval by the studio. This feature is also commonly found in organizations. As emphasized by Hayek (1945) and Jensen and Meckling (1992), information relevant to decision making is dispersed, and important part of information is specific to "the particular circumstances of time and place." Furthermore, as Arrow (1974) emphasizes, the acquisition of information is costly and there is "a complementarity between a productive activity and some kinds of information. (p.42)" In the example of a new product development in the automobile industry, the product manager who is typically an engineer exerts considerable efforts before the project is ratified, such as recruiting project members from functional departments, spending off-duty hours for acquiring new knowledge, developing the prototype products, and so on (Niihara, 2010).

To study a decision process with these two features, we consider a two-agent organization the owner of which hires a decision maker and an implementer.[6] The decision maker selects one of two relevant projects and the implementer decides whether or not to implement the selected project after observing the cost of implementation. A project succeeds if and only if it "fits" the true state of nature *and* the implementation effort is exerted. Furthermore, before project choice, the implementer chooses an information-gathering effort to obtain a signal about the state of nature. The probability that an informative signal is observed is increasing in his effort. The informative signal indicates which project is more likely to succeed.

[6]Throughout this chapter we assume the decision maker is female and the implementer is male, for the purpose of identification only.

We analyze two cases separately, the case of symmetric information in which the signal gathered by the implementer is observable to the decision maker as well, and the case of asymmetric information where the signal is the implementer's private and soft information and hence there is a strategic communication problem.[7]

We are in particular interested in diversity in values or preferences between the decision maker and the implementer. The Coppola-Paramount example suggests that their initial divergent preferences have incentive effects that eventually lead to good outcomes. It is frequently emphasized in business press and by business people that diversity in the workplace pays. For example, the Stanford GSB lecturer and chairman of JetBlue Airways Joel Peterson writes as follows.[8]

> More important, building a homogeneous organization is just bad business. You won't have the variety of perspectives, backgrounds, and skills that are invaluable when you're up against big problems, or facing big opportunities. You want to work with a group of people who challenge each others' perspectives, and push each other beyond perceived limitations. The value of a great hire becomes clear when people on your team are forced out of their comfort zone by an infusion of new ideas. That's when the world begins to look a little different.

Research on diversity or heterogeneity in organizations has also been proliferating in management literature, although its effects on performance are mixed, partly due to the vague meaning of diversity (see, for example, Harrison and Klein, 2007, for a recent overview of the literature from the standpoint of defining diversity). There is also literature showing evidence of the bright side of intragroup conflict in organizations, in particular, task-related diversity such as dissimilarity in expertise, education, organizational tenure, and so on (see, for example, Horwitz and Horwitz, 2007, for a recent

[7] If the signal is the implementer's private and hard information, all the results under symmetric information continue to hold.

[8] `http://www.gsb.stanford.edu/insights/joel-peterson-what-are-most-common-hiring-mistakes`

review of the literature).

To capture preference diversity between the decision maker and the implementer, we assume that each of them prefers one of two projects to be implemented than the other, *ceteris paribus*, and enjoys a higher private benefit from the success of the former, favorite project than that of the latter. We call the organization *homogeneous* if their favorite projects coincide, and call it *heterogeneous* if their favorite projects differ. The unbiased owner chooses either homogeneous or heterogeneous organization to maximize her expected profit.[9]

Under the assumption of symmetric information, we find three reasons why preference heterogeneity between the decision maker and the implementer becomes optimal for the owner. First, the decision maker is more likely to "react" to the signal and to select her unfavorite project when the signal indicates it is more likely to succeed (Paramount probably reacted to Coppola in order to motivate him to direct the film enthusiastically). The decision maker is more likely to react under the heterogeneous organization because her unfavorite project is the implementer's favorite one, and hence the implementer is more motivated to exert effort to implement the project.

Second, the implementer is more motivated to exert effort to gather additional information under the heterogeneous organization since "ignorance" is more costly (Coppola was probably more motivated to gather additional information in order to avoid status quo casting). Suppose that the signal is so informative that, whether preferences are homogeneous or heterogeneous, the decision maker reacts to the signal and implements the project with a higher probability of success. If no informative signal is observed, the decision maker simply chooses her favorite project, which is the unfavorite one for the implementer under the heterogeneous organization. The implementer with the conflicting preference thus has a stronger incentive to exert effort to avoid ending up

[9] Our study is thus similar in spirit to Prendergast (2008), who shows that "firms partially solve agency problems by hiring agents with particular preferences (p.201)" and the agents' biases rise as contracting distortions become larger, although we assume away contracting issues.

with no additional information and implementing his unfavorite project. We call it the *ignorance-avoiding effect*.

The third reason why the owner prefers diversity comes from interaction between the decision maker's reactivity and his incentive to gather additional information (Coppola was probably more motivated to gather additional information, in order to induce Paramount to react). Suppose that the informativeness of the signal is intermediate and the decision maker reacts to it only under the heterogeneous organization. Then the only case in which the implementer can implement his favorite project is that the signal favoring that project is observed under the heterogeneous organization. This incentive to implement the favorite project in turn reinforces his incentive to gather information if the signal is sufficiently important.

Of course, diversity of preferences has its own cost. The decision maker chooses her favorite project when the signal favors it or when no additional information is available. It is however the implementer's unfavorite project and hence his motivation to implement the project is lower under the heterogeneous organization. We in fact show that the owner *strictly* prefers the homogeneous organization if the signal is little informative, or if it is reasonably informative but the implementer's marginal cost of information-gathering effort is sufficiently high. However, we show that the heterogeneous organization is optimal for the owner if *both* the signal is sufficiently informative and the implementer's marginal cost is sufficiently low.

We then extend the analysis to the case in which the signal is the implementer's private and soft information and the implementer can send any "cheap talk" message to the decision maker. The implementer has no incentive to manipulate information under the homogeneous organization. Under the heterogeneous organization, however, the implementer has incentives to induce the decision maker to choose his favorite project by deviating from truth-telling, and in general there is no equilibrium in which the signal observed by the implementer is perfectly communicated to the decision maker.

This lack of information does not always reduce the performance of the heterogenous organization because the implementer's favorite project is more likely to be selected and thus his motivation to implement it increases. The owner of the heterogenous organization thus benefits from asymmetric information when the implementer's marginal cost of information acquisition is sufficiently high. Otherwise, however, the heterogeneous organization is less likely to be optimal for the owner, and in particular, the ignorance-avoiding effect, on which the second reason why the owner prefers diversity is based, no longer exists (while the other two effects are still at work). We argue that the vulnerability of heterogenous organization to the manipulation of soft information points to a critical importance of information sharing among members when they have conflicting preferences.

The separation of decision and implementation has recently been formalized and analyzed by Blanes i Vidal and Möller (2007), Marino et al. (2010), Van den Steen (2010b), and Zábojník (2002). These papers study issues different from us, such as leadership, interpersonal authority, labor market conditions, and delegation of authority. Landier et al. (2009) is most closely related to ours. They show that preference heterogeneity between the decision maker and the implementer may be optimal for the owner. In their model, it is the decision maker who observes an informative signal. Furthermore, the decision maker always observes an informative signal without cost, and hence the incentive to acquire information is not an issue. Borrowing from their modeling approach, we study a complementary situation in which the implementer, exactly because he is the one who executes a project, can access to information valuable to decision making, only by exerting costly effort.[10]

Since the seminal work Dessein (2002), literature on strategic communication problems in organizations have been growing fast. We study how the implementer's incentive to

[10] Chiba and Leong (2013) is also related though in their model the decision maker both chooses and implements a project. The other agent in their model is an advisor who observes a signal privately and communicates it to the decision maker.

acquire information is affected by differences of preferences, and in this respect, our study is related to Che and Kartik (2009), Dur and Swank (2005), Gerardi and Yariv (2008), Hori (2008), Omiya et al. (2014), and Van den Steen (2010a). Che and Kartik (2009) and Van den Steen (2010a) show that an agent who has "opinion" different from the decision maker (modeled as different priors) has more incentive to acquire information to persuade the decision maker. Dur and Swank (2005), Gerardi and Yariv (2008), Hori (2008), and Omiya et al. (2014) point out that biased preferences can have positive effects on the agent's incentive to acquire information, which are similar to our ignorance-avoiding effect. In contrast to our model, however, the privately informed agent in these papers is an "adviser" who does not engage in implementation of a project.

The bottom line is that our study is an attempt to study the benefits and costs of preference diversity in organizations by unifying two issues previously analyzed separately, that is, (a) the separation of choice and implementation and (b) information acquisition and strategic communication.

Our theoretical analysis offer some interesting implications for complementarities in organizations. Our results imply that organizational practices such as information technology usage, investment in human capital, and information sharing exhibit complementarities, that is consistent with much of the existing empirical evidence (Ennen and Richter, 2010; Baker and Gil, 2012). However, we show that such complementarities exist *only in the heterogenous organization.* We are currently unaware of any empirical research studying complementarities among organizational elements including preference diversity.

The rest of this chapter is structured as follows. In Section 2.2, we introduce the model, and in Section 2.3 we report the main results under the assumption of symmetric information. In Section 2.4 we analyze alternative settings such as the decision maker exerting effort to gather information, and discuss how our results change. In Section 2.5, we assume that additional signal is the implementer's private information and analyze strategic communication issues. In section 2.6, the concluding section, we discuss empirical implications.

2.2. The Model

An owner of a hierarchical organization hires two agents, decision maker (hereafter DM, female) and implementer (IM, male), to select and execute a project. The owner first chooses either a *homogeneous* or *heterogeneous* organization (whose meanings are to be explained below). DM then chooses a project. There are potentially many projects, of which only two, called projects 1 and 2, are relevant: there are two possible states of nature $\theta \in \{1, 2\}$, and project $d \in \{1, 2\}$ is efficient if and only if the true state is $\theta = d$. We assume $\mathbb{P}[\theta = 1] = \mathbb{P}[\theta = 2] = 1/2$.

IM then exerts effort $e \in \{0, 1\}$ to implement and execute the selected project. Effort $e = 1$ costs $\tilde{c}$ to IM, which is random and distributed according to a cumulative distribution function $F(\cdot)$ with $f(\cdot)$ as the corresponding density function. We assume $F(0) = 0$ and $F(\cdot)$ is strictly increasing. IM chooses effort after observing the realization of $\tilde{c}$.

Project efficiency and IM's effort are perfect complements: The implemented project d succeeds if and only if it is efficient ($\theta = d$) *and* IM chooses $e = 1$. If the project succeeds, the owner obtains profit which we normalize to 1, and DM and IM enjoy private benefits $B > 0$ and $b > 0$, respectively. The payoffs to all three parties are zero, otherwise. We can interpret private benefits as intrinsic motivation, perks on the jobs, acquisition of human capital, benefits from other ongoing projects, the possibility of signaling abilities, and so on.

Furthermore, private benefits to DM and IM depend on whether or not their *favorite* projects are implemented. Without loss of generality, we assume DM prefers project 1, *ceteris paribus*, and obtains $B = B_H$ if project 1 is implemented and succeeds, while her private benefit is $B = B_L < B_H$ if project 2 is implemented and succeeds. Similarly, IM enjoys b_H (b_L) if his favorite (respectively, unfavorite) project is implemented and succeeds, where $b_H > b_L$ holds.

When IM prefers project 1, DM and IM agree about the favorite project and we call such an organization *homogeneous*. The organization where IM prefers project 2 is called *heterogeneous*. We denote DM's *bias* toward her favorite project as $\Gamma \equiv B_H/B_L > 1$ and IM's bias as $\gamma \equiv b_H/b_L > 1$. The owner, in contrast, has no bias toward a particular project, and hence chooses an organization to maximize the probability of success.

In addition to implementation and execution of a project, IM can engage in information acquisition and generate signal $\sigma \in \{\phi, 1, 2\}$. Before DM chooses a project, IM chooses information-gathering effort $\pi \in [0, 1]$. The cost of information-gathering effort π is denoted by $\eta(\pi; k)$, where $k \in (0, +\infty)$ is a parameter representing, for example, investment in information technology, the extent of IM's discretion over his time allocation between information acquisition and other tasks, the magnitude of organizational support for his activities, and so on, that reduces the marginal cost of effort. For simplicity, we assume it is quadratic in π, that is, $\eta(\pi; k) = \pi^2/(2k)$.

When IM chooses $\pi \in [0, 1]$, each value of the signal realizes with the following probabilities: For $d, d' \in \{1, 2\}$ and $d' \neq d$,

$$\mathbb{P}[\sigma = d \mid \theta = d] = \pi\alpha$$
$$\mathbb{P}[\sigma = d' \mid \theta = d] = \pi(1 - \alpha)$$
$$\mathbb{P}[\sigma = \phi \mid \theta = d] = 1 - \pi$$

where $\alpha \in (1/2, 1]$ is the informativeness of the signal: IM succeeds in gathering additional information $\sigma \in \{1, 2\}$ with probability π, while with probability $1 - \pi$ no additional information is available ($\sigma = \phi$ realizes). The posterior probability is hence $\mathbb{P}[\theta = d \mid \sigma = d] = \alpha > 1/2$ and $\mathbb{P}[\theta = d \mid \sigma = d'] = 1 - \alpha < 1/2$. Parameter α can be interpreted, for example, as IM's knowledge about technological environments relevant to the projects, the importance of information acquisition for decision making, and so on. Given that information gathering is successful, the probability of observing $\sigma = 1$ and that of observing $\sigma = 2$ are equal to 1/2.

The timing of decisions and information structure are summarized as follows.

1. The owner selects either a homogeneous or heterogeneous organization.[11] The owner chooses the homogenous organization if indifferent. Whether the organization is homogeneous or heterogeneous, as well as private benefits, are observable to DM and IM.

2. IM chooses information-gathering effort $\pi \in [0, 1]$ that is unobservable to DM.

3. Signal $\sigma \in \{\phi, 1, 2\}$ realizes. We assume σ is observable to DM and IM before Section 2.5, where we alternatively assume σ is IM's private information and IM sends a message to DM.

4. DM chooses a project $d \in \{1, 2\}$, which is observable to IM. DM chooses her favorite project 1 if indifferent.

5. The cost of implementation $\tilde{c}$ is realized and observed only by IM.

6. IM chooses the effort of implementation $e \in \{0, 1\}$.

7. The outcome of the project is realized.

2.3. Analysis

We solve the subgame perfect equilibrium of the model by moving backwards, analyzing in order (i) IM's implementation decision, (ii) DM's project choice, (iii) IM's information-gathering effort, and (iv) the owner's choice of an organization. The proofs not in the main text are found in Appendix.

[11] We assume that project choice, implementation decision, outcomes, additional signal, and payoffs to IM and DM are all unverifiable and hence the owner cannot design contingent payment schemes.

2.3.1. Project Implementation

IM's choice of implementation effort depends on which project DM has chosen as well as whether IM has additional information about the state of nature. Suppose throughout this subsection DM has chosen project $d \in \{1, 2\}$ with IM's private benefit $b \in \{b_L, b_H\}$. We denote the probability that the project is implemented given signal σ by $q(b, d, \sigma) \equiv \mathbb{P}[e = 1 \mid b, d, \sigma]$.

First, suppose IM has no additional information, so that he only knows the project selected by DM succeeds with probability 1/2. IM then chooses $e = 1$ if and only if $(b/2) - \tilde{c} \geq 0$. DM then expects IM to exert implementation effort with $q(b, d, \phi) = F(b/2)$.

Next, suppose IM obtains additional information. If $\sigma = d \in \{1, 2\}$, IM provides implementation effort for project d if and only if $\alpha b - \tilde{c} \geq 0$. If $\sigma \neq d$,[12] IM chooses $e = 1$ to implement project d if and only if $(1 - \alpha)b - \tilde{c} \geq 0$. The probabilities that IM chooses $e = 1$ are thus given as $q(b, d, d) = F(\alpha b)$ and $q(b, d, d') = F((1 - \alpha)b)$, respectively. Note that these probabilities are strictly increasing in b: IM is more likely to implement a project if it is his favorite one. To guarantee that they are less than one for all α, we assume $F(b_H) \leq 1$ throughout this chapter.

2.3.2. Project Choice

Moving backwards, we next analyze DM's project choice. We denote the probability of the project being successful by $p(b, d, \sigma)$ given IM's private benefit b, project d, and signal σ. For each signal σ, DM chooses a project that maximizes her expected benefit, which we denote by $d^*_{\text{hom}}(\sigma)$ and $d^*_{\text{het}}(\sigma)$ under the homogeneous organization and the heterogeneous organization, respectively.

[12] By $\sigma \neq d$, we always mean $\sigma = d' \in \{1, 2\}$ and $d' \neq d$.

No Additional Information

First suppose $\sigma = \phi$. Then IM chooses $e = 1$ with probability $q(b, d, \phi)$, and then the project succeeds with probability 1/2. Hence

$$p(b, d, \phi) = \frac{1}{2} q(b, d, \phi) = \frac{1}{2} F\left(\frac{b}{2}\right).$$

DM's expected benefit given her private benefit B is then

$$p(b, d, \phi) B = \frac{1}{2} F\left(\frac{b}{2}\right) B.$$

Under the homogeneous organization in which project 1 is the favorite project for both DM and IM, it is obvious that DM chooses project 1 because it's success probability as well as her private benefit is higher under $d = 1$ than $d = 2$: $p(b_H, 1, \phi)B_H > p(b_L, 2, \phi)B_L$.

Under the heterogeneous organization in which DM (IM) prefers project 1 (2, respectively), there is a tradeoff. If DM chooses her favorite project 1, her private benefit under success will be higher while IM is less likely to implement the project. DM's expected benefits under $d = 1$ and $d = 2$ are, respectively, given as follows:

$$\begin{aligned} p(b_L, 1, \phi) B_H &= \frac{1}{2} F\left(\frac{b_L}{2}\right) B_H \\ p(b_H, 2, \phi) B_L &= \frac{1}{2} F\left(\frac{b_H}{2}\right) B_L \end{aligned}$$

DM chooses her favorite project 1 if $p(b_L, 1, \phi)B_H \geq p(b_H, 2, \phi)B_L$, which is equivalent to

$$\Gamma = \frac{B_H}{B_L} \geq \frac{F(b_H/2)}{F(b_L/2)}. \tag{2.1}$$

In order to focus on a natural and interesting case where DM prefers her favorite project without further information, from now on we assume (2.1).

Assumption 1. $\Gamma \geq F(b_H/2)/F(b_L/2)$.

DM is more intrinsically biased than IM in the sense of Assumption 1. We think this represents a realistic situation in which an important decision is made at a higher hierarchical rank and those who make the decision are more experienced and confident than those who implement the decision at lower ranks.[13] Under Assumption 1, it is optimal for DM to choose her favorite project 1 without additional information, even when the organization is heterogeneous: $d^*_{\text{hom}}(\phi) = d^*_{\text{het}}(\phi) = 1$.

In addition, we sometimes make the following assumption that directly compares the bias of DM and that of IM.

Assumption 2. $\Gamma \geq \gamma$.

Assumptions 1 and 2 are equivalent if $\tilde{c}$ is uniformly distributed over $[0, 1]$. If $F(\cdot)$ is convex, Assumption 2 is implied by Assumption 1.

Additional Information

Next suppose $\sigma \in \{1, 2\}$. The success probabilities are given as follows.

$$p(b, d, d) = \alpha q(b, d, d) = \alpha F(\alpha b)$$
$$p(b, d, d') = (1 - \alpha)q(b, d, d') = (1 - \alpha)F((1 - \alpha)b)$$

First, consider the homogeneous organization. If $\sigma = 1$, the optimal project for DM is again project 1 since (i) project 1 is more likely to succeed than project 2, (ii) IM is more likely to implement project 1, and (iii) success yields higher private benefit B_H. We thus obtain $d^*_{\text{hom}}(1) = 1$.

[13] The corresponding assumption is also made in Landier et al. (2009). If Assumption 1 does not hold, DM chooses her unfavorite project even though there is no additional information, in order to raise IM's implementation probability. In the discussion section (Section 2.4) we explain how the results change under this alternative assumption.

On the other hand, if $\sigma = 2$, DM's expected benefit from her favorite project 1 is $p(b_H, 1, 2)B_H = (1-\alpha)F((1-\alpha)b_H)B_H$. DM's expected benefit from project 2 is $p(b_L, 2, 2)B_L = \alpha F(\alpha b_L)B_L$. Then $d^*_{\text{hom}}(2) = 2$ if and only if

$$\alpha F(\alpha b_L)B_L > (1-\alpha)F((1-\alpha)b_H)B_H$$

holds. Define $\alpha_{\text{hom}} \in (1/2, 1)$ as the solution to

$$\alpha F(\alpha b_L) = (1-\alpha)F((1-\alpha)b_H)\Gamma. \tag{2.2}$$

Then $d^*_{\text{hom}}(2) = 2$ if and only if $\alpha > \alpha_{\text{hom}}$.

We say DM is *reactive* to signal σ if for each signal DM chooses a project with higher probability of success: $d^*_{\text{hom}}(\sigma) = \sigma$ for $\sigma \in \{1, 2\}$. Under the homogeneous organization, DM is reactive if $\alpha > \alpha_{\text{hom}}$. Otherwise, she always chooses her favorite project 1 irrespective of the informative signal, in which case DM is called *non-reactive*.

Next consider the heterogeneous organization. If $\sigma = 1$ is received, DM's expected benefit from her favorite project 1 is $p(b_L, 1, 1)B_H = \alpha F(\alpha b_L)B_H$. Similarly, her expected benefit from project 2 is given as $p(b_H, 2, 1)B_L = (1-\alpha)F((1-\alpha)b_H)B_L$. Using $\alpha > 1/2$ and Assumption 1 yield

$$\alpha F(\alpha b_L)B_H > \frac{1}{2}F\left(\frac{b_L}{2}\right)B_H \geq \frac{1}{2}F\left(\frac{b_H}{2}\right)B_L > (1-\alpha)F((1-\alpha)b_H)B_L,$$

and hence $d^*_{\text{het}}(1) = 1$: Under Assumption 1, there is no difference between homogeneous and heterogeneous organizations if the signal indicates that project 1 is more likely to succeed.

If $\sigma = 2$, on the other hand, DM's expected benefits from projects 1 and 2 are, respectively, given as $p(b_L, 1, 2)B_H = (1-\alpha)F((1-\alpha)b_L)B_H$ and $p(b_H, 2, 2)B_L = \alpha F(\alpha b_H)B_L$.

DM is reactive if

$$\alpha F(\alpha b_H) B_L > (1-\alpha) F((1-\alpha) b_L) B_H.$$

Define $\alpha_{\text{het}} \in [1/2, 1)$ as the solution to

$$\alpha F(\alpha b_H) = (1-\alpha) F((1-\alpha) b_L) \Gamma. \tag{2.3}$$

Then $d^*_{\text{het}}(2) = 2$ if and only if $\alpha > \alpha_{\text{het}}$ holds.

From (2.2) and (2.3) one can easily show $1/2 \leq \alpha_{\text{het}} < \alpha_{\text{hom}} < 1$: *DM is more likely to be reactive under the heterogeneous organization than under the homogeneous organization.* We have solved for DM's optimal project choice as summarized in the following lemma.[14]

Lemma 1. *Under Assumption 1, there exist thresholds* α_{hom} *and* α_{het} *satisfying* $1/2 \leq \alpha_{\text{het}} < \alpha_{\text{hom}} < 1$*, such that DM's optimal project choice is* $d^*_{\text{hom}}(\phi) = d^*_{\text{het}}(\phi) = 1$ *for all* $\alpha \in (1/2, 1]$*, and for informative signals, it is given as follows:*

Case 1: *If* $\alpha \in (1/2, \alpha_{\text{het}}]$*, then DM is non-reactive under both organizations:* $d^*_{\text{hom}}(\sigma) = d^*_{\text{het}}(\sigma) = 1$ *for* $\sigma \in \{1, 2\}$*;*

Case 2: *If* $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$*, then DM is non-reactive under the homogeneous organization but is reactive under the heterogeneous organization:* $d^*_{\text{hom}}(\sigma) = 1$ *and* $d^*_{\text{het}}(\sigma) = \sigma$ *hold for* $\sigma \in \{1, 2\}$*;*

Case 3: *If* $\alpha \in (\alpha_{\text{hom}}, 1]$*, DM is reactive under both organizations:* $d^*_{\text{hom}}(\sigma) = d^*_{\text{het}}(\sigma) = \sigma$ *for* $\sigma \in \{1, 2\}$*.*

As Lemma 1 and Table 2.1 given below make clear, there is no difference in project choice between homogeneous organization and heterogeneous organization if the signal is uninformative or a good news for DM's favorite project 1. DM possibly makes a different

[14] If Assumption 1 holds with equality, (2.3) yields $\alpha_{\text{het}} = 1/2$ and hence Case 1 in the proposition does not arise. Similar remarks apply to other results as well.

choice if the signal favors her unfavorite project 2. In either organization, DM is reactive if the signal is sufficiently informative. DM's incentive to be reactive is stronger under the heterogeneous organization because IM derives a higher private benefit from project 2 and is hence more likely to implement it.

Table 2.1.: DM's optimal project choice

	Homogeneous		Heterogeneous	
	$\alpha \leq \alpha_{\text{hom}}$	$\alpha > \alpha_{\text{hom}}$	$\alpha \leq \alpha_{\text{het}}$	$\alpha > \alpha_{\text{het}}$
$\sigma = \phi$	project 1		project 1	
$\sigma = 1$	project 1		project 1	
$\sigma = 2$	project 1	project 2	project 1	project 2

2.3.3. IM's Incentive to Gather Additional Information

Moving backwards further, we now analyze IM's optimal information-gathering effort. Let $K(b, d, \sigma)$ be IM's expected net benefit given private benefit b, project d, and signal σ:

$$K(b, d, \sigma) = p(b, d, \sigma)b - \mathbb{E}[\tilde{c} \mid b, d, \sigma]$$

where IM's expected cost of implementation effort $\mathbb{E}[\tilde{c} \mid b, d, \sigma]$ is given by

$$\mathbb{E}[\tilde{c} \mid b, d, \sigma] = \int_0^{\mathbb{P}[\theta = d | \sigma] b} cf(c)dc.$$

Then for each signal σ, IM's expected net benefit is calculated as follows:

$$\begin{aligned}
K(b, d, \phi) &= \frac{1}{2}F\left(\frac{b}{2}\right)b - \int_0^{b/2} cf(c)dc = \int_0^{b/2} F(c)dc \\
K(b, d, d) &= \alpha F(\alpha b)b - \int_0^{\alpha b} cf(c)dc = \int_0^{\alpha b} F(c)dc \\
K(b, d, d') &= (1-\alpha)F((1-\alpha)b)b - \int_0^{(1-\alpha)b} cf(c)dc = \int_0^{(1-\alpha)b} F(c)dc
\end{aligned}$$

Hence we simply write these as $K(b/2)$, $K(\alpha b)$, and $K((1-\alpha)b)$, respectively. $K(x) = \int_0^x F(c)dc$ satisfies $\partial K(x)/\partial x > 0$ and $\partial^2 K(x)/\partial^2 x > 0$ for all $x > 0$.

Homogeneous Organization

Consider the homogeneous organization and suppose first $\alpha \leq \alpha_{\text{hom}}$ so that DM is non-reactive. IM's expected payoff is equal to the expected benefit minus the cost of information acquisition:

$$\frac{\pi}{2}\left[K(\alpha b_H) + K((1-\alpha)b_H)\right] + (1-\pi)K\left(\frac{b_H}{2}\right) - \eta(\pi; k).$$

The first-order condition with respect to π yields the optimal effort as follows:

$$\pi_{\text{hom}}^{\text{N}}(\alpha, k) = \min\left\{k\left(\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right)\right), 1\right\}.$$

Note that $\pi_{\text{hom}}^{\text{N}}(\alpha, k)$ is strictly increasing in α and k if $\pi_{\text{hom}}^{\text{N}}(\alpha, k) < 1$. Furthermore, $\pi_{\text{hom}}^{\text{N}}(\alpha, k) > 0$ holds for all $\alpha \in (1/2, 1]$ and $k > 0$ by the strict convexity of $K(\cdot)$: *Although DM is non-reactive, IM still has an incentive to gather additional information.* This is because additional information enables him to decide whether or not to implement project 1 contingent on the informative signal. With additional information, IM chooses to implement project 1 if $c \leq \alpha b_H$ under signal $\sigma = 1$ and $c \leq (1-\alpha)b_H$ under signal $\sigma = 2$. With no additional information, his decision can depend only on whether $c \leq (1/2)b_H$ holds or not.

Suppose next $\alpha > \alpha_{\text{hom}}$ so that DM is reactive. IM's expected payoff is given by

$$\frac{\pi}{2}\left[K(\alpha b_H) + K(\alpha b_L)\right] + (1-\pi)K\left(\frac{b_H}{2}\right) - \eta(\pi; k).$$

By taking the first-order condition with respect to π, we obtain the optimal effort as follows:

$$\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) = \min\left\{k\left(\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K(\alpha b_L) - K\left(\frac{b_H}{2}\right)\right), 1\right\},$$

which is strictly increasing in α unless $\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) = 1$. The following lemma proves that $\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) > 0$ holds for all $\alpha \in (\alpha_{\mathrm{hom}}, 1]$ and $k > 0$ under Assumptions 1 and 2. By this lemma, $\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k)$ is strictly increasing in k if $\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) < 1$.

Lemma 2. *Under Assumptions 1 and 2,* $\pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) > 0$ *holds for all* $\alpha \in (\alpha_{\mathrm{hom}}, 1]$ *and* $k > 0$.

Denote the optimal level of the information-gathering effort under the homogeneous organization by $\pi_{\mathrm{hom}}(\alpha, k)$:

$$\pi_{\mathrm{hom}}(\alpha, k) = \begin{cases} \pi^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k) & \text{if } \alpha \leq \alpha_{\mathrm{hom}} \\ \pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k) & \text{if } \alpha > \alpha_{\mathrm{hom}} \end{cases}$$

Suppose $\pi^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k) < 1$. Then $\pi_{\mathrm{hom}}(\alpha, k)$ discontinuously jumps up at $\alpha = \alpha_{\mathrm{hom}}$ if and only if $\Gamma > \gamma$. To see this, first note $\pi^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k) = \pi^{\mathrm{R}}_{\mathrm{hom}}(\alpha, k)$ holds when $\alpha b_L = (1-\alpha) b_H$, or

$$\alpha = \alpha_\gamma \equiv \frac{\gamma}{1+\gamma}, \tag{2.4}$$

which satisfies $\alpha_\gamma \leq \alpha_{\mathrm{hom}}$ if and only if Assumption 2 holds, with strict inequality if $\Gamma > \gamma$. Then when α is in the interval $(\alpha_\gamma, \alpha_{\mathrm{hom}}]$, IM would have stronger incentives to gather additional information if DM were reactive. However, the precision of the signal is not high enough for DM to react to it. Hence IM's incentives rise discontinuously at α_{hom} beyond which DM becomes reactive.[15] In Figure 2.1 given below, $\pi_{\mathrm{hom}}(\alpha, k)$ is depicted as the dashed curve under the assumption of uniform distribution.

[15]If Assumption 2 is not satisfied and hence $\Gamma < \gamma$, then $\alpha_\gamma > \alpha_{\mathrm{hom}}$ holds and $\pi_{\mathrm{hom}}(\alpha, k)$ *drops* discontinuously at $\alpha = \alpha_{\mathrm{hom}}$, possibly to zero. Our main results are valid without Assumption 2 since the homogeneous organization then becomes even less desirable than when Assumption 2 is satisfied.

Define also $\overline{k}_{\text{hom}}(\alpha) > 0$ as the minimum k satisfying $\pi_{\text{hom}}(\alpha, k) = 1$: $\overline{k}_{\text{hom}}(\alpha) = \overline{k}^{\text{N}}_{\text{hom}}(\alpha)$ for $\alpha \leq \alpha_{\text{hom}}$; and $\overline{k}_{\text{hom}}(\alpha) = \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$ for $\alpha > \alpha_{\text{hom}}$, where

$$\begin{aligned}
\overline{k}^{\text{N}}_{\text{hom}}(\alpha) &= \left(\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right)\right)^{-1} \\
\overline{k}^{\text{R}}_{\text{hom}}(\alpha) &= \left(\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K(\alpha b_L) - K\left(\frac{b_H}{2}\right)\right)^{-1}.
\end{aligned}$$

It is easy to see $\overline{k}_{\text{hom}}(\alpha)$ is strictly decreasing in α, and discontinuously drops at $\alpha = \alpha_{\text{hom}}$ if $\Gamma > \gamma$.

Heterogenous Organization

Consider next the heterogeneous organization. We can obtain IM's optimal information-gathering effort $\pi_{\text{het}}(\alpha, k)$ in a way similar to $\pi_{\text{hom}}(\alpha, k)$:

$$\pi_{\text{het}}(\alpha, k) = \begin{cases} \pi^{\text{N}}_{\text{het}}(\alpha, k) & \text{if } \alpha \leq \alpha_{\text{het}} \\ \pi^{\text{R}}_{\text{het}}(\alpha, k) & \text{if } \alpha > \alpha_{\text{het}} \end{cases}$$

where $\pi^{\text{N}}_{\text{het}}(\alpha, k)$ and $\pi^{\text{R}}_{\text{het}}(\alpha, k)$ are defined as follows.

$$\begin{aligned}
\pi^{\text{N}}_{\text{het}}(\alpha, k) &= \min\left\{k\left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K((1-\alpha)b_L) - K\left(\frac{b_L}{2}\right)\right), 1\right\}; \\
\pi^{\text{R}}_{\text{het}}(\alpha, k) &= \min\left\{k\left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K(\alpha b_H) - K\left(\frac{b_L}{2}\right)\right), 1\right\}
\end{aligned}$$

Both of them are strictly increasing in α and k (unless they are equal to one) and positive for all $\alpha > 1/2$ and $k > 0$. It is easy to show that for all $\alpha \in (1/2, 1]$, $\pi^{\text{R}}_{\text{het}}(\alpha, k) \geq \pi^{\text{N}}_{\text{het}}(\alpha, k)$ holds with strict inequality if $\pi^{\text{N}}_{\text{het}}(\alpha, k) < 1$: IM would have more incentives to gather information if DM were reactive. In Figure 2.1, $\pi_{\text{het}}(\alpha, k)$ is depicted as the solid curve.

We also define $\overline{k}_{\text{het}}(\alpha)$ as the minimum k satisfying $\pi_{\text{het}}(\alpha, k) = 1$: $\overline{k}_{\text{het}}(\alpha) = \overline{k}^{\text{N}}_{\text{het}}(\alpha)$

for $\alpha \le \alpha_{\text{het}}$ and $\overline{k}_{\text{het}}(\alpha) = \overline{k}^{\text{R}}_{\text{het}}(\alpha)$ for $\alpha > \alpha_{\text{het}}$ where

$$\overline{k}^{\text{N}}_{\text{het}}(\alpha) = \left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K((1-\alpha)b_L) - K\left(\frac{b_L}{2}\right)\right)^{-1}$$
$$\overline{k}^{\text{R}}_{\text{het}}(\alpha) = \left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K(\alpha b_H) - K\left(\frac{b_L}{2}\right)\right)^{-1}$$

$\overline{k}_{\text{het}}(\alpha)$ is strictly decreasing in α, and discontinuous at $\alpha = \alpha_{\text{het}}$.

Comparison

We examine how IM's incentive to gather additional information differs between two organizations. We sometimes adopt the following assumption.

Assumption 3. *$xf(x)$ is (weakly) increasing in $x > 0$.*

This assumption means that $F(\cdot)$ is not "very concave." It is satisfied if $F(\cdot)$ is convex. In particular, it holds if $\tilde{c}$ is uniformly distributed.

The following proposition summarizes the result.

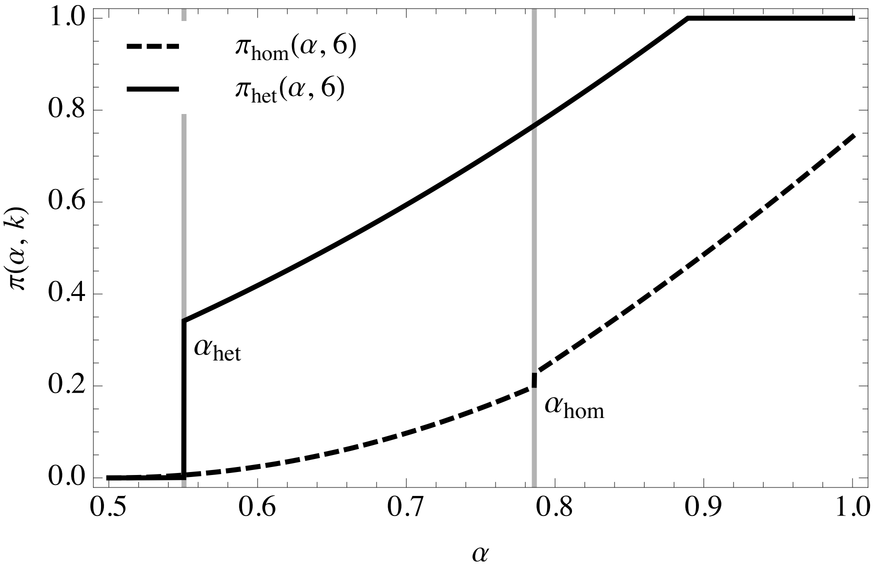
Proposition 1. *Under Assumptions 1 and 2, IM's incentive to gather additional information differs between homogeneous and heterogeneous organizations as follows.*

Case 1: *Suppose $\alpha \in (1/2, \alpha_{\text{het}}]$. If Assumption 3 is also satisfied, $\pi_{\text{hom}}(\alpha, k) \ge \pi_{\text{het}}(\alpha, k)$ for all $k > 0$. The inequality is strict if $k < \overline{k}_{\text{het}}(\alpha)$: IM is more likely to obtain information under the homogeneous organization than under the heterogeneous organization.*

Case 2: *Suppose $\alpha \in (\alpha_{\text{het}}, 1]$. Then $\pi_{\text{hom}}(\alpha, k) \le \pi_{\text{het}}(\alpha, k)$ holds for all $k > 0$. The inequality is strict if $k < \overline{k}_{\text{hom}}(\alpha)$: IM is more likely to obtain information under the heterogeneous organization than under the homogeneous organization.*

Figure 2.1 illustrates Proposition 1 by depicting IM's optimal level of the information-gathering efforts. If the informativeness of the signal is so low that DM is non-reactive

Figure 2.1.: Comparison of Incentives to Gather Information



In the figure, we assume $\tilde{c}$ is uniformly distributed over $[0, 1]$, $b_L = B_L = 0.3$, $b_H = 0.9$, and $B_H = 1.35$. Then $\alpha_{\text{het}} \approx 0.55$, $\alpha_{\text{hom}} \approx 0.78$, and $\alpha_\gamma = 0.75$. The cost parameter is set to $k = 6$.

under either organization (Case 1), IM is more likely to gather additional information when the project selected by DM is his favorite one. This is because additional information is more valuable to IM when he decides whether or not to implement his favorite project 1 than his unfavorite project 2. Assumption 3 is not necessary. The strict relationship $\pi_{\text{hom}}(\alpha, k) > \pi_{\text{het}}(\alpha, k)$ can hold if $F(\cdot)$ is not "very concave." The conclusion may not hold if $F(\cdot)$ is so concave that gathering information is "much more risky" under IM's favorite project than under his unfavorite one.

Next suppose the signal is sufficiently informative (Case 2). There are two sub-cases. If $\alpha > \alpha_{\text{hom}}$, then DM is reactive under either organization. The difference in IM's incentive to gather information is then solely due to the difference in his expected benefit under no additional information. Without additional information, DM chooses project 1, which is IM's favorite (unfavorite) project under the homogeneous (respectively, heterogeneous) organization. IM thus has a stronger incentive to acquire information under the latter organization, in order to avoid ending up with no additional information and implementing his unfavorite project. We call it the *ignorance-avoiding effect.*[16]

Finally, if $\alpha_{\text{het}} < \alpha \leq \alpha_{\text{hom}}$, DM is reactive only under the heterogeneous organization. The difference in the marginal benefit from acquiring information, which in turn determines the difference in the optimal efforts, consists of the following three effects:

$$\begin{aligned}
&\left[\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K(\alpha b_H) - K\left(\frac{b_L}{2}\right)\right] - \left[\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right)\right] \\
&\quad = \left[K\left(\frac{b_H}{2}\right) - K\left(\frac{b_L}{2}\right)\right] + \frac{1}{2}\left[K(\alpha b_H) - K((1-\alpha)b_H)\right] - \frac{1}{2}\left[K(\alpha b_H) - K(\alpha b_L)\right]
\end{aligned} \tag{2.5}$$

The difference in the first brackets represents the ignorance-avoiding effect, which is positive. The terms in the second and third brackets represent the effects from the difference in reactivity between two organizations. The difference in the second brackets is positive because DM chooses the more successful project 2 given signal $\sigma = 2$ only if IM succeeds in gathering additional information under the heterogenous organization. This effect of divergent preferences increases IM's motivation for implementation because he finds the project selected is more likely to succeed.

However, there is a cost of preference heterogeneity as represented by the difference in the last brackets. This cost is due to the fact that DM, when she observes $\sigma = 1$, chooses her favorite project 1, which IM does not like and is less likely to implement under the heterogenous organization.

While the ignorance-avoiding effect is positive, the other effects may hurt the incentive to gather information: the sum of the second and third effects is not necessarily positive for all $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$. It is positive if $\alpha > \alpha_\gamma$ but negative if $\alpha < \alpha_\gamma$. And which of

[16] The ignorance-avoiding effect should be distinguished from the "persuasion effect" pointed out by Che and Kartik (2009) and Van den Steen (2010a), which arises from different priors. An effect similar to our ignorance-avoiding effect is pointed out by Dur and Swank (2005), Gerardi and Yariv (2008), Hori (2008), Omiya et al. (2014), as well as Che and Kartik (2009, Section VI).

α_{het} and α_γ is larger depends on the biases of DM and IM as follows:[17]

$$\alpha_{\text{het}} \gtreqless \alpha_\gamma \quad \Leftrightarrow \quad \Gamma \gtreqless \Gamma_\gamma \equiv \frac{\alpha_\gamma F(\alpha_\gamma b_H)}{(1-\alpha_\gamma)F((1-\alpha_\gamma)b_L)}. \tag{2.6}$$

If DM's bias is sufficiently high, α_{het} is so high that in the relevant range of α, the positive second effect always more than offsets the negative third effect. If DM's bias is lower than Γ_γ, however, the sum of the second and third effects first reduces the advantage of heterogenous organization due to the ignorance-avoiding effect for $\alpha \in (\alpha_{\text{het}}, \alpha_\gamma)$, and then reinforces the ignorance-avoiding effect for $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$. Figure 2.1 corresponds to the latter case ($\alpha_{\text{het}} < \alpha_\gamma$). Despite this negative third effect, however, Proposition 1 (Case 2) states that the heterogenous organization is advantageous in terms of information acquisition for all $\alpha \in (\alpha_{\text{het}}, 1]$.

2.3.4. Optimal Organization

We finally investigate the optimal organization for the owner. Let $V_{\text{hom}}(\alpha, k)$ and $V_{\text{het}}(\alpha, k)$ be the owner's expected profits:[18]

$$V_{\text{hom}}(\alpha,k) = \begin{cases} V^{\text{N}}_{\text{hom}}(\alpha,k) & \text{if } \alpha \leq \alpha_{\text{hom}} \\ V^{\text{R}}_{\text{hom}}(\alpha,k) & \text{if } \alpha > \alpha_{\text{hom}} \end{cases}$$

$$V_{\text{het}}(\alpha,k) = \begin{cases} V^{\text{N}}_{\text{het}}(\alpha,k) & \text{if } \alpha \leq \alpha_{\text{het}} \\ V^{\text{R}}_{\text{het}}(\alpha,k) & \text{if } \alpha > \alpha_{\text{het}} \end{cases}$$

Each of $V_{\text{hom}}(\alpha, k)$ and $V_{\text{het}}(\alpha, k)$ is equal to the success probability of the respective organization, and depends on whether DM is non-reactive (represented by superscript N) or reactive (superscript R).

We first present the main result formally in the following proposition, and then dis-

[17]For example, if $\tilde{c}$ is uniformly distributed over $[0, 1]$, $\Gamma_\gamma = \gamma^3$.
[18]We relegate the exact formulas to Appendix A1.

cuss intuition in detail. To this purpose, we define another important threshold for informativeness. Define $\hat{\alpha} \in (1/2, \alpha_\gamma)$ as the solution to

$$\alpha F(\alpha b_L) = (1-\alpha)F((1-\alpha)b_H). \tag{2.7}$$

While $\hat{\alpha}$ is smaller than α_{hom}, which of α_{het} and $\hat{\alpha}$ is larger depends on the biases of DM and IM as follows:[19]

$$\alpha_{\text{het}} \gtreqless \hat{\alpha} \quad \Leftrightarrow \quad \Gamma \gtreqless \hat{\Gamma} \equiv \frac{\hat{\alpha}F(\hat{\alpha}b_H)}{(1-\hat{\alpha})F((1-\hat{\alpha})b_L)}. \tag{2.8}$$

We thus define $\hat{\alpha}_{\text{het}} \equiv \max\{\alpha_{\text{het}}, \hat{\alpha}\}$.

Proposition 2. *Under Assumptions 1–3, the optimal organization for the owner is given as follows.*

Case 1: *If $\alpha \in (1/2, \alpha_{\text{het}}]$, then $V_{\text{het}}(\alpha) < V_{\text{hom}}(\alpha)$ holds for all $k > 0$.*

Case 2: *If $\alpha \in (\hat{\alpha}_{\text{het}}, 1]$, there exists threshold $k(\alpha) \in \left(0, \overline{k}_{\text{het}}(\alpha)\right)$ such that $V_{\text{het}}(\alpha) < V_{\text{hom}}(\alpha)$ for all $k < k(\alpha)$ and $V_{\text{het}}(\alpha) \geq V_{\text{hom}}(\alpha)$ for all $k \geq k(\alpha)$, with strict inequality if $k \in (k(\alpha), \overline{k}_{\text{hom}}(\alpha))$*

In Appendix, we prove this proposition through three steps (lemmas). First, suppose $\alpha \in (1/2, \alpha_{\text{het}}]$. It is obvious from the definitions of the owner's expected profits that $V_{\text{hom}}(\alpha, k) > V_{\text{het}}(\alpha, k)$ holds for *all* $k > 0$. If the additional information is so uninformative that DM is non-reactive under either organization, the owner's optimal choice is the homogenous organization *irrespective of IM's incentive to gather information.* The owner prefers the homogenous organization for two reasons: (i) IM is more likely to implement the project; and (ii) he is more likely to obtain additional information. These advantages of the homogenous organization originate from DM's non-reactive decision to choose IM's favorite project.

[19] For example, if $\tilde{c}$ is uniformly distributed over $[0, 1]$, $\hat{\Gamma} = \gamma^2$.

Second, suppose the additional information obtained by IM is sufficiently informative: $\alpha \in (\alpha_{\text{hom}}, 1]$. DM then becomes reactive under both organizations. The difference in the owner's expected profit between heterogenous and homogeneous organizations is given by

$$\begin{aligned}\Delta_V^{\mathrm{R}}(\alpha, k) &\equiv V_{\text{het}}^{\mathrm{R}}(\alpha, k) - V_{\text{hom}}^{\mathrm{R}}(\alpha, k) \\ &= \frac{1}{2}\Delta_\pi^{\mathrm{R}}(\alpha, k)\left[\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\right] \\ &\quad - \frac{1}{2}(1 - \pi_{\text{het}}^{\mathrm{R}}(\alpha, k))\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right],\end{aligned} \tag{2.9}$$

where $\Delta_\pi^{\mathrm{R}}(\alpha, k) \equiv \pi_{\text{het}}^{\mathrm{R}}(\alpha, k) - \pi_{\text{hom}}^{\mathrm{R}}(\alpha, k)$. To understand the difference, first consider a hypothetical situation in which under either organization DM obtained additional information with the same, exogenously given probability π. Then the first term of $\Delta_V^{\mathrm{R}}(\alpha, k)$ would become zero and hence $\Delta_V^{\mathrm{R}}(\alpha, k) < 0$ unless $\pi = 1$: *the owner strictly prefers the homogeneous organization* because IM with no additional information is then more likely to implement the project selected by DM (project 1) than under the heterogenous organization.

A main feature of our model is that information acquisition is endogenously determined by IM's effort. Proposition 1 tells us that the ignorance-avoiding effect provides IM with a stronger incentive to gather information under the heterogenous organization than under the homogeneous organization. That is, $\Delta_\pi^{\mathrm{R}}(\alpha, k) \geq 0$ holds for all $\alpha \in (\alpha_{\text{hom}}, 1]$ and $k > 0$, and the inequality is strict for (α, k) satisfying $\pi_{\text{hom}}^{\mathrm{R}}(\alpha, k) < 1$ (or equivalently, $k < \bar{k}_{\text{hom}}(\alpha)$). Furthermore, both $\pi_{\text{het}}^{\mathrm{R}}(\alpha, k)$ and $\Delta_\pi^{\mathrm{R}}(\alpha, k)$ are increasing in k. Hence there exists a threshold of k such that (a) if k is smaller than the threshold, the stronger information-gathering incentive from heterogeneity does not overturn the implementation advantage of homogeneity; and (b) if k is larger than the threshold, the stronger information-gathering incentive from heterogeneity benefits the owner so much that the heterogeneous organization is optimal.

The remaining case is $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$ in which while DM is reactive under heterogenous organization, she is non-reactive under homogeneous organization. The difference in the owner's expected profit is written as follows:

$$
\begin{aligned}
\Delta_V^{\text{RN}}(\alpha, k) \equiv\ & V_{\text{het}}^{\text{R}}(\alpha, k) - V_{\text{hom}}^{\text{N}}(\alpha, k) \\
=\ & \frac{1}{2}\pi_{\text{het}}^{\text{R}}(\alpha, k)\left[\alpha F(\alpha b_L) - (1-\alpha)F((1-\alpha)b_H) + F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \\
& - \frac{1}{2}\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \\
& + \frac{1}{2}\left[\pi_{\text{het}}^{\text{R}}(\alpha, k) - \pi_{\text{hom}}^{\text{N}}(\alpha, k)\right]\left[\alpha F(\alpha b_H) + (1-\alpha)F((1-\alpha)b_H) - F\left(\frac{b_H}{2}\right)\right]
\end{aligned}
\tag{2.10}
$$

Suppose first that the probability of obtaining additional information were exogenously given as π. If $\pi = 1$, then the last term is zero and hence which organization is optimal for the owner would be entirely determined by the sign of $\alpha F(\alpha b_L) - (1-\alpha)F((1-\alpha)b_H)$: the heterogenous organization has an advantage from DM's reactivity to signal $\sigma = 2$, while it has an disadvantage from IM's lower incentive to implement the unfavorite project under signal $\sigma = 1$. These effects cancel out at $\alpha = \hat{\alpha}$. Hence given $\pi = 1$, the owner would strictly prefer the heterogenous organization if $\alpha > \hat{\alpha}_{\text{het}} = \max\{\alpha_{\text{het}}, \hat{\alpha}\}$. If $\pi < 1$, however, the *homogeneous* organization is strictly preferred even at $\alpha = \hat{\alpha}_{\text{het}}$ because the reactivity advantage of the heterogenous organization is more than offset by the disadvantage due to its weaker implementation incentive under $\sigma = \phi$: the sum of the first two terms of (2.10) is negative.

Now return to our setting in which IM's information-gathering effort is endogenous and the heterogenous organization provides IM with stronger effort incentives. Then the fact that DM is non-reactive under the homogeneous organization for $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$ also affects IM's optimal information-gathering effort. This effect is captured in the first and third terms of (2.10), and they are strictly positive for $\alpha > \hat{\alpha}_{\text{het}}$. Since both $\pi_{\text{het}}^{\text{R}}(\alpha, k) - \pi_{\text{hom}}^{\text{N}}(\alpha, k)$ and $\pi_{\text{het}}^{\text{R}}(\alpha, k)$ are increasing in k, we can again show that there exists a threshold of k such that the heterogeneous organization is optimal if and only if k is equal to or above the threshold. This completes the intuitive explanation of Proposition 2.

Comparison with the related result of Landier et al. (2009) helps understand our result further. They show that the heterogeneous organization is strictly preferred by the owner to the homogenous organization if the informativeness of the signal satisfies $\alpha \in (\hat{\alpha}_{\text{het}}, \alpha_{\text{hom}})$, while the owner is indifferent between homogeneous and heterogenous organizations if the signal is sufficiently informative, that is, $\alpha \in [\alpha_{\text{hom}}, 1]$. In Landier et al. (2009), the additional information is always available ($\pi = 1$), and hence the advantage of the heterogenous organization is exclusively due to the fact that DM is more likely to react to additional information $\sigma = 2$ and select IM's favorite project 2.

Our result differs from theirs in two respects. First, in our model additional information is not always available ($\pi < 1$). As we have explained above, *this modification itself benefits the homogeneous organization* since IM without additional information is more motivated to implement his favorite project. As long as the probability of obtaining additional information is exogenously given, the homogenous organization is more likely to succeed than the heterogenous organization except for the extreme case of $\pi = 1$ where they are indifferent.

Our second, more fundamental extension is that IM engages in information-gathering activity and hence π is determined endogenously. The heterogenous organization can then have an additional advantage from IM's stronger incentive to acquire information via the ignorance-avoiding effect when the additional signal is sufficiently informative, as shown in (2.9). Furthermore, the reactivity advantage of the heterogenous organization may also amplify IM's information-gathering incentive, as shown in (2.10).

Note, however, that IM's stronger information-gathering incentive does not always result in the optimality of heterogenous organization. Proposition 2 in fact shows that if k is sufficiently small, the owner prefers the homogeneous organization *however informative* *the signal is.* And we show in Case 1 of Proposition 2 that if the informativeness of the signal is lower than α_{het}, the homogeneous organization is optimal for *all* $k > 0$.

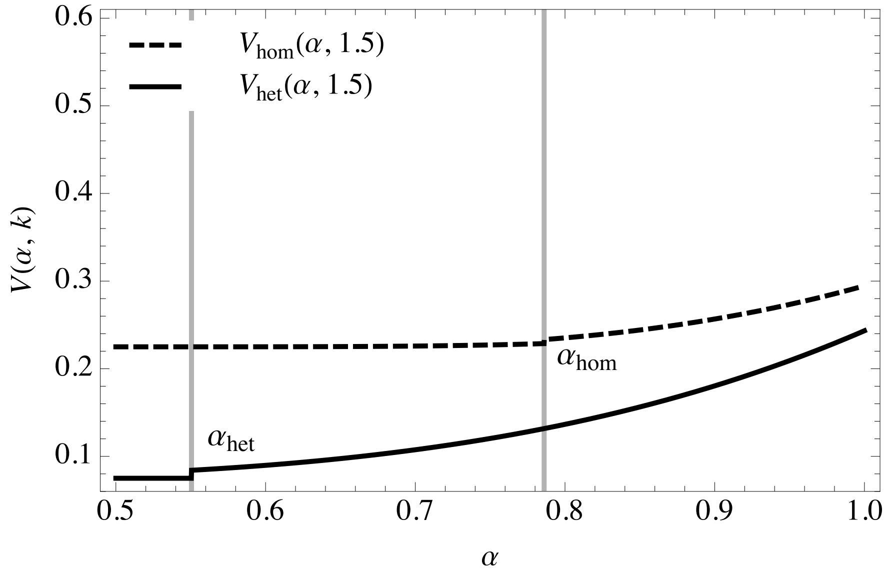
Based on Proposition 2, we can show that there exist two thresholds of k, *independent of* α, such that if k is below the smaller one of the thresholds, the homogeneous organization is optimal for *all* $\alpha \in (1/2, 1]$, while the heterogenous organization is optimal for *all* $\alpha \in (\hat{\alpha}_{\text{het}}, 1]$ if k is above the larger one.

Corollary 1. *Under Assumptions 1–3, there exist thresholds* $\underline{k}$ *and* $\overline{k}$ *satisfying* $0 < \underline{k} < \overline{k} < \overline{k}_{\text{het}}(\hat{\alpha}_{\text{het}})$*, such that the optimal organization for the owner is given as follows.*

(a) *If* $k < \underline{k}$*, then* $V_{\text{het}}(\alpha, k) < V_{\text{hom}}(\alpha, k)$ *holds for all* $\alpha \in (1/2, 1)$.

(b) *If* $k > \overline{k}$*, then* $V_{\text{het}}(\alpha, k) \geq V_{\text{hom}}(\alpha, k)$ *holds for all* $\alpha \in (\hat{\alpha}_{\text{het}}, 1]$*. The inequality is strict if* $k \in (\overline{k}, \overline{k}_{\text{hom}}(\alpha))$.

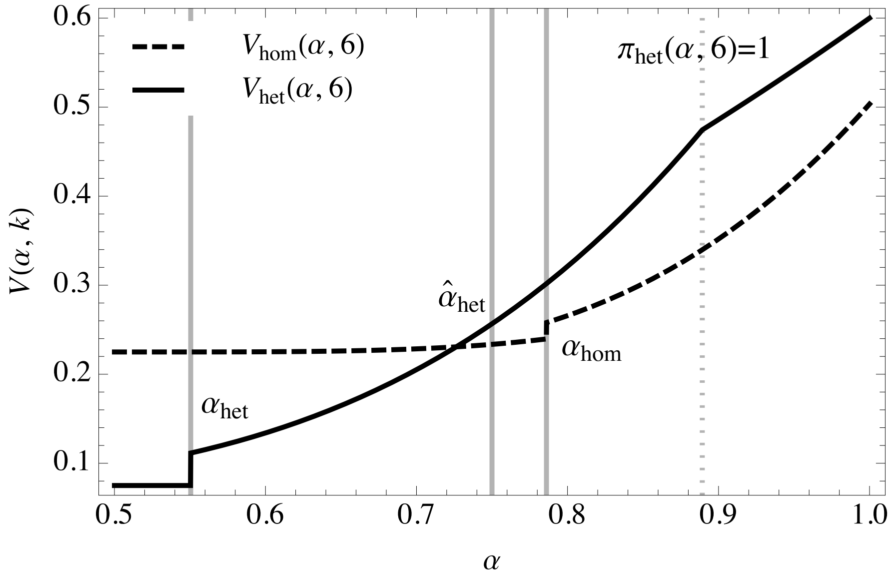
Figure 2.2.: The Optimal Organization ($\Gamma < \hat{\Gamma}$, $k < \underline{k}$)



In the figure, we assume $\tilde{c}$ is uniformly distributed over $[0, 1]$, $b_L = B_L = 0.3$, $b_H = 0.9$, and $B_H = 1.35$. The cost parameter is set to $k = 1.5$.

Figure 2.2 depicts Corollary 1 (a), and Figures 2.3 and 2.4 depict Corollary 1 (b). The solid curve represents $V_{\text{het}}(\alpha, k)$ and the dashed curve $V_{\text{hom}}(\alpha, k)$. The parameter values

Figure 2.3.: The Optimal Organization ($\Gamma < \hat{\Gamma}$, $k > \overline{k}$)



In the figure, we assume $\tilde{c}$ is uniformly distributed over $[0, 1]$, $b_L = B_L = 0.3$, $b_H = 0.9$, and $B_H = 1.35$. The cost parameter is set to $k = 6$.

are the same as those in Figure 2.1, except k (Figure 2.2) and B_H (Figure 2.4). In Figure 2.2, $k = 1.5 < \underline{k} \approx 2.2$, and thus the owner prefers the homogenous organization for all $\alpha \in (1/2, 1)$. In Figure 2.3, $k = 6 > \overline{k} \approx 5.2$ and $k = 6 < \overline{k}_{\text{hom}}(\alpha)$ for all $\alpha \in (\hat{\alpha}_{\text{het}}, 1]$. In Figure 2.4, B_H is changed to $B_H = 6.6$ and hence $\Gamma = 22$. Then $\hat{\alpha}_{\text{het}} = \alpha_{\text{het}}$ holds. Since $k = 6 > \overline{k} \approx 5.85$, the heterogenous organization is *strictly* preferred to the homogeneous organization for all $\alpha \in (\alpha_{\text{het}}, 1]$.

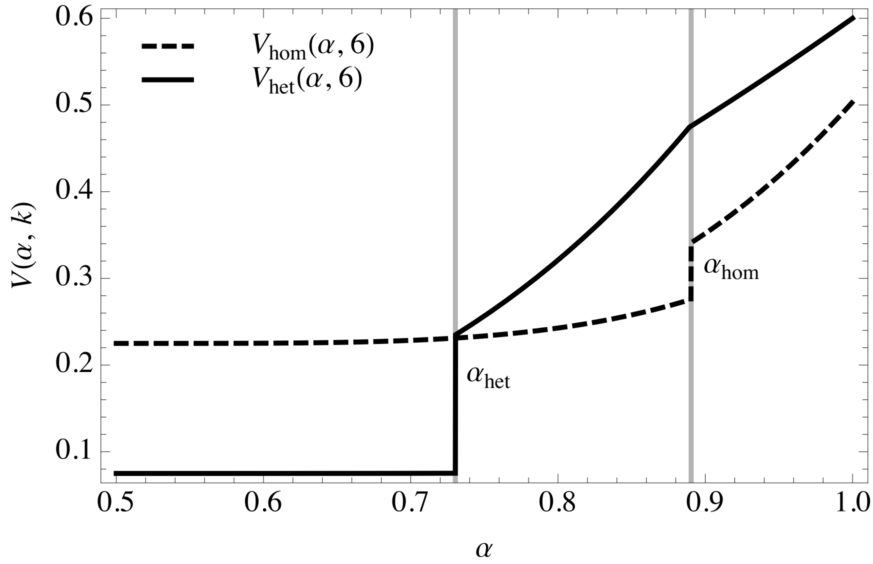
2.3.5. Complementarities

The analysis of the optimal organization in the previous subsection suggests that the heterogenous organization is more likely to be optimal as *both* α and k are sufficiently high. In fact, we can show the following result.

Proposition 3. *Suppose Assumptions 1–3 are satisfied.*

(a) $V_{\text{hom}}(\alpha, k)$ *exhibits increasing differences in* (α, k) *if* $\alpha > \max\{\alpha_{\text{het}}, \alpha_\gamma\}$.

Figure 2.4.: The Optimal Organization ($\Gamma > \hat{\Gamma}$, $k > \overline{k}$)



In the figure, we assume $\tilde{c}$ is uniformly distributed over $[0, 1]$, $b_L = B_L = 0.3$, $b_H = 0.9$, and $B_H = 6.6$. The cost parameter is set to $k = 6$.

(b) $V_{\text{het}}(\alpha, k)$ *exhibits increasing differences in* (α, k).

(c) $V_{\text{het}}(\alpha, k) - V_{\text{hom}}(\alpha, k)$ *is increasing in* (α, k) *if* $\alpha > \alpha_{\text{het}}$ *and* $k < \overline{k}^{\text{R}}_{\text{het}}(\alpha)$.

Proposition 3 (a) and (b) imply that under either organization, decreasing IM's marginal cost of information acquisition (e.g., investing more in IT, granting IM more discretion over his time use, and so on) improves the performance of the organization more as additional signal is more informative (e.g., more training in human capital, higher knowledge in relevant technology and environments, and so on). These results are consistent with existing empirical evidence (Ennen and Richter, 2010; Baker and Gil, 2012).

Furthermore, Proposition 3 (c) shows that, as we suggested in the previous subsection, the lower IM's marginal cost is or/and the more informative the signal is, the more performance improvement a change from homogeneous to heterogenous organization brings about. We are currently unaware of any empirical analysis studying the relationship between preference diversity in organizations and other organizational practices. Our analysis contributes to the empirical literature on complementarities by offering new testable predictions.

2.4. Discussions

In this section we discuss our results by modifying some of our settings and assumptions. The formal analysis is relegated to Online Appendix.[20] In Subsection A2 we argue that if Assumption 1 does not hold, the heterogenous organization no longer enjoys its main advantage that IM is more motivated to gather additional information. In particular, if Assumption 2 fails to hold as well (e.g., $\tilde{c}$ is uniformly distributed), IM's optimal effort under heterogenous organization is *never* higher than that under homogeneous organization.

In Subsection A2, we modify the decision process such that it is DM who exerts a information-gathering effort, before choosing a project. Then we argue that the relative advantage of the heterogenous organization over the homogeneous organization in terms of information acquisition is smaller than when IM engages in gathering additional information. In particular, if $\tilde{c}$ is uniformly distributed and DM's bias is sufficiently large, IM's optimal effort under homogeneous organization is higher than that under heterogeneous organization. This suggests that preference diversity is more likely to enjoy information acquisition and benefits the organization if the agent who implements the decision also engages in gathering information.

2.4.1. Less Biased Decision Maker

In the main analysis we makes Assumption 1 that implies DM's bias is sufficiently high and hence without additional information DM's optimal project choice is her favorite project 1 under heterogenous organization. We further adpot Assumption 2

[20]It is available at (https://sites.google.com/site/kimiyukimorita/home/online-appendix-itoh-morita).

that states directly that DM's bias is equal to or higher than IM's bias. In this subsection, we instead assume neither Assumption 1 nor Assumption 2 holds: $\Gamma < \min\{F(b_H/2)/F(b_L/2), \gamma\}$.[21] Under this alternative assumption, DM's optimal project choice and IM's optimal information-gathering effort under the homogeneous organization are the same as those in the previous section, and hence we focus on the heterogenous organization.

Since IM is relatively more biased, DM, observing $\sigma = \phi$, chooses IM's favorite project 2 in order to boost his implementation motive. Furthermore, if the informativeness of the signal α is not sufficiently high, DM chooses project 2 even after observing $\sigma = 1$. We can show there exists $\breve{\alpha}_{\text{het}} \in (1/2, \alpha_{\text{hom}})$ such that DM's optimal choice after observing $\sigma = 1$ is project 2 if $\alpha < \breve{\alpha}_{\text{het}}$, and project 1 if $\alpha \geq \breve{\alpha}_{\text{het}}$. If $\sigma = 2$, DM always reacts and chooses project 2 since it is more likely to be implemented and succeed.

The optimal project choice is thus summarized as follows. If no additional information is available, DM chooses project 1 under homogeneous organization and *project 2 under heterogenous organization.* If the informativeness of the additional signal is low ($\alpha < \breve{\alpha}_{\text{het}}$), DM is non-reactive under either organization and chooses project 1 under homogeneous organization and *project 2 under heterogenous organization.* If the informativeness is intermediate ($\breve{\alpha}_{\text{het}} \leq \alpha \leq \alpha_{\text{hom}}$), DM is again non-reactive under homogeneous organization. Under heterogenous organization, she is reactive. Finally, if the informativeness is sufficiently high ($\alpha > \alpha_{\text{hom}}$), DM is reactive under either organization.

Now consider IM's information-gathering effort under heterogenous organization. Since IM can implement his favorite project even without additional information, there is no longer the ignorance-avoiding effect and IM's incentive to acquire information is attenuated relative to that in the previous analysis. In fact, we can show that *IM's optimal effort under heterogenous organization is never higher than that under homogeneous organization.* Specifically, the optimal information-gathering effort is equal between two

[21] In Online Appendix we also study the case in which Assumption 1 does not hold but Assumption 2 is satisfied.

organizations when DM is either non-reactive under both organizations or reactive under both. And when DM is reactive only under heterogenous organization, IM's optimal effort is *lower* under heterogenous organization. Intuitively, while DM chooses a project less successful but favorite to IM under homogeneous organization and $\sigma = 2$, she chooses a project more successful but unfavorite to IM under heterogenous organization and $\sigma = 1$. Since IM's bias is high, the fact that his unfavorite project may be chosen works crucially against his incentive to gather additional information under heterogenous organization.

2.4.2. Information Acquisition by the Decision Maker

Our results in the previous section show that the heterogenous organization benefits the owner mainly because additional information is more likely to acquired. We argue that an important reason for this benefit from preference diversity to realize is that it is IM who engages in gathering information. To this purpose, we instead assume DM chooses a costly effort to gather additional information before choosing a project. Note that IM's implementation decision and DM's project choice are not affected by this modification.

If $\tilde{c}$ is uniformly distributed and DM's bias is sufficiently large, IM's optimal effort under homogeneous organization is *always higher* than that under heterogeneous organization.[22] The main reason DM's incentive for information acquisition is undermined under heterogenous organization is that the signal good for her favorite project ($\sigma = 1$) is bad for IM's implementation incentive (his unfavorite project will be implemented) and hence results in the probability of implementation lower than signal $\sigma = 2$. This misalignment does not arise under homogeneous organization where IM's favorite project will be implemented under signal $\sigma = 1$. And if it is IM who engages in information acquisition as in our previous analysis, this misalignment results not under heterogeneous

[22] In Online Appendix, we also shows that the same conclusion holds if the general distribution satisfies a certain condition and DM's bias is sufficiently large.

organization but under homogeneous organization.

2.5. Information Manipulation

So far we have analyze the model by assuming that signal σ is observable to both DM and IM. In this section, we assume that the signal is IM's private information and examine whether or not IM reports it truthfully. We denote IM's reported message by $\tilde{\sigma}$. We further assume that signal σ is *soft information*, so that for each signal $\sigma \in \{\phi, 1, 2\}$, IM can report any element of $\{\phi, 1, 2\}$.[23]

Our main concern is whether or not there is an equilibrium in which IM reports the signal truthfully. We call such an equilibrium a *full communication equilibrium*: In a full communication equilibrium, IM reports $\tilde{\sigma} = \sigma$ for all $\sigma \in \{\phi, 1, 2\}$, and DM chooses an optimal project $d_h^*(\sigma)$ for $\sigma \in \{\phi, 1, 2\}$, where $h \in \{\text{hom}, \text{het}\}$. If a full communication equilibrium exists, our results under the assumption of symmetric information do not change.

Note that if DM is non-reactive, IM has obviously no incentive to manipulate information and hence a full communication equilibrium exists under either organization. Our analysis below thus focuses mostly on the case in which DM is reactive.

First, consider the homogeneous organization and suppose DM is reactive ($\alpha > \alpha_{\text{hom}}$). Since IM's favorite project is 1, he has no incentive to deviate from truthful revelation when $\sigma \in \{\phi, 1\}$. If $\sigma = 2$, IM can report $\tilde{\sigma} \in \{\phi, 1\}$ so as to induce DM to choose the favorite project 1. IM reports truthfully ($\tilde{\sigma} = \sigma = 2$) if

$$\alpha F(\alpha b_L) b_L > (1 - \alpha) F((1 - \alpha) b_H) b_H \tag{2.11}$$

holds, which is equivalent to $\alpha > \alpha_\gamma$. This condition is satisfied under Assumption

[23] If signal σ is *hard information*, that is, if IM can conceal the evidence of the signal but cannot make up false evidence ($\tilde{\sigma} \in \{\sigma, \phi\}$), it is easy to show that under either organization, truth-telling is a best response to DM's optimal project choice given DM's belief that IM reports the true signal. Hence our previous analysis applies.

2 since $\alpha_\gamma \leq \alpha_{\text{hom}}$ holds. Therefore, a full communication equilibrium exists for all $\alpha \in (1/2, 1)$ under the homogeneous organization.

Next, consider the heterogenous organization. We show that it is optimal for IM to report the signal truthfully only if either (i) DM is non-reactive or (ii) DM is reactive but the signal is so informative and the marginal cost of information acquisition is so low that $\pi^{\text{R}}_{\text{het}}(\alpha, k) = \pi^{\text{R}}_{\text{hom}}(\alpha, k) = 1$ holds. A full communication equilibrium fails to exist if DM is reactive ($\alpha > \alpha_{\text{het}}$) but the signal is not sufficiently informative ($\alpha \leq \alpha_\gamma$) or IM's optimal information-gathering effort is less than one.

Suppose that $\alpha > \alpha_{\text{het}}$, and DM expects IM to choose π and report truthfully. Since IM's favorite project is 2, he chooses to report truthfully when $\sigma = 2$ is observed. If IM observes $\sigma = 1$, he does not deviate from reporting truthfully if $\alpha > \alpha_\gamma$ holds, for the same reason as IM, if he favored project 1 and observed $\sigma = 2$, would report truthfully.

When IM observes $\sigma = \phi$, reporting honestly leads DM to choose IM's unfavorite project 1. His expected benefit is $(1/2)F(b_L/2)b_L$. If he instead reports $\tilde{\sigma} = 2$, DM chooses his favorite project 2 and his expected benefit is $(1/2)F(b_H/2)b_H$. IM thus prefers to deviate from truthful revelation. Hence for a full communication equilibrium to exist, $\sigma = \phi$ cannot occur with a positive probability. In other words, IM's optimal effort choice must be $\pi = \pi^{\text{R}}_{\text{het}}(\alpha, k) = 1$. This is equivalent to $k \geq \bar{k}^{\text{R}}_{\text{het}}(\alpha)$.

Furthermore, $\pi^{\text{R}}_{\text{hom}}(\alpha, k) = 1$ must hold as well; otherwise, IM would prefer to deviate to some $\pi < 1$. To see this, suppose IM deviates from $\pi^{\text{R}}_{\text{het}}(\alpha, k) = 1$ to some $\pi < 1$. Then the best he can do, after obtaining $\sigma = \phi$, is to report $\tilde{\sigma} = 2$ to induce DM to choose his favorite project 2. He does not deviate to π if

$$\frac{1}{2}\left[K(\alpha b_L) + K(\alpha b_H)\right] - \eta(1; k) \geq \frac{\pi}{2}\left[K(\alpha b_L) + K(\alpha b_H)\right] + (1-\pi)K\left(\frac{b_H}{2}\right) - \eta(\pi; k)$$

for all π. Since the right-hand side is maximized at $\pi = \pi^{\text{R}}_{\text{hom}}(\alpha, k)$, the existence of full communication equilibrium requires $\pi^{\text{R}}_{\text{hom}}(\alpha, k) = 1$. This is equivalent to $k \geq \bar{k}^{\text{R}}_{\text{hom}}(\alpha)$.

Since $\overline{k}^{\mathrm{R}}_{\mathrm{hom}}(\alpha) > \overline{k}^{\mathrm{R}}_{\mathrm{het}}(\alpha)$ holds, the discussion given above concerning the existence of full communication equilibrium can be summarized as follows.

Proposition 4. *Suppose signal σ is IM's private and soft information, and Assumptions 1–3 hold. Then* (a) *under the homogeneous organization, there exists a full communication equilibrium for all $\alpha \in (1/2, 1)$ and $k > 0$; and* (b) *under the heterogeneous organization, a full communication equilibrium exists if and only if either* (i) *DM is non-reactive ($\alpha \leq \alpha_{\mathrm{het}}$), or* (ii) *$\alpha > \tilde{\alpha}_{\mathrm{het}} \equiv \max\{\alpha_{\mathrm{het}}, \alpha_\gamma\}$ and $k \geq \overline{k}^{\mathrm{R}}_{\mathrm{hom}}(\alpha)$ hold.*

Partial Communication Equilibrium

When no full communication equilibrium exists under the heterogenous organization with reactive DM, we consider the following *partial communication equilibrium*:

- IM reports $\tilde{\sigma} = 1$ when he observes $\sigma = 1$.
- IM reports $\tilde{\sigma} = 2$ when he observes $\sigma \in \{\phi, 2\}$.
- DM chooses $d^*_{\mathrm{het}}(\tilde{\sigma}) = \tilde{\sigma}$ for $\tilde{\sigma} \in \{1, 2\}$.
- DM chooses $d^*_{\mathrm{het}}(\phi) = 1$ with some consistent off-the-equilibrium beliefs.

We obtain conditions for each of IM and DM not to deviate from the specified strategies under the heterogeneous organization. The following proposition summarizes the conditions.[24]

Proposition 5. *Suppose signal σ is IM's private and soft information, and Assumptions 1–3 hold. A partial communication equilibrium exists under the heterogenous organization if and only if either* (i) *DM is non-reactive ($\alpha \leq \alpha_{\mathrm{het}}$) or* (ii) *$\alpha > \tilde{\alpha}_{\mathrm{het}}$, $k < \overline{k}^{\mathrm{R}}_{\mathrm{hom}}(\alpha)$, and $\Gamma < \tilde{\Gamma}(\alpha, k)$ hold, where $\tilde{\Gamma}(\alpha, k) > 1$ is an upper bound of DM's bias Γ and is increasing in α and k.*

[24]Note that if $k \geq \overline{k}^{\mathrm{R}}_{\mathrm{hom}}(\alpha)$, then IM never observes $\sigma = \phi$. The partial communication equilibrium specified above is then identical to the full communication equilibrium. In the proof, we show that if $k \geq \overline{k}^{\mathrm{R}}_{\mathrm{hom}}(\alpha)$, the condition on Γ is always satisfied for $\alpha > \tilde{\alpha}_{\mathrm{het}}$

A partial communication equilibrium does not exist if DM's bias is so high that it is optimal for her to choose her favorite project 1 even after receiving IM's report $\tilde{\sigma} = 2$. This condition determines the upper bound $\tilde{\Gamma}(\alpha, k)$. It also fails to exist if $\alpha \in (\alpha_{\text{het}}, \alpha_\gamma]$, since the informativeness of additional information is so low that IM prefers to report $\tilde{\sigma} = 2$ when project 1 is more likely to succeed. Thus if α_γ is above α_{het} (and hence $\tilde{\alpha}_{\text{het}} = \alpha_\gamma$), there is a range of informativeness $(\alpha_{\text{het}}, \alpha_\gamma]$ in which neither full nor partial communication equilibrium exists under the heterogenous organization, despite its reactivity advantage.[25] Then only a "babbling equilibrium" exists in which IM sends a same report irrespective of the signal, and hence DM simply chooses her favorite project 1. DM is hence non-reactive for $\alpha \in (\alpha_{\text{het}}, \alpha_\gamma]$ under the heterogenous organization. Note, however, that as we have explained before, IM still has an incentive to choose a positive effort $\pi^{\text{N}}_{\text{het}}(\alpha, k) > 0$ in this region.

Comparison

To compare between homogeneous and heterogenous organizations, we focus on most informative equilibrium, which is the full communication equilibrium for all $\alpha \in (1/2, 1)$ under homogenous organization. Under heterogenous organization, DM is non-reactive for $\alpha \leq \tilde{\alpha}_{\text{het}}$, and hence whether communication is full or partial or uninformative does not matter. For $\alpha > \tilde{\alpha}_{\text{het}}$, we assume $\Gamma < \tilde{\Gamma}(\alpha, k)$ and consider the partial communication equilibrium. Then IM's optimal information-gathering effort under the heterogeneous organization becomes as follows.

$$\tilde{\pi}_{\text{het}}(\alpha, k) = \begin{cases} \pi^{\text{N}}_{\text{het}}(\alpha, k) & \text{if } \alpha \in (1/2, \tilde{\alpha}_{\text{het}}] \\ \pi^{\text{R}}_{\text{hom}}(\alpha, k) & \text{if } \alpha \in (\tilde{\alpha}_{\text{het}}, 1] \end{cases}$$

[25]By (2.6), $\alpha_\gamma > \alpha_{\text{het}}$ is equivalent to $\Gamma < \Gamma_\gamma$, and it is easy to show $\Gamma_\gamma > \tilde{\Gamma}(\alpha_\gamma, k)$. Hence $\alpha_\gamma > \alpha_{\text{het}}$ and $\Gamma < \tilde{\Gamma}(\alpha_\gamma, k)$ are compatible.

By comparing with the optimal effort under heterogenous organization with symmetric information reported in Proposition 1, we find IM's incentive to acquire information under heterogeneous organization is weaker under asymmetric information than under symmetric information for two reasons. First, since $\tilde{\alpha}_{\text{het}} \geq \alpha_{\text{het}}$, IM's incentive to implement his favorite project by misreporting $\sigma = 1$ may enlarge the range of α in which DM acts non-reactively under heterogenous organization (Case 1). Second, the ignorance-avoiding effect no longer exists, and hence $\tilde{\pi}_{\text{het}}(\alpha, k) = \pi^{\text{R}}_{\text{hom}}(\alpha, k) < \pi^{\text{R}}_{\text{het}}(\alpha, k)$ for $\alpha > \tilde{\alpha}_{\text{het}}$.

The comparison of IM's incentive to acquire information under two organizations also changes for these two reasons, as reported in Proposition 6 below. We focus on the case in which $\tilde{\alpha}_{\text{het}} = \alpha_\gamma > \alpha_{\text{het}}$ (equivalently $\Gamma < \Gamma_\gamma$)[26] and thus assume $\Gamma \leq \tilde{\Gamma}(\alpha_\gamma, k)$.

Proposition 6. *Suppose signal σ is IM's private and soft information, and $\Gamma \leq \tilde{\Gamma}(\alpha_\gamma, k)$ as well as Assumptions 1–3 holds. IM's optimal information-gathering effort differs as follows.*

Case 1: *If $\alpha \in (1/2, \alpha_\gamma]$, then $\pi_{\text{hom}}(\alpha, k) \geq \tilde{\pi}_{\text{het}}(\alpha, k)$ holds. The inequality is strict if $k < \overline{k}^{\text{N}}_{\text{het}}(\alpha)$: IM is more likely to obtain information under the homogeneous organization than under the heterogeneous organization.*

Case 2: *If $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$, then $\pi_{\text{hom}}(\alpha, k) \leq \tilde{\pi}_{\text{het}}(\alpha, k)$ holds. The inequality is strict if $k < \overline{k}^{\text{N}}_{\text{hom}}(\alpha)$: IM is more likely to obtain information under the heterogeneous organization than under the homogeneous organization.*

Case 3: *If $\alpha \in (\alpha_{\text{hom}}, 1]$, then $\pi_{\text{hom}}(\alpha, k) = \tilde{\pi}_{\text{het}}(\alpha, k)$ holds.*

The immediate consequence from the fact that the ignorance-avoiding effect no longer exists is that if the signal is sufficiently important (Case 3), there is no difference in

[26] If instead $\alpha_{\text{het}} > \alpha_\gamma$, then both $\Gamma > \Gamma_\gamma$ and $\Gamma < \tilde{\Gamma}(\alpha, k)$ must be satisfied. Such a Γ does not always exist, however, for $\alpha > \alpha_{\text{het}}$ since $\tilde{\Gamma}(\alpha_{\text{het}}, k) = F(b_H/2)/F(b_L/2) < \Gamma_\gamma$. In this case, we need an additional assumption on the region of α to guarantee that the two conditions are satisfied.

IM's optimal effort between two organizations. The advantage of the heterogenous organization in terms of IM's effort incentive survives, however, when DM is not reactive under the homogeneous organization but reactive under the heterogenous organization (Case 2): This difference in reactivity in turn affects IM's optimal information-gathering effort. Remember that the difference in the marginal benefit from acquiring information consisted of three effects in (2.5). Although there is no ignorance-avoiding effect, the other two effects are still at work. And as we have explained, the sum of the latter two effects is positive for $\alpha > \alpha_\gamma$ as in Case 2.

We finally compare the owner's expected profit between homogeneous and heterogenous organizations. The expected profit to the owner under the heterogenous organization is equal to

$$\tilde{V}_{\text{het}}(\alpha, k) = \begin{cases} V^{\text{N}}_{\text{het}}(\alpha, k) & \text{if } \alpha \in (1/2, \tilde{\alpha}_{\text{het}}] \\ V^{\text{R}}_{\text{hom}}(\alpha, k) & \text{if } \alpha \in (\tilde{\alpha}_{\text{het}}, 1]. \end{cases}$$

We then obtain the following result.

Proposition 7. *Suppose signal σ is IM's private and soft information, and $\Gamma \leq \tilde{\Gamma}(\alpha_\gamma, k)$ as well as Assumptions 1–3 holds. Then the optimal organization for the owner is given as follows.*

(a) If $\alpha \in (1/2, \alpha_\gamma]$, then $\tilde{V}_{\text{het}}(\alpha, k) < V_{\text{hom}}(\alpha, k)$ holds for all $k > 0$.

(b) If $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$, then $\tilde{V}_{\text{het}}(\alpha, k) > V_{\text{hom}}(\alpha, k)$ holds for all $k > 0$.

(c) If $\alpha \in (\alpha_{\text{hom}}, 1]$, then $\tilde{V}_{\text{het}}(\alpha, k) = V_{\text{hom}}(\alpha, k)$ holds for all $k > 0$.

The possibility of IM's manipulation of his private information generally hurts the heterogeneous organization. First, DM becomes non-reactive for $\alpha \in (\alpha_{\text{het}}, \alpha_\gamma]$ where additional information were important enough to make her reactive in the case of symmetric information. Hence the homogenous organization is more likely to be optimal when the informativeness of the signal is low (Proposition 7 (a)). Second, IM's incentive to gather information is weaker, due to the lack of the ignorance-avoiding effect, and hence the owner never strictly prefers the heterogenous organization even though both α and k are very high (Proposition 7 (c)).

However, the lack of the ignorance-avoiding effect can benefit the heterogenous organization *when k is small*. IM can induce DM to choose his favorite project 2 under no additional information, and hence he is more likely to implement the project than when information is symmetric and DM chooses project 1 under no additional information. This new positive effect eliminates the advantage of homogeneous organization under $k < k(\alpha)$, and hence the heterogenous organization is strictly preferred to the homogeneous organization for *all* $k > 0$ when the informativeness of the signal is intermediate, as in Case (b). Note that this result favoring heterogenous organization under information manipulation is in part due to an artifact of our assumption that the owner is indifferent between two projects under no additional information.

The vulnerability of heterogenous organization to the manipulation of soft information is in contrast to the result of Landier et al. (2009). In their model, it is DM who always observes an informative signal privately without any cost. DM's project choice thus serves as a costly signaling device and the heterogeneous organization makes the project choice more informative about the true state. Hence private information benefits heterogenous organization. In our model, it is IM who chooses costly information-acquisition effort and is privately known about the signal. Then heterogenous organization is less beneficial to the owner under private information than under symmetric information because the possibility of information manipulation by IM attenuates his effort incentive to gather additional information.

2.6. Concluding Remarks

We have analyzed a decision process of two-member organization with two main features that are studied separately in existing literature: (a) separation of project choice by a decision maker and costly implementation by an implementer; and (b) costly information acquisition by the implementer. We have shown that when additional information is symmetrically observed, preference diversity between the decision maker and the implementer can be optimal because (i) the decision maker is more likely to react to additional information (ii) the implementer is also more motivated to acquire information to avoid being uninformative of the true state, and (iii) the reactivity advantage may reinforce the implementer's incentive to gather information. If additional information is the implementer's private and soft information, the second advantage due to the "ignorance-avoiding" effect no longer exists, and hence preference diversity is in general less likely to be optimal than under the symmetrically informed case.

A testable hypothesis obtained from our analysis is that choice of organization with preference diversity tends to be observed together with training in human capital, use of information technology, and information sharing or "transparency" of organizations, in particular, when information acquisition by lower-tier members is crucially important for decision making. Whether or not there is diversity in preferences among members, organizational investments in information acquisition such as information technology and human knowledge are obviously important. However, our analysis reveals that such investments are more important for organizations with preference diversity. Furthermore, only the performance of the heterogenous organization improves by making additional soft information symmetrically observed rather than privately known by implementers.

Our results in fact imply that these organizational practices exhibit complementarities. While there is ample evidence of complementarities (Ennen and Richter, 2010; Baker and Gil, 2012), in particular, between information technology usage and human skills (see Bresnahan et al., 2002, among others), and between skills training and information sharing (see Ichniowski et al., 1997, among others), we are unaware of any empirical research studying complementarities among organizational elements including preference diversity, partly because of various difficulties defining and measuring diversity (Harrison and Klein, 2007). We hope our theoretical results will contribute to our further understandings of organizational complementarity by stimulating future empirical research.

Chapter 3.

Optimal Contracts for Human Capital Acquisition and Organizational Beliefs

3.1. Introduction

It is well documented that human capital acquisition is a primary task in organizations. If workers improve their ability levels, it will be beneficial to organizations. However, the extent to which the acquisition will increase ability levels is generally uncertain and we tend to have preconceived notions about our learnability. Our belief regarding learnability has strong impact on our decision makings and incentives; for example, if ability is considered to be exogenously given, people are less likely to have incentives to learn and acquire human capital. There is lack of the economics analysis on such a belief, although psychologists have been examining effects of that belief.

Experimental evidence from the field of psychology shows the importance of a person's belief on the malleability of, for example, abilities and personalities. Psychologists refer to such a belief as a mindset and they classify it into two categories, namely a *fixed* mindset, and a *growth* mindset. For example, a person who has a fixed mindset considers an ability to be a fixed trait, whereas a person who has a growth mindset considers an ability to be a malleable trait. After conducting numerous experiments, psychologists have found that people's decision-makings differ by the category. In particular, psychological evidence suggests that people's views on the malleability of their abilities play an important role when they fail. A failure reveals inadequacies of the ability, and individuals with a fixed mindset tend to feel helpless but those who are able to recover from it are considered to have a growth mindset. Thus, an individual who has a growth mindset is more resilient to failure than those who have a fixed mindset. I review related psychological evidence in Section 3.1.2.

Industry practitioners have also emphasized the importance of a person's mindset. For example, Google aims to hire people with a growth mindset, who they refer to as "learning animals." Eric Schmidt, ex-CEO of Google, and Jonathan Rosenberg, an adviser to Google CEO Larry Page write as follows:[1]

> "We know plenty of very bright people who, when faced with the roller coaster of change, will choose the familiar spinning-teacups ride instead. They would rather avoid all those gut-wrenching lurches; in other words, reality. [...] Our ideal candidates are the ones who prefers roller coasters, the one who keep learning. These 'learning animals' have the smarts to handle massive change and the character to love it. Psychologist Carol Dweck has another term for it. She calls it a 'growth mindset'."

A person's mindset is a *non-cognitive* skill, a concept gaining much attention in economics and psychology. According to Heckman and Rubinstein (2001), non-cognitive skill is a trait that cannot be captured by a standard assessment of cognitive skills(e.g., IQ) and knowledge, for example, self-control is a non-cognitive skill. Several empirical studies in economics provide a comprehensive review, for example, Heckman and Rubinstein (2001); Heckman et al. (2006, 2013) and Borghans et al. (2008). These studies confirm that cognitive skills as well as non-cognitive skills are required to achieve good outcomes in schools, labor markets, and life. West et al. (2014) whose study is closely

[1] Schmidt et al. (2014, p.102).

related to the present study, tests the relationship between four non-cognitive skills— conscientiousness, self-control, grit, and growth mindset— and examines their impact on school achievement. Using test scores for math and English, they show that a growth mindset is most strongly related to school achievements.

Among the mindsets regarding various traits, this study focuses on analyzing the mindset regarding ability, or as I call it, *learnability*. With this study, I aim to demonstrate the incentive effects of beliefs regarding learnability, particularly when there is uncertainty in an agent's ability level and he acquires an opportunity to develop his ability.

To study, I consider a dynamic moral hazard model in which a principal(female[2]) hires an agent(male) for two periods. Both the principal and the agent are risk neutral and I impose the limited liability constraint. The agent exerts effort to undertake an identical project in each period. A project's outcome depends on both the agent's effort and his ability: the success probability of a project is increasing in the agent's effort and it succeeds if his ability level is greater than that required for the project' success. In the second period, the agent obtains valuable information for an ability development but only after exerting effort in the first period[3], and can develop his ability level. For example, if a firm introduces a new technology or product in a production plant, then it is natural that the firm will develop prototype products[4] and thus, there must be potentially much learning opportunity. I can interpret the outcome of the project represents whether or not the product is deficient. If the agent has sufficient ability to produce a product, the product will have no deficiency.

A key feature of the model is that the principal and the agent openly agree to disagree and have differing prior beliefs regarding learnability. The principal and the agent have differing priors even though they have no private information. If each party meets those

[2]In this study, I assume the principal is a female, and the agent is a male only for the identification purpose.
[3]In Section 3.5.2, I obtain the same result without this assumption.
[4]Levitt et al. (2013) investigates the learning process in a major auto producer's assembly plant.

who has differing prior beliefs, he or she does not update his or her belief. In the related literature, it is standard to adopt this assumption to study an agent's biased belief[5].

As a benchmark case, I consider a corresponding one-shot model. If there are uncertainty in the agent's ability level and the learning opportunity in a static model, the expected implementation cost is decreasing in the agent's belief regarding learnability, and hence the principal's expected profit is increasing in the agent's belief. This is a well-known result. Intuitively, if the agent has an upward biased belief, then it will easy to induce him to work.

In the two-period model, I consider a possibility of renegotiation, that is, the principal has an opportunity of a renegotiation in the beginning of the second period. I assume that the principal can not commit not to renegotiate. In this complete contracting setting, I can restrict my attention to the renegotiation-proof contract. By restricting the contract design, I can focus on the incentive effect of the belief regarding learnability.

As a main result, I found that the agent's upward bias has a counterproductive effect on the implementation cost. Since after success, both the principal and the agent know that the agent's ability level is greater than that required, the expected payment after success does not depend on the agent's belief regarding learnability. However, after failure, there is still uncertainty in the agent's ability level, and thus, the agent has the incentive to develop his ability. The agent with an upward biased belief is more likely to work because such an agent highly evaluates the effect of the ability development. Thus, the expected payment after failure is decreasing in the agent's belief as in the benchmark case. I call this *the positive incentive effect* of the belief regarding learnability. However, in the first period, the expected payment is increasing in the agent's belief. Since there is the positive incentive effect after failure, the principal exploits it by lowering wages. Thus, the agent's expected rent after failure is decreasing in his belief. The expected rent in the second period affects the agent's incentive to work in the first period. Hence,

[5] For example, see Kim (2015).

the agent's belief regarding learnability hurts the work incentive in the first period. I call this *the counterproductive effect* of the agent's belief. This is a novel result. I show that the principal's belief regarding learnability determines which effect dominates.

In the main analysis, I adopt the differing prior assumption. If instead they share a common prior belief on learnability, the results will change. Under the common prior assumption, the expected payment is always increasing in the belief regarding learnability. While after failure, the positive incentive effect still exists, the probability that the wage is paid is increasing in the belief and this effect dominates the positive incentive effect. Under the differing prior assumption, the principal's perceived probability that the wage is paid is not tied with the agent's belief. Under the common prior assumption, their beliefs are not separated and the increase in the belief regarding learnability raises the expected payment. However, the principal prefers higher belief regarding learnability if the profit that she earns from project's success is sufficiently high. As mentioned, under the common prior assumption, the success probability increases if the belief increases. Hence, if the profit is sufficiently high, an increase in expected payment is dominated by that in the expected profit.

3.1.1. Related Economics Literature

Since the seminal paper Becker (1962), some papers have investigated the issue of human capital acquisition. For example, Prendergast (1993) shows that promotion serves as an incentive to collect skills when it is difficult to compensate workers for human capital acquisition. My modeling approach is similar to that of Krakel (2015) which extends the classic theory of human capital investment by incorporating workers' incentive to invest. He analyzes a moral hazard problem and derives the condition under which firms invest in general human capital. While these studies adopt the common prior assumption, the present analysis examines the effect of the agent's biased belief on the incentive to acquire human capital.

This study also contributes to the literature on the agent's biased belief which has been grown fast. There are two strands in the literature. Some studies consider that the principal has an objective and unbiased belief and only the agent has biased belief. de la Rosa (2011) shows the effect of the agent's overconfidence on the optimal contract design, and Santos-Pinto (2008) analyzes the agent's positive belief in a more general setting. Fang and Moscarini (2005) explain wage compression by using the morel hazard model in which agents have biased beliefs. Recently, Anja (2013) experimentally examines the effect of the agent's biased belief in a principal-agent setting. She finds that the principal exploits the agent's upward biased belief by lowering the compensation. While these studies adopt one-shot moral hazard model, this research shows the incentive effect of the agent's biased belief in a dynamic moral hazard model.

There are other papers which adopt the differing prior assumption. Van den Steen (2005) demonstrates that a manager with a strong belief attracts employees with similar beliefs and discusses when the manager's strong belief is important for organizations. Van den Steen (2010a) shows the cost and benefit of homogeneity in the sense of shared beliefs in organizations. Kim (2015) which studies the optimal contract under multiple agents, points out that the heterogeneous priors between a principal and agents lead to differences in optimal contract design. In these studies, both the principal and the agent have biased beliefs and their prior beliefs can be different. The present study also adopts a differing prior assumption and considers its effect on human capital acquisition.

3.1.2. Related Psychological Evidence

Psychological literature on people's mindsets has been growing fast[6] since the seminal work Dweck and Leggett (1988). In this section, I review related psychological experiments among them. Before reviewing the experiments, I first discuss how psychologists measure the mindset of subjects in experiments. Psychologists use a questionnaire that

[6] Please see Dweck (2000) for a comprehensive review.

consisted of several statements, for example, "You have a certain amount of intelligence, and you can't really do much to change it." Subjects answers the extent to which they agree or disagree with each statement and are then, classified into each mindset category based on their responses.

An experiment conducted at the University of Hong Kong (Hong et al., 1997) is frequently cited. In the experiment, Dweck and her co-authors asked subjects about the course on offer in the upcoming semester, including their interest in a remedial English course. At the University of Hong Kong, all classes are taken in English but not all students are proficient in English. Of the subjects who were less proficiency students, those with a growth mindset indicated that they were very likely to take the course while those with a fixed mindset indicated they were not interested. This result implied that those students with a fixed mindset did not wish to admit to and confront their deficiency.

There is also a difference in brain activity between the two groups. Using a neuroscience model, Mangels et al. (2006) examine that how a mindset affects attention to valuable information feedback. They found that those with a fixed mindset cared more about negative performance feedback and less about informative feedback. In their study, 464 subjects answered 476 general knowledge questions twice. After the first test, subjects were given feedbacks that consisted of the correct answers and information about response accuracy (negative or positive feedback), during which brain activities were recorded. Then, subjects were asked to take a surprise retest. At the end of the first test, the subjects did not know they would take the test again. Despite the similar performance at the first test, subjects with a growth mindset demonstrated significantly greater improvements in the retest. According to the authors, this is because those with a fixed mindset exert less effort in memory-related activities to correct information than those with a growth mindset. Hence, the difference between the two categories in the degree of semantic processing can explain why those with a growth mindset are often able to rebound after an academically failure.

This study focuses on the difference between the two categories of people within organizations. Similarly, Murphy and Dweck (2011) investigate the organizational cultural differences that are captured by people's mindsets. They consider an organizational mindset to be shared beliefs of individuals within an organization. As an example of an organization with a fixed mindset, they quote the following description of Enron[7]

> "It was a company that prized 'sheer brainpower' above all else, where the task of sorting out 'intellectual stars' from the 'merely super-bright' was the top priority when making hires and promotions."

As an example of an organization with a growth mindset, they quote the following description of Xerox[8]

> "[...] Instead of proving how smart a person or a division was, the company's focus was on the making a contribution, investing in the experiences and development of a larger portion of talent, and intense on-the-job learning."

In their experiment, subjects apply either "entity" or "incremental" tutoring club. The former club emphasizes the group's view that intelligence is a fixed quality and the latter club emphasizes the group's view that intelligence is a malleable quality. As a result, they found that people present their "smarts" in an organization with a fixed mindset and their "motivation" in an organization with a growth mindset. However, they claim that this result is more likely to result from a person's judgment than mindset. In addition, they consider an alternative setting in which participants decides candidates who should be hired. They found that participants who applied entity club hired the candidates who highlighted smarts and those in the incremental club hired candidates who highlighted motivation. This implied that mindsets affect hiring decisions.

[7]McLean and Elkins(2003) cited in Murphy and Dweck (2011).
[8]George and McLean(2005) cited in Murphy and Dweck (2011)

More recently, Dweck has begun analyzing the impact of a growth mindset on companies' profits. In her words, "That's our burning question[9]." With this study, I hope to answer this burning question.

The rest of this chapter is structured as follows. In Section 2, I introduce the model. In Section 3, I analyze the effect of learnability confidence in a corresponding one-shot model as a benchmark case. In Section 4, I show the main results. In Section 5, I extend my model. Then, I conclude in Section 6. All proofs are available in Appendix B.

3.2. The Model

I consider a model in which a principal(female[10]) hires an agent(male) for two periods $t = 1, 2$. Both the principal and the agent are assumed to be risk neutral and have a common discount factor which is normalized to 1.

In each period t, the agent exerts effort $e_t \in \{0, 1\}$ to implement an identical project and his effort decision is unobservable to the principal. I refer to $e_t = 1$ as working and $e_t = 0$ as shirking[11]. The cost of effort is given by $c(e_t) = ce_t$, $c > 0$. Let $x_t \in \{s, f\}$ denote the outcome of the project in period t, which is either success ($x_t = s$) or failure ($x_t = f$) for $t = 1, 2$. The project's outcome depends on both the agent's effort and ability. Denote $\theta \in \{\theta_L, \theta_H\}$, $\theta_L < \theta_H$ as the agent's ability level and $p(\theta, e_t)$ as the success probability of the project. I assume the project is successful only if the agent's ability level is greater than the required level of ability $\underline{\theta} \in (\theta_L, \theta_H)$[12], which is common knowledge in the organization. Thus, $p(\theta_L, e_t) = 0$ for all e_t, and denote simply $p(\theta_H, e_t) = p_{e_t}$ where $1 > p_1 > p_0 > 0$. The principal and the agent have common prior belief regarding the agent's ability level, which is given by $\mathbb{P}[\theta = \theta_H] = r$ and

[9] Harvard Business Staff (2014).

[10] I assume a principal is female, and an agent is male only the purpose of identification.

[11] For simplicity, I assume that the agent works if it is indifferent between working and shirking. This is a standard assumption in the related literature.

[12] This assumption simplifies the analysis. While I do not derive the main result without this assumption, I conjecture that it will hold without the assumption under some conditions.

$\mathbb{P}[\theta = \theta_L] = (1-r)$, $r \in (0,1)$. The probability that the agent's ability level is greater than the required level is written as $\mathbb{P}[\theta > \underline{\theta}] = \mathbb{P}[\theta = \theta_H] = r$. For example, consider a production in a plant. The outcome of the project represents the product that the agent is engaging in has deficiency or not. I can interpret $\underline{\theta}$ as the qualified level of ability above which the agent can produce the product without any deficiency.

At the beginning of the second period, the agent obtains an learning opportunity[13] if and only if he works in the first period[14]. In this sense, the first-period effort has a long-term effect. For example, if a firm introduces a new project, it will not have experienced workers who can teach or accumulations of know-how to produce the product. In such a case, it is natural that the agent acquires some valuable information or know-how to develop his ability by undertaking the project. In the second period, if there is a learning opportunity, then the agent can develop his ability by working on the project($e_2 = 1$). While it is not necessary for the results, this learning-by-doing assumption simplifies the analysis[15]. The ability development succeeds in increasing the agent's ability level from θ_L to θ_H with probability α and fails with probability $(1-\alpha)$. If it fails, the agent's ability level does not change. Parameter α represents a learnability of the ability related to the project. The outcome of the ability development is unobservable to both the principal and the agent.

In the first period, the success probability of the project is given by $\mathbb{P}[\theta = \theta_H]p(\theta_H, e_1) = rp_{e_1}$. In the second period, when the first-period outcome is success, it is obvious that the agent's ability level is greater than that for required, $\mathbb{P}[\theta = \theta_H] = 1$, and thus, the success probability is reduced to p_{e_s} where e_s denotes the second-period effort after success($x_1 = s$). In the case of failure, there is still uncertainty in the agent's ability

[13]Since this study focuses on the incentive to acquire human capital and I do not consider any problem after investing the human capital, the agent's reservation utility in the second period remains the same, that is, zero. Thus the main results hold under general human capital and various specific human capitals.

[14]In Section 3.5.2, I obtain the same result as in the main analysis if the agent has the learning opportunity for all $e_1 \in \{0,1\}$.

[15]The main result still holds if instead the agent exerts a developing effort in addition to the executing effort, e_t.

level and the agent has the incentive to develop his ability. After failure, the posterior belief on the agent's ability level according to Bayes' rule is written as follows:

$$q_{e_1} = \mathbb{P}[\theta = \theta_H \mid x_1 = f, e_1] = \frac{r(1-p_{e_1})}{r(1-p_{e_1}) + (1-r)}.$$

The posterior depends on the first-period effort and is decreasing in e_1. After working ($e_1 = 1$) and failure, the success probability is written as follows:

$$\begin{aligned}
&[\mathbb{P}[\theta = \theta_H \mid x_1 = f, 1] + ((1 - \mathbb{P}[\theta = \theta_H \mid x_1 = f, 1])e_f\alpha)]p(\theta_H, e_t) \\
&\quad = [q_1 + (1-q_1)e_f\alpha]p_{e_f}.
\end{aligned}$$

where e_f denotes the second-period effort after failure($x_1 = f$). If the agent shirks in the first period or $\alpha = 0$, the agent's ability level will not change and then, the success probability is given by $\mathbb{P}[\theta = \theta_H \mid x_1 = f, e_1 = 0]p(\theta_H, e_f) = q_0 p_{e_f}$.

The key feature of the model is the assumption of differing prior beliefs regarding the success probability of the ability development, in other words, learnability of ability. I allow that the principal and the agent openly agree to disagree about the learnability even though they have no private information[16]. According to Aumann (1976), the openly disagreement requires that they have differing prior beliefs. Note that if each party meets those with differing prior beliefs, he or she does not update his or her belief because both the principal and the agent have no private information about the learnability[17]. Denote α_{A} as the agent and α_{P} as the principal's belief on the learnability. I call each party's belief regarding the learnability as her or his learnability confidence. If a party has high learnability confidence, then the party highly evaluates the effect of

[16]The following statement by Harsanyi (1968) is frequently cited as a reference.

> "For, by the very nature of subjective probabilities, even if two individuals have exactly the same information and are at exactly the same high level of intelligence, they may very well assign different subjective probabilities to the very same events."

[17]Even if a party has private information, I consider that it will cost too much to persuade another party.

the ability development. A party's high learnability confidence corresponds to a growth mindset and his or her less learnability confidence corresponds to a fixed one. In Section 3.4.2, I discuss how this differing prior assumption affects the results.

If a project succeeds, the principal obtains profit $V > 0$ and zero otherwise. For simplicity, I assume that the principal's profit V is so large that she prefers to implement $e_t = 1$ in every period t[18]. Since the project's outcome is observable and verifiable, the principal offers the contract $l = \{(w_s, w_f), (w_{ss}, w_{sf}), (w_{fs}, w_{ff})\}$ contingent upon the outcomes. The contract must satisfy the limited liability constraint, w_{x_1}, $w_{x_1 x_2} \geq 0$, for all x_1, x_2, (LL). For simplicity, I assume that the agent is unable to save or borrow.

The timing of the game is as follows:

1. The principal offers a contract $l = \{(w_s, w_f), (w_{ss}, w_{sf}), (w_{fs}, w_{ff})\}$.

2. The agent either accepts or rejects the offer. If the agent accepts the offer, the game goes on to the next stage; otherwise, the game ends and each party obtains reservation utility which is normalized to 0.

3. The agent decides effort level $e_1 \in \{0, 1\}$. This decision is unobservable to the principal.

4. The outcome in the first period is realized and the agent is paid according to the contract.

5. If the first-period outcome is success, the agent chooses his effort level $e_s \in \{0, 1\}$. If not, the agent chooses his effort level $e_f \in \{0, 1\}$ and only after $e_1 = 1$, he can develop his ability.

6. The outcome in the second period is realized and the agent is paid according to the contract.

[18] In Section 3.5.1, I derive the condition under which the principal prefers to implement $e_1 = e_s = e_f = 1$.

3.3. Benchmark: One-Shot Model

I start my analysis by studying the incentive effect of the agent's belief regarding learnability in the corresponding one-shot model where the agent exerts effort $e_1 \in \{0, 1\}$ and the relationship terminates at the end of the first period. I assume the principal's profit is so large, she offers a contract (w_s, w_f) to implement $e_1 = 1$.

The key contribution of this study is to show the incentive effect of the agent's biased belief in a dynamic moral hazard model. Since this benchmark presents the reference result in a static environment, it will be helpful to understand the contribution in the main analysis.

There are two relevant cases depending on the uncertainty of the ability level. First, suppose that the agent has the learning opportunity and his ability level is uncertain($\mathbb{P}[\theta = \theta_H] = r$). Then, this case corresponds to the second period after failure and working in the main analysis. The agent chooses his effort level to maximize the following expected benefit:

$$
\begin{aligned}
&(\mathbb{P}[\theta = \theta_H] + (1 - \mathbb{P}[\theta = \theta_H])e_1\alpha_{\mathrm{A}})p(\theta_H, e_1)w_s \\
&\quad + (1 - (\mathbb{P}[\theta = \theta_H] + (1 - \mathbb{P}[\theta = \theta_H])e_1\alpha_{\mathrm{A}})p(\theta_H, e_1))w_f - ce_1, \\
&\quad = (r + (1-r)e_1\alpha_{\mathrm{A}})p_{e_1}w_s + (1 - (r + (1-r)e_1\alpha_{\mathrm{A}})p_{e_1})w_f - ce_1.
\end{aligned}
$$

If the principal offers a contract (w_s, w_f), then her expected payment is given by

$$
(r + (1-r)e_1\alpha_{\mathrm{P}})p_{e_1}w_s + (1 - (r + (1-r)e_1\alpha_{\mathrm{P}})p_{e_1})w_f.
$$

Since the principal wants to implement $e_1 = 1$, her problem is written as the following cost minimization problem:

$$
\min_{(w_s, w_f)} (r + (1-r)\alpha_{\mathrm{P}})p_1 w_s + (1 - (r + (1-r)\alpha_{\mathrm{P}})p_1)w_f.
$$

subject to

$$(r+(1-r)\alpha_{\mathrm{A}})p_1 w_s + (1-(r+(1-r)\alpha_{\mathrm{A}})p_1)w_f - c \geq rp_0 w_s + (1-rp_0)w_f, \quad (3.1)$$

$$(r+(1-r)\alpha_{\mathrm{A}})p_1 w_s + (1-(r+(1-r)\alpha_{\mathrm{A}})p_1)w_f - c \geq 0, \quad (3.2)$$

$$w_s, w_f \geq 0. \quad \text{(LL)}$$

The inequality (3.1) is the incentive compatibility constraint and the inequality (3.2) is the participation constraint. By the limited liability constraint (LL), the participation constraint (PC) is not effective. At the optimum, $w_f = 0$ must be hold. Under $w_f = 0$, the optimal wage upon success is determined at the incentive compatibility constraint holds with equality. Thus, if there is uncertainty in the agent's ability level and the agent has the learning opportunity, the optimal contract is given by $(w_s,\ w_f)$=$(w_{s1}(\alpha_{\mathrm{A}}), 0)$, where $\Delta_p = p_1 - p_0 > 0$, and $w_{s1}(\alpha_{\mathrm{A}}) = \frac{c}{r\Delta_p+(1-r)\alpha_{\mathrm{A}}p_1}$. Hence, the agent who has strong learnability confidence highly evaluates the effect of the ability development and has more incentive to work. I call this the *positive incentive effect* of the learnability confidence. The principal's expected payment is decreasing in α_{A} due to the positive incentive effect.

Next, suppose there is no learning opportunity. Then, this case is corresponding to the first period in the main analysis. By the standard argument, I can derive the optimal wages as follows: $(w_s, w_s) = (w_{s2}, 0)$ where $w_{s2} = \frac{c}{r\Delta_p}$.

3.4. Main Analysis: Two-Period Model

Now, I move on to the two-period model. First, in Section 3.4.1, I derive the renegotiation-proof contract and show the effect of the agent's learnability confidence on the contract. Next, I discuss the role of the differing prior assumption in Section 3.4.2.

3.4.1. Optimal Contract

It is often difficult to commit to a long-term contract and to not to renegotiate. If the principal is a manager and the agent is an employee, then the manager generally cannot provide the employee the contract with commitment. I consider that the principal has an opportunity of renegotiation at the beginning of the second period after the first-period outcome is realized and cannot commit not to renegotiate. In this complete contracting setting, I can restrict my attention to the renegotiation-proof contract without loss of generality.

In the second period, given that a contract l and the agent's effort decision in the first period, the agent chooses his effort level to maximize his expected benefits. The agent's expected benefit after success is given by

$$u_s(e_s; l) = p_{e_s} w_{ss} + (1 - p_{e_s}) w_{sf} - c e_s.$$

After failure, the agent's expected benefit differs with the first-period effort level, and is given by follows.

$$u_f(e_1, e_f, \alpha_{\mathrm{A}}; l) = \begin{cases} u_f(1, e_f, \alpha_{\mathrm{A}}; l) & \text{if } e_1 = 1, \\ u_f(0, e_f; l) & \text{if } e_1 = 0 \end{cases}$$

where

$$u_f(1, e_f, \alpha_{\mathrm{A}}; l) = [q_{e_1} + (1 - q_{e_1}) e_f \alpha_{\mathrm{A}}] p_{e_f} w_{fs} + (1 - [q_{e_1} + (1 - q_{e_1}) e_f \alpha_{\mathrm{A}}] p_{e_f}) w_{fs} - c e_f,$$
$$u_f(0, e_f; l) = q_0 p_{e_f} w_{fs} + (1 - q_0 p_{e_f}) w_{ff} - c e_f.$$

Since the agent has the learning opportunity only after working($e_1 = 1$), only the expected benefit after failure and working, that is, $u_f(1, e_f, \alpha_{\mathrm{A}}; l)$, depends on the agent's learnability confidence.

In the first period, the agent chooses e_1 to maximize the following total expected benefit given a contract l and the effort decisions in the second period.

$$U(e_1, e_s, e_f, \alpha_{\mathrm{A}}; l) = rp_{e_1}w_s + (1-rp_{e_1})w_f - ce_1 + rp_{e_1}u_s(e_s; l) + (1-rp_{e_1})u_f(e_1, e_f, \alpha_{\mathrm{A}}; l).$$

The agent's reservation utility is assumed to be 0; hence the participation constraint for the agent is given by

$$U(1, 1, 1, \alpha_{\mathrm{A}}; l) \geq 0. \tag{PC}$$

I now derive the incentive compatibility constraints in the second period. If the project succeeds in the first period, then both the agent and the principal know that the agent's ability level exceeds that required for the project. After success, the agent works($e_s = 1$) if and only if $u_s(1; l) \geq u_s(0; l)$ which is rewritten as follows.

$$\Delta_p \left(w_{ss} - w_{sf} \right) \geq c. \tag{IC2$_s$}$$

After failure, given that the agent works($e_1 = 1$) in the first period, the agent chooses $e_f = 1$ if and only if $u_f(1, 1, \alpha_{\mathrm{A}}; l) \geq u_f(1, 0; l)$ [19], which is rewritten as

$$\left[\left(q_1 + (1 - q_1)\alpha_{\mathrm{A}} \right) p_1 - q_1 p_0 \right] \left(w_{fs} - w_{ff} \right) \geq c. \tag{IC2$_f$}$$

There is still uncertainty about the agent's ability level, and thus the agent's effort decision depends on his learnability confidence, α_{A}. Off-the-equilibrium path, the agent shirks($e_1 = 0$) in the first period. After shirking and failure, the agent chooses $e_f = 1$ if and only if $u_f(0, 1; l) \geq u_f(0, 0; l)$, which is rewritten as $q_0 \Delta_p (w_{fs} - w_{ff}) \geq c$.

Given $e_s = e_f = 1$, in the first period, the agent chooses $e_1 = 1$ if and only if

[19]Note that if the agent chooses $e_f = 0$, his expected benefit does not depend on α_{A}.

$U(1,1,1,\alpha_{\mathrm{A}};l) \geq U(0,1,1;l)$. I can rewrite this inequality as follows:

$$r\Delta_p(w_s - w_f) + \Delta_{u_2}(\alpha_{\mathrm{A}}) \geq c \tag{IC1}$$

where $\Delta_{u_2}(\alpha_{\mathrm{A}}) = r\Delta_p u_s(1;l) + (1-rp_1)u_f(1,1,\alpha_{\mathrm{A}};l) - (1-rp_0)u_f(0,1;l)$ represents the net expected rent the agent earns in the second period. In each period, the agent gains positive rent due to the limited liability constraint, and thus, in the first period, the agent's effort decision is subject to his learnability confidence through the expected rent after failure. Since the first-period effort has the long-term effect, the expected rent after failure differs with the effort choice in the first period.

If the principal offers a contract $l = \{(w_s, w_f), (w_{ss}, w_{sf}), (w_{fs}, w_{ff})\}$, then the principal's total expected payment, denoted by $W(e_1, e_s, e_f, \alpha_{\mathrm{P}}; l)$, is written as

$$\begin{aligned} W(e_1, e_s, e_f, \alpha_{\mathrm{P}}; l) &= rp_{e_1} w_s + (1-rp_{e_1})w_f + rp_{e_1}\left[p_{e_s} w_{ss} + (1-p_{e_s})w_{sf}\right] \\ &\quad + (1-rp_{e_1})\left[(q_{e_1} + (1-q_{e_1})e_f\alpha_{\mathrm{P}})p_{e_f} w_{fs} + (1-(q_{e_1} + (1-q_{e_1})e_f\alpha_{\mathrm{P}})p_{e_f})w_{ff}\right]. \end{aligned}$$

I first show the result and then discuss the intuition. The following lemma shows the renegotiation-proof contract.

Lemma 3. *Suppose the principal can not commit not to renegotiate. Then the renegotiation-proof contract is given by* $l^*(\alpha_{\mathrm{A}}) = \Big\{(w_s^*(\alpha_{\mathrm{A}}), 0), (w_{ss}^*, 0), (w_{fs}^*(\alpha_{\mathrm{A}}), 0)\Big\}$*, where* $w_s^*(\alpha_{\mathrm{A}})$*,* w_{ss}^**, and* $w_{fs}^*(\alpha_{\mathrm{A}})$ *are as follows:*

$$w_s^*(\alpha_{\mathrm{A}}) = \frac{c - \Delta_{u_2}(\alpha_{\mathrm{A}})}{r\Delta_p} > 0,\ w_{ss}^* = \frac{c}{\Delta_p},\ w_{fs}^*(\alpha_{\mathrm{A}}) = \frac{c}{q_1\Delta_p + (1-q_1)\alpha_{\mathrm{A}} p_1}.$$

In the second period, the principal prefers to offer the wages that are optimal in the corresponding one-shot model. The optimal wages after success $(w_{ss}^*, 0)$ are corresponding to those without the learning opportunity in the one-shot model, that is, $(w_{s2}, 0)$. Since after success, there is no uncertainty in the agent's ability level, I obtain the optimal wages w_{ss}^* by substituting $r = 1$ into w_{s2}. The optimal wages after failure, $(w_{fs}^*(\alpha_{\mathrm{A}}), 0)$, are corresponding to the optimal wages with the learning opportunity in the one-shot model. The probability that the agent's ability level is greater than that required is updated in the beginning of the second period, and thus I obtain the optimal wages by replacing r with q_1. If the principal offers $\{(w_{ss}^*, 0), (w_{fs}^*(\alpha_{\mathrm{A}}), 0)\}$, both the incentive compatibility constraint after success and failure are binding. Hence, there are no other contracts under which both the principal and the agent are mutually better off.

In the first period, $w_f = 0$ must be hold at the optimum. Given the optimal contract in the second period and $w_f = 0$, the optimal wage in the first period, $w_s^*(\alpha_{\mathrm{A}})$, is determined at (IC1) binds.

The agent's learnability confidence has two effects on the incentive contract. First, the expected payment after failure, $w_{fs}^*(\alpha_{\mathrm{A}})$, is decreasing in the agent's learnability confidence. This is a well-know effect of the agent's biased belief[20]. As in the one-shot model, the agent's learnability confidence has the *positive incentive effect* on his effort incentive. The principal exploits the positive incentive effect by lowering the wage after failure. By the exploitation, the agent is worse off. Differentiation yields

$$\frac{\partial u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} = -\frac{(1 - q_1)p_1 q_1 p_0}{(q_1 \Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1)^2} c < 0.$$

Hence, the agent's expected rent after failure is strictly decreasing in his learnability confidence due to the exploitation.

Second, the agent's learnability confidence increases the expected payment in the first period, $w_s^*(\alpha_{\mathrm{A}})$. This is a novel result. The first-period wage depends on the agent's learnability confidence only through the expected rent after failure. By differentiating

[20]For example, see Anja (2013).

$w_s^*(\alpha_{\mathrm{A}})$ with respect to α_{A}, I obtain

$$\begin{aligned}\frac{\partial w_s(\alpha_{\mathrm{A}})}{\partial \alpha_{\mathrm{A}}} &= -\frac{1}{r\Delta_p}\frac{\partial \Delta_{u_2}(\alpha_{\mathrm{A}})}{\partial \alpha_{\mathrm{A}}}, \\ &= -\frac{1}{r\Delta_p}(1-rp_1)\frac{\partial u_f(1,1,\alpha_{\mathrm{A}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} > 0.\end{aligned}$$

As I discussed, there is the positive incentive effect after failure and the principal exploits it by lowering the wage w_{fs}. Hence, in the first period, the agent's learnability confidence undermines his incentive to work in the first period. I call this the *counterproductive effect* of the agent's belief regarding learnability. Note that in the benchmark case, there is no counterproductive effect. The long-term effect of the first-period effort seems significant for the result because the coefficient of expected rent after failure is positive in $\Delta_{u_2}(\alpha_{\mathrm{A}})$ due to the long-term effect. However, I show that the result still holds without the long-term effect in Section 3.5.2.

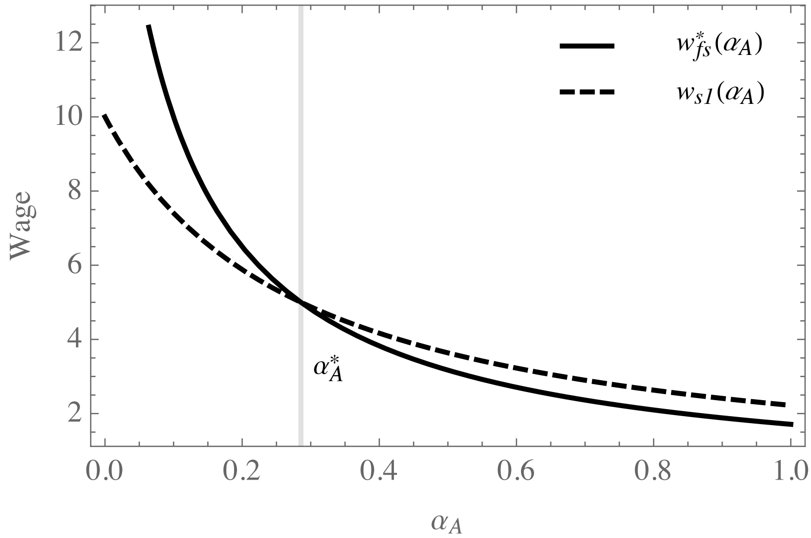
I now compare the optimal wages in the dynamic model with those in the benchmark case. In the second period, after failure and working, there is the learning opportunity, and then, $w_{fs}^*(\alpha_{\mathrm{A}})$ corresponds to $w_{s1}(\alpha_{\mathrm{A}})$. By comparing the wages, I obtain the following corollary.

Corollary 2. *There exists* α_{A}^**, satisfying* $0 < \alpha_{\mathrm{A}}^* < 1$*, such that* $w_{fs}^*(\alpha_{\mathrm{A}}) \leq w_{s1}(\alpha_{\mathrm{A}})$ *holds if and only if* $\alpha_{\mathrm{A}} \geq \alpha_{\mathrm{A}}^*$*.*

As Fang and Moscarini (2005) point out, information that lowers the agent's expected ability level hurts his work incentive. In my model, failure indicated that the agent's ability level is more likely to be low(r is decreased to q_1). However, if the agent has high learnability confidence, then the implementation cost is decreased even after failure. Hence, the agent's belief regarding learnability is more important when the agent's ability level is more likely to be low. Figure 3.1 depicts the positive incentive effect and the difference between $w_{fs}^*(\alpha_{\mathrm{A}})$ and $w_{s1}(\alpha_{\mathrm{A}})$. The solid curve represents $w_{fs}^*(\alpha_{\mathrm{A}})$ and the dashed curve $w_{s1}(\alpha_{\mathrm{A}})$. In Figure 3.1, I assume that $r = 0.5$, $p_1 = 0.7$, $p_0 = 0.5$, and

$c = 1$. Then $q_1 = \frac{3}{13}(\approx 0.23)$ and $\alpha_{\mathrm{A}}^* = \frac{2}{7}(\approx 0.29)$.

Figure 3.1.: Positive Incentive Effect



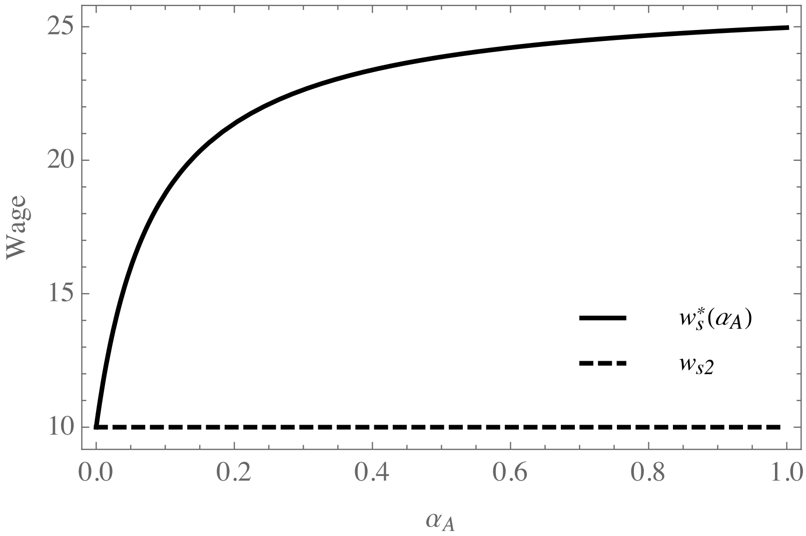
In the first period, there is no learning opportunity, and thus $w_s^*(\alpha_{\mathrm{A}})$ corresponds to w_{s2}. The only difference between $w_s^*(\alpha_{\mathrm{A}})$ and w_{s2} is in the net expected benefit in the second period, $\Delta_{u_2}(\alpha_{\mathrm{A}})$. Since $\Delta_{u_2}(\alpha_{\mathrm{A}}) < 0$ holds, the principal must compensate more to motivate the agent to work in the dynamic model. Figure 3.2 depicts the counterproductive effect. The solid curve represents $w_s^*(\alpha_{\mathrm{A}})$ and the dashed curve w_{s2}. In Figure 3.2, I use the same parameter values as those in the Figure 3.1.

To the best of my knowledge, no psychologist has presented the counterproductive effect, possibly because they focus mainly on the effect of mindsets on behaviors after failure and do not examine ex-ante behaviors.

Although there is the counterproductive effect, can the agent with high learnability confidence be optimal for the organization? Let $V(e_1, e_s, e_f, \alpha_{\mathrm{P}}; l)$ denote the principal's expected profit. Suppose $e_1 = e_s = e_f = 1$. Then under the renegotiation-proof contract $l^*(\alpha_{\mathrm{A}})$, the principal's expected profit is written as follows:

$$V(1,1,1,\alpha_{\mathrm{P}}; l^*(\alpha_{\mathrm{A}})) = \left[rp_1 + rp_1^2 + (1 - rp_1)(q_1 + (1 - q_1)\alpha_{\mathrm{P}})p_1\right] V - W(1,1,1,\alpha_{\mathrm{P}}; l^*(\alpha_{\mathrm{A}})).$$

Figure 3.2.: Counterproductive Effect



Since I adopt the differing prior assumption, the following equality holds.

$$\frac{\partial V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} = -\frac{\partial W(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}}.$$

Thus, the expected profit depends on the agent's learnability confidence only through the expected payment level. This is a common feature of the model with differing prior beliefs[21]. Hence, I can show the agent's optimal belief regarding learnability by analyzing the effect of his belief on the expected payment. I summarize the result in the following proposition.

Proposition 8. *Suppose the principal can not commit not to renegotiate and offers $l^*(\alpha_{\mathrm{A}})$. Then there exit thresholds α_{P}^*, $\underline{p}_0$ and $\overline{p}_0$, satisfying $0 < \underline{p}_0 < \overline{p}_0 < p_1$, such that the principal's expected profit is decreasing in the agent's belief regarding learnability if and only if $\alpha_{\mathrm{P}} < \alpha_{\mathrm{P}}^*$ where $\alpha_{\mathrm{P}}^* \in (0,1)$ for $p_0 \in (\underline{p}_0, \overline{p}_0)$.*

Proposition 8 represents the main result. Since there are two effects: positive incentive effect and counterproductive effect, the principal's expected profit is decreasing in

[21]For example, see de la Rosa (2011).

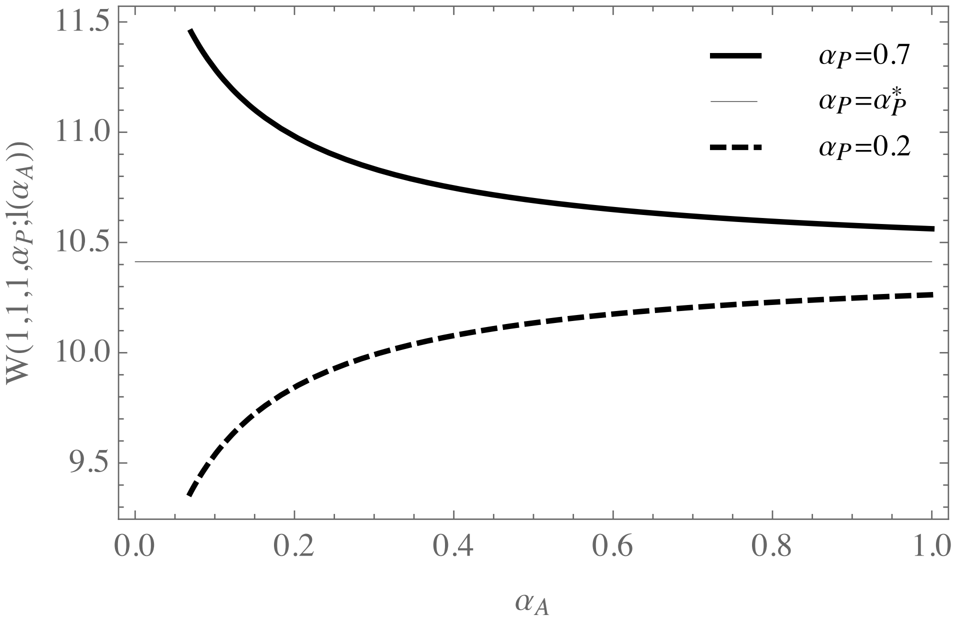
the agent's learnability confidence if the latter effect dominates the former effect. The principal's learnability confidence determines which of the two effects is more important. If the principal has high learnability confidence, then she highly evaluates the success probability of the ability development and hence she considers the exploitation after failure is sufficiently beneficial. As a result, the principal compensates more to induce the acquisition of the learning opportunity. On the other hand, the principal who has less learnability confidence underestimates the benefit of the exploitation and considers that the counterproductive effect is more important. Hence, such a principal compensates more when the agent learns. Proposition 8 implies that organizations tend to share homogenous beliefs regarding learnability: the principal with low(high) learnability confidence prefers the agent who also has low(resp. high) learnability confidence. Figure 3.3 illustrates the effect of the agent's belief on the expected implementation cost. The solid curve depicts $W(1, 1, 1, 0.7; l^*(\alpha_{\mathrm{A}}))$ and the dashed curve $W(1, 1, 1, 0.2; l^*(\alpha_{\mathrm{A}}))$. In the figure, I use the same parameter values as those in the Figure 1 and then, $\underline{p}_0 = 0.35$ and $\overline{p}_0 = \frac{91}{160}(\approx 0.56)$, and $\alpha_{\mathrm{P}}^* = \frac{9}{20}(\approx 0.45)$.

However, for example, if p_0 is sufficiently small, then the principal who does not believe in the success of the ability development will prefer the agent with high learnability confidence.

Corollary 3. *Suppose that the principal can not commit not to renegotiate and offers $l^*(\alpha_{\mathrm{A}})$. Then the principal's expected profit is increasing in α_{A} for all α_{P} if $p_0 < \underline{p}_0$ and decreasing in α_{A} for all α_{P} if $p_0 > \overline{p}_0$.*

First suppose $p_0 < \underline{p}_0$. Then $\alpha_{\mathrm{P}}^* < 0$. The counterproductive effect is severe if the agent's expected rent after failure is large. Since $\partial u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}}))/\partial \alpha_{\mathrm{A}}$ is increasing in p_0 and $u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) = 0$ at $p_0 = 0$, the expected rent after failure is small if the sensitivity of effort is high(p_0 is low). Thus, the counterproductive effect is not significant for the low value of p_0. Hence, when the agent's effort is necessary to succeed, the positive incentive effect dominates even if the principal does not believe the success

Figure 3.3.: The Expected Implementation Cost



of ability development and has $\alpha_{\mathrm{P}} = 0$.

Next, suppose $p_0 > \overline{p}_0$. Then $\alpha^*_{\mathrm{P}} > 1$. As I point out, it is more important to compensate the agent in the first period if p_0 is large. For $p_0 > \overline{p}_0$, the counterproductive effect dominates, and thus, the principal's expected profit is decreasing in α_{A} for all α_{P}. Hence, the principal who fully believes in the success of the ability development ($\alpha_{\mathrm{P}} = 1$), will prefer the agent with low learnability confidence.

Does the agent benefit from having high learnability confidence? By differentiating the agent's total expected benefit, I obtain

$$\begin{aligned}\frac{\partial U(1,1,1,\alpha_{\mathrm{A}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} &= rp_1 \frac{\partial w_s(\alpha_{\mathrm{A}})}{\partial \alpha_{\mathrm{A}}} + (1-rp_1)\frac{\partial u_f(1,1,\alpha_{\mathrm{A}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} \\ &= (1-rp_1)(1-\frac{p_1}{\Delta_p})\frac{\partial u_f(1,1,\alpha_{\mathrm{A}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}}.\end{aligned}$$

The sign is positive because $1 - p_1/\Delta_p < 0$ and $\partial u_f(1,1,\alpha_{\mathrm{A}};l^*(\alpha_{\mathrm{A}}))/\partial \alpha_{\mathrm{A}} < 0$ hold. Hence, under the renegotiation-proof contract $l^*(\alpha_{\mathrm{A}})$, the agent's expected benefit is increasing in α_{A}.

While the principal extracts a positive surplus from the agent's confidence, the agent obtains greater benefit from his higher learnability confidence. This is because the extra payment that the principal compensates to induce him to work in the first period exceeds the loss from the exploitation after failure.

3.4.2. Role of Differing Prior Assumption

In this section, I discuss the role of the differing prior assumption. To this end, suppose instead that both the principal and the agent share a common prior belief regarding learnability, denoted by α. Here, α is not so much the party's confidence but represents the project's learnability: necessary ability to succeed in the project is difficult (easy) to learn if α is low (resp. high).

First, I show the effect of the common prior belief on the implementation cost. Following from Lemma 3, under the common prior α, the renegotiation-proof contract is rewritten by $l^*(\alpha) = \{(w_s^*(\alpha), 0), (w_{ss}^*, 0), (w_{fs}^*(\alpha), 0)\}$. If the principal offers the contract $l^*(\alpha)$, then the expected payment is written as follows:

$$W(1, 1, 1, \alpha; l^*(\alpha)) = rp_1 w_s^*(\alpha) + rp_1^2 w_{ss} + (1 - rp_1)(q_1 + (1 - q_1)\alpha)p_1 w_{fs}^*(\alpha).$$

The following proposition shows the effect of the common prior α on the expected payment.

Proposition 9. *Suppose that the principal can not commit not to renegotiate and the principal and the agent have common prior belief. Then the expected payment* $W(1, 1, 1, \alpha; l^*(\alpha))$ *is always increasing in* α.

This result shows the important role of the differing prior assumption: the optimal wage level after failure is separated from the probability that the wage is paid. In the main analysis, the increase of α_{A} does not increase the success probability after failure perceived by the principal because *the agent's belief is not tied with the principal's belief* due to the differing prior assumption. Under the common prior assumption, their beliefs are tied, and thus the increase of the belief regarding learnability increases the probability that the wage $w^*_{fs}(\alpha)$ is paid. By differentiating $W(1,1,1,\alpha;l^*(\alpha))$, I obtain

$$\begin{aligned}\frac{\partial W(1,1,1,\alpha;l^*(\alpha))}{\partial\alpha} &= rp_1\frac{\partial w^*_s(\alpha)}{\partial\alpha} + (1-rp_1)(q_1+(1-q_1)\alpha)p_1\frac{\partial w^*_{fs}(\alpha)}{\partial\alpha}\\ &\quad + (1-rp_1)(1-q_1)p_1 w^*_{fs}(\alpha).\end{aligned}$$

The second line represents the effect that the probability that $w^*_{fs}(\alpha)$ is paid is increasing in α. Although the wage level $w^*_{fs}(\alpha)$ is still decreasing in α, the increase of the probability that the wage is paid dominates. Hence, the expected payment is always increasing in α.

Next, I show the optimal belief regarding learnability. If the principal and the agent have the common prior belief, then $-\partial W(1,1,1,\alpha,l^*(\alpha))/\partial\alpha$ is not equal to $\partial V(1,1,1,\alpha;l^*(\alpha))/\partial\alpha$. Under the renegotiation-proof contract $l^*(\alpha)$, the principal's expected profit is written as

$$V(1,1,1,\alpha;l^*(\alpha)) = \left[rp_1 + rp_1^2 + (1-rp_1)(q_1+(1-q_1)\alpha)p_1\right]V - W(1,1,1,\alpha;l^*(\alpha)).$$

Now, both the expected benefit and the implementation cost depend on α. The following proposition shows when the principal prefers the project with higher learnability.

Proposition 10. *Suppose that the principal can not commit not to renegotiate and the principal and the agent have common prior belief regarding learnability. Then, there exits a threshold* $\underline{V} > 0$ *such that the principal's expected profit* $V(1,1,1,\alpha;l^*(\alpha))$ *is increasing in* α *if* $V > \underline{V}$.

In comparison with the result under the differing prior assumption, the success probability after failure is increasing in α, and thus, the probability that the principal obtains profit V, is also increasing in α. This is the marginal benefit from the increase of the belief α and which is increasing in the value of profit V. However, as I discussed, there is the marginal cost, that is, the expected payment is always increasing in α. If V is sufficiently large, the marginal benefit exceeds the marginal cost. Hence, under the common prior assumption, the principal is more likely to prefer the project with greater learnability if the project is important and V is large. This result differs from the main results: under the differing prior assumption, the optimal level of the agent's belief does not depend on the value of V. The differing prior assumption allows the separation between the principal 's and the agent's belief, and hence, this separation is crucial to derive the main results.

3.5. Extension

In this section, I extend the main model . In Section3.5.1, I show the condition under which the principal prefers to implement $e_t = 1$ for all t. In Section 3.5.2, I show that the main results still hold under the alternative specifications of the ability development.

3.5.1. Termination

In the main analysis, I assume that V is so large that the principal wants to implements $e_t = 1$ in each period t. In this section, I analyze the principal's effort choice, especially after failure. If the project fails in the first period, the principal may prefer to terminate the project and want to implement $e_f = 0$. In order to study the effort choice, let $e = (e_1, e_s, e_f)$ denote the effort profile that the principal wants to implement. Below, I derive the condition under which the principal prefers $e = (1, 1, 1)$ to $e = (1, 1, 0)$.

First, I derive the optimal contract to implement the effort profile $e = (1, 1, 0)$. If the principal wants to implement $e_f = 0$, it is obvious that the optimal wages after failure are given by $(w_{fs}, w_{ff}) = (0, 0)$. After success, the optimal wage is the same as in the main analysis. In the first period, given the optimal wages in the second period, the optimal wages are given by $(w_s, w_f) = (w_s^{**}, 0)$ where $w_s^{**} = \frac{c-\Delta_{u_2}}{r\Delta_p}$ is determined at the incentive compatibility constraint binds. Thus, the optimal contract that implements $e = (1, 1, 0)$ is written as $l^{**} = \{(w_s^{**}, 0), (w_{ss}^{*}, 0), (0, 0)\}$. Under the effort profile $e = (1, 1, 0)$, the agent does not acquire human capital, and thus, the wage after failure and the wage in the first period do not depend on the agent's belief regarding learnability, α_{A}. Let $V(1, 1, 0, l^{**})$ be the principal's expected profit under the contract l^{**}. By comparing the principal's expected profits $V(1, 1, 1, \alpha_{\mathrm{P}}; l^{*}(\alpha_{\mathrm{A}}))$ and $V(1, 1, 0, l^{**})$, I obtain the following result.

Proposition 11. *Suppose the principal can not commit not to renegotiate. Then there exists $V^{*}(\alpha_{\mathrm{P}}, \alpha_{\mathrm{A}}) > 0$ such that the principal's expected profit under the effort profile $e = (1, 1, 1)$ is greater than that under the effort profile $e = (1, 1, 0)$ if and only if $V \geq V^{*}(\alpha_{\mathrm{P}}, \alpha_{\mathrm{A}})$.*

Since the ability development increases the success probability after failure, the probability that the principal obtains the profit V is increasing in e_f, but the implementation cost is also increasing in e_f. Hence, the principal prefers to implement $e_f = 1$ if the value of V is so high that the benefit from the increase in the success probability dominates. The threshold $V^{*}(\alpha_{\mathrm{P}}, \alpha_{\mathrm{A}})$ is decreasing in α_{P}, and the sign of $\partial V^{*}(\alpha_{\mathrm{P}}, \alpha_{\mathrm{A}})/\partial \alpha_{\mathrm{A}}$ is equal to the sign of $\partial W(1, 1, 1, \alpha_{\mathrm{P}}; l^{*}(\alpha_{\mathrm{A}}))/\partial \alpha_{\mathrm{A}}$. Therefore, the principal who has high learnability confidence is more likely to implement $e_f = 1$ and prefers the agent with high learnability confidence.

3.5.2. Alternative Specifications

In this section, I consider two alternative specifications about the ability development. First, I consider that the agent has the learning opportunity even if he shirks in the first period. Under this alternative specification, the long-term effect of the first-period effort disappears. When the first-period outcome is failure, only the difference after working and shirking is in the posterior on the agent's ability level, q_{e_1}. The optimal wages after working and failure is the same as those in the main analysis. After failure and shirking, the optimal wages are given $(w_{fs}, w_{ff}) = (\hat{w}^*_{fs}(\alpha_{\mathrm{A}}), 0)$ where $\hat{w}^*_{fs}(\alpha_{\mathrm{A}}) = \frac{c}{q_0\Delta_p + (1-q_0)\alpha_{\mathrm{A}} p_1}$. Under the optimal wages, his expected rent after failure and shirking is rewritten as follows:

$$\hat{u}_f(0, 1, \alpha_{\mathrm{A}}) = (q_0 + (1 - q_0)\alpha_{\mathrm{A}})p_1 \hat{w}^*_{fs}(\alpha_{\mathrm{A}}) - c.$$

It is obvious that the positive incentive effect of the learnability confidence exits under this alternative specification regardless of the first-period effort level. Now, I derive the effect of α_{A} on the first-period work incentive. The net expected rent in the second period is rewritten as

$$\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}}) = \frac{1}{2}\Delta_p u_s(1; l^*(\alpha_{\mathrm{A}})) + (1 - \frac{1}{2}p_1)u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) - (1 - \frac{1}{2}p_0)\hat{u}_f(0, 1, \alpha_{\mathrm{A}}).$$

Since the coefficient of $\hat{u}_f(0, 1, \alpha_{\mathrm{A}})$ is negative in $\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}})$, it is possible $\partial\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} > 0$ and the counterproductive effect no longer exists. However, in the following Proposition, I show that the counterproductive effect still exits under this alternative specification.

Proposition 12. *Suppose the principal can not commit not to renegotiate and the agent has the learning opportunity regardless of the first-period effort decision. Then the optimal wage in the first period is increasing in* α_{A}.

Next, consider that the agent has the learning opportunity in the first period. In my model, I focus on the case in which the agent has the learning opportunity only after working and it is one of key features of my model. However, in the existing literature on the human capital acquisition[22], the agent invests in the first period and which will be realized in the second period. In this section, I show how the main result depends on this specification of the ability development. To study, suppose instead that the agent has

[22] For example, see Prendergast (1993).

valuable information for the ability development in the first period[23]. Then, the agent develops in the first period and it will increase the agent's ability level in the second period.

Under this alternative specification, the optimal wage after failure is given by $\tilde{w}_{fs}(\alpha_{\mathrm{A}}) = \frac{c}{(q_1+(1-q_1)\alpha_{\mathrm{A}})\Delta_p}$. Since this wage is also decreasing in α_{A}, there is still positive incentive effect after failure. However, under this optimal wage, the agent's expected rent after failure equals to the expected rent after success:

$$(q_1 + (1-q_1)\alpha_{\mathrm{A}})p_1\tilde{w}_{fs}(\alpha_{\mathrm{A}}) - c = \frac{p_0}{\Delta_p}c = u_s(1; l^*(\alpha_{\mathrm{A}})).$$

This is because the agent's effort for the development has already sunk. Thus, the net expected rent in the second period equals zero. Hence, the agent's learnability confidence has no counterproductive effect and the principal always prefers an agent with high learnability confidence.

3.6. Concluding Remarks

In this study, I have shown that the optimal contract for the learning opportunity acquisition and the effect of differing prior beliefs regarding learnability on the contract. When the principal can not commit not to renegotiate, the agent's belief regarding learnability has the following two effects: (1) the positive incentive effect in the second period; and (2) the counterproductive effect in the first period. The principal's belief determines which effect dominates. In the second period, after failure, the agent with high learnability confidence is more likely to work due to the positive incentive effect. The principal exploits the positive incentive effect by lowering the wage. In the first period, the exploitation after failure increases the payment. Since the agent's work incentive in the first period depends on the expected rent in the second period, the

[23] For simplicity, I assume the human capital that the agent acquire is firm-specific human capital and his reservation wage remains zero in the second period.

exploitation hurts his incentive to work in the first period. If the principal has strong learnability confidence, the positive incentive effect dominates, and hence the principal compensates more in the first period.

In the main analysis, I adopt the differing prior assumption. If instead the principal and the agent have a common prior belief regarding learnability, the expected implementation cost is always increasing in the belief. This is because the probability that the wage after failure is paid is increasing in the belief. Under the differing prior assumption, the principal's belief is separated from that of the agent, and thus the expected payment after failure is always decreasing in the agent's belief. Hence, the differing prior assumption is crucial to derive the main results.

My analysis has the following testable implication. Recently, Dweck and her coauthors[24] point out that firms share learnability confidence and firms with higher learnability confidence tend to conduct more innovative projects. My analysis predicts that innovative firms that shares high learnability confidence provide more compensation when workers obtains learning opportunities. For example, if such a firm introduces new project, then workers obtain greater rent when they build a prototype product.

[24] Staff (2014).

Chapter 4.

Optimality of Straight Talk: Information Feedback and Learning

There are no two words in English language more harmful than "good job."

[Fletcher, *Whiplash*]

4.1. Introduction

Performance feedback is commonly used in organizations. It is natural that a supervisor has superior information regarding a subordinate's performance and ability and gives feedback. A supervisor's feedback may boost or hurt a subordinate's self-esteem. This role of feedback has been investigated in the fields of economics and management. When a supervisor provides feedback, does a supervisor care only about its effect on subordinate's self-esteem? If the answer is yes, then those who have bad news regarding subordinate's ability are less likely to tell the truth.

However, in practice, straight talk is often found in organizations. For example, Pixar Animation Studios adopts a system that induces straight feedback, called "Braintrust ." Ed CatMull, co-founder of Pixar Animation Studio and the president of both Pixar and Walt Disney Animation Studios, writes as follows[1]

> The Braintrust, ..., is our primary delivery system for straight talk.

He also explains why Pixar Animation Studios adopts such a system

> ...candor could not be more crucial to our creative process. Why? Because, *all* of our movies.... Pixar films are not good at first, and our job is to make them..., as I say, "from suck to no-suck."

If it will hurt employee's self-esteem, why is straight talk often used in organizations? In the celebrated book, Baron and Kreps (1999), Baron and Kreps list the purposes of performance evaluation. One of the purposes is that

> *Training and career development.* Either through self-improvement or through more external efforts, performance appraisal can be used to guide training and career development efforts for the individual.

After receiving feedback which may hurt self-esteem, if a subordinate develops his or her ability and improves his or her performance, the straight feedback will be beneficial to the organization. Although the importance of feedback in this respect, there are few economic analyses.

To address this issue, I develop the model based on Bénabou and Tirole (2002) and extend it to a principal-agent relationship. There is a principal (female[2]) and an agent. Their relationship lasts for two periods. The agent decides whether or not to implement a project. If the agent does not implement the project, it will fail. If the agent implements the project, its success probability depends only on the agent's ability level which is uncertain. Both the principal and the agent obtain benefit if the project succeeds. They obtain nothing otherwise. While the principal cannot offer any monetary incentive, she can give feedback regrading agent's ability level. My modeling approach on the

[1] Catmull and Wallace (2014)

[2] I assume the principal is female and the agent is male for identification purpose only.

information transmission is based on Bénabou and Tirole (2002). Since the principal usually has superior information, this setting is natural. The principal observes the true signal which informs the agent's ability level. The signal is either good news or bad news, and following Bénabou and Tirole (2002), I refer to no news as good news. I assume that the principal can suppress the bad news, but cannot fabricate, and I focus on the case where the principal observes the bad news.

A key feature of the model is that the agent can develop his ability level after receiving feedback, but before implementing the project. First, I assume that the agent can develop his ability only after receiving the bad news regarding his ability level. For example, a signal that informs that the agent's ability is low can be an informative suggestion for the ability development[3]. Later, I relax this assumption and obtain the same result but with additional conditions. Another key feature of the model is the assumption on the belief regarding the success probability of the ability development. I refer to the success probability of the ability development as learnability. Under the differing prior assumption, the principal and the agent openly disagree with the learnability. Thus, if a player meets with someone who has different prior beliefs, then he or she does not update his or her belief.

The principal chooses a feedback strategy to induce (i) the project implementation and (ii) the ability development. By telling the good news, the principal can motivate the agent to implement the project. This is because, after observing the good news, the agent's expected ability level is increased. I call this the *status effect*. The benefit of the status effect is large if a reliability of the transmitted information is high. On the other hand, by telling the bad news, the principal can induce the agent to develop his ability level. The ability development increases the success probability of the implemented project. I call this the *motivation effect*. The principal's benefit from the motivational

[3] Meyer et al. (1965) conducted interview study of performance appraisal in a large GE plant. They found that praise was often related to general performance characteristics, but criticism was focused on specific performance items. Hence, this evidence implies that bad news will be more helpful to improve performance.

effect is increasing in the agent's and the principal's belief regarding learnability.

As a benchmark case, I first show the optimal feedback strategy under a common prior assumption. Under this assumption, the principal and the agent share a belief regarding learnability. The principal tells the bad news truthfully if the belief regarding learnability is high. This is because, the benefit of the motivational effect dominates. On the other hand, if the belief regarding learnability is low, the benefit from the status effect dominates, and the principal suppresses the bad news.

Under the differing prior assumption, if both the principal's and the agent's belief regarding learnability are low, as in the benchmark case, suppressing the bad news is beneficial. However, if the principal has sufficiently high belief regarding learnability, then telling the bad news is beneficial. In this case, even if the agent's belief regarding learnability is low, the principal tells the bad news truthfully.

Finally, I consider an alternative specification. In the main analysis, I assume that the agent has the learning opportunity only after receiving the bad news. Instead, suppose that the agent has the ability development opportunity regardless of the transmitted signal. Then, with additional conditions, I obtain the same result as in the main analysis.

4.1.1. Related Literature

The literature on the feedback has been grown fast. There are the following three strands. First, Aoyagi (2010), Goltsman and Mukherjee (2011), Ederer (2010), and Hansen (2013) study the optimal feedback strategy in the dynamic tournament.

Second, Chen and Chiu (2013) and Chen (2015) analyze effects of interim performance feedback under a dynamic moral hazard model.

Third, the feedback strategy as means of confidence management has been analyzed by Bénabou and Tirole (2002), Bénabou and Tirole (2003), Dessí (2008), Dessí and Zhao (2015). My modeling approach is based on Bénabou and Tirole (2002), but they consider an individual decision making and an intra-personal communication. This study differs with Bénabou and Tirole (2002) in the following two respects: (i) I extend their model to the interpersonal communication; and (i) the receiver of the feedback has the ability development opportunity. There are some studies which also based on or related to Bénabou and Tirole (2002). In a principal-agent model, Bénabou and Tirole (2003) study a role of monetary incentives on the agent's self-confidence. Dessí (2008) extends their model to an interpersonal(or intergenerational) relationship and investigates a cultural transmission. More recently, Dessí and Zhao (2015) examine an interaction between overconfidence and a stability of an environment.

I adopt the differing prior assumption. The role of the differing priors have been investigated, for example, Van den Steen (2005), Van den Steen (2010c), Van den Steen (2010b). Furthermore, the belief regarding the learnability has been analyzed in psychology since the seminal paper, Dweck and Leggett (1988). For a comprehensive survey, see Dweck (2000). My companion paper, Morita (2016) also summarizes related studies.

The rest of this chapter is structured as follows. In Section 2, I introduce my model. I show the main result in Section 3 and discuss the alternative specification in Section 4. Then, I conclude in Section 5.

4.2. The Model

I develop the model based on Bénabou and Tirole (2002). The model has a principal (female[4]) and an agent (male). Both are risk neutral. There are two periods, $t = 0, 1, 2$. At the beginning of $t = 0$, the principal receives a signal regarding the agent's ability level, and then, she transmits the information. Given the available information, the agent may develop his ability level. After that, in $t = 1$, he decides whether or not to implement a project. In the second period, $t = 2$, the outcome of the project is realized, which is either success or failure. If the project is not implemented, then it always fails. The success probability of the implemented project depends only on the agent's ability

[4]I assume that the principal is female and that the agent is male for identification purposes only.

level, for simplicity, I assume this is equal to the agent's ability level, θ. If the project succeeds, both the principal and the agent obtain benefit, which is normalized to 1. They obtain nothing if the project fails.

While the principal cannot provide any monetary incentives to the agent, she has superior information regarding the agent's ability level, θ. I can also interpret θ as the value of the project the agent engages in. For example, if the principal is a supervisor, then it is natural that she will have more knowledge about a subordinate's ability or experience, which is useful to estimate the project's value. At the beginning of $t = 0$, the principal observes the true signal s regrading the agent's ability level. The signal s is either bad news ($s = B$) or no news ($s = \phi$). Following Bénabou and Tirole (2002), I refer to no news as good news. Conditional on the true signal, the agent's expected ability level is given by

$$\theta_L = \mathbb{E}[\theta \mid s = B] < \theta_H = \mathbb{E}[\theta \mid s = \phi],$$

where $0 < \theta_L < \theta_H < 1$. Bad news tells the agent's expected ability level is low. For example, bad news ($s = B$) represents that the agent's past performance is not good. After observing the true signal, the principal decides whether or not to tell the truth. Denote $\hat{s} \in \{B, \phi\}$ as the information transmitted to the agent. The principal cannot fabricate news but can hide the signal. Then, after observing $s = \phi$, there is no possibility of information manipulation and the principal always tells $\hat{s} = \phi$. If, instead $s = B$, then the principal can tell the bad news truthfully ($\hat{s} = B$) or suppress the bad news ($\hat{s} = \phi$).

After receiving the transmitted signal $\hat{s}$, the agent estimates his ability level based on his belief regarding the true signal and a principal's feedback strategy. The agent's prior belief regarding the true signal is that $s = B$ with probability $(1 - q)$, and $s = \phi$ with probability q. Define h as the principal's *feedback strategy*, which is the probability that the principal tells the bad news truthfully:

$$h = \mathbb{P}[\hat{s} = B \mid s = B].$$

Let h^* be the agent's belief regarding the principal's feedback strategy. I can interpret h^* as a degree of trust in the transmitted information by the principal. In equilibrium, h^* must be equal to h. After observing $\hat{s}$, the agent updates his belief according to Bayes' rule with using h^*. If the principal tells the bad news ($\hat{s} = B$). Then, it is obvious that the agent's ability level is low ($\theta = \theta_L$). However, after observing $\hat{s} = \phi$, the agent has to estimate a reliability of the transmitted signal. Let r be the reliability of the signal $\hat{s} = \phi$, which is given by

$$r = \mathbb{P}[s = \phi \mid \hat{s} = \phi; h^*] = \frac{q}{q + (1-q)(1-h^*)}.$$

If the agent receives $\hat{s} = \phi$, then his expected ability level is written as follows:

$$\theta^S(r) = r\theta_H + (1-r)\theta_L.$$

The superscript S stands for suppressing the bad news.

After receiving the signal $\hat{s}$, the agent may have the opportunity to develop his ability. For simplicity, I first assume that the agent can develop his ability level only after receiving bad news[5] ($\hat{s} = B$). For example, the supervisor's feedback, which informs the inadequacy of the subordinate's ability, may also be the informative suggestion for the ability development. Let $i \in \{0, 1\}$ be ability development effort[6]. The cost of the development is given by di, $d > 0$. The ability development succeeds with probability $\alpha \in (0, 1)$, and upon success, it increases the agent's ability level from θ_L to θ_H. If it fails, his ability level does not change. Thus, after receiving $\hat{s} = B$, the agent's expected

[5]In Section 4.4.2, I relax this assumption and obtain the same result, under additional conditions.

[6]For simplicity, I assume that the agent chooses $i = 1$ if he is indifferent between $i = 1$ and $i = 0$.

ability level differs with i, and is given as follows:

$$\theta^T(i,\alpha) = \begin{cases} \theta^T(1,\alpha) & \text{if } i = 1 \\ \theta_L & \text{if } i = 0, \end{cases}$$

where

$$\theta^T(1,\alpha) = \theta_L + \alpha\Delta_\theta,$$

and $\Delta_\theta = \theta_H - \theta_L > 0$. The superscript T stands for telling the bad news truthfully. After observing $\hat{s} = B$, the agent knows his ability level is low , and thus, if he does not develop it, it will remain low.

Given the transmitted signal and the ability development, the agent decides whether or not to implement the project. Let $e \in \{0,1\}$ be an implementation effort. The cost of project implementation ($e = 1$), denoted by c, is random and distributed according to a cumulative distribution function $F(\cdot)$ over $[0,1]$. Here, $f(\cdot)$ denotes a corresponding density function. I assume that $F(0) = 0$ and $F(\cdot)$ is strictly increasing. The agent chooses the implementation effort after observing the realization of c.

A key feature of the model is the assumption on the differing prior beliefs regarding the ability development. This is a standard assumption in the related literature[7]. Under this assumption, the principal and the agent openly disagree about the success probability of the ability development. Thus, if the principal or the agent meets someone who has a different prior belief, then she or he does not update her or his belief. Hence, after the development ($i = 1$), the success probability perceived by the principal can be different from that perceived by the agent. I refer to the success probability of the ability development as the *learnability*. Let α_{P} be the principal's belief regarding learnability and α_{A} be the agent's belief regarding learnability.

[7]Several studies adopt the differing prior assumption(for example, Van den Steen (2005), Van den Steen (2010c), Van den Steen (2010b)). In the field of psychology, literature on the belief regarding learnability have been grown rapidly. For example, see Dweck (2000) for a comprehensive review. In addition, Morita (2016) gives a detailed discussion on the prior belief regarding learnability.

I summarize the sequence of decision-making as follows.

1. The principal receives the true signal $s \in \{B, \phi\}$.

2. The principal decides the feedback strategy and transmits $\hat{s}$.

3. Only after observing $\hat{s} = B$, the agent has the ability development opportunity, and decides whether or not to develop his ability level.

4. The cost of project implementation is realized. After observing the realized cost, the agent chooses the effort level $e \in \{0, 1\}$ to implement the project.

5. The outcome of the project is realized.

4.3. Analysis

In this section, I analyze (i) the project implementation; (ii) the ability development; and (iii) the feedback strategy, in order. The proofs not in the main text are found in Appendix C.

4.3.1. Project Implementation

I start by analyzing the agent's effort choice to implement the project. Suppose the principal transmits $\hat{s} = \phi$. Then, the project succeeds with probability $\theta^S(r)$ if it is implemented. Thus, the agent implements the project ($e = 1$) if and only if

$$\theta^S(r) \geq c.$$

Since $\theta^S(r)$ is increasing in r, the agent, observing $\hat{s} = \phi$, is more likely to implement the project if the transmitted signal is more reliable. By transmitting $\hat{s} = \phi$, the principal expects the agent to implement the project ($e = 1$) with probability $F(\theta^S(r))$.

Suppose the principal tells the bad news ($\hat{s} = B$). Then, given the ability development decision, the project succeeds with probability $\theta^T(i, \alpha_{\mathrm{A}})$, if it is implemented. Thus, the agent chooses $e = 1$ if and only if

$$\theta^T(i, \alpha_{\mathrm{A}}) \geq c.$$

If the agent develops his ability level ($i = 1$), then the agent with higher α_{A} implements the project with higher probability. By telling the bad news ($\hat{s} = B$), the principal expects the agent to implement the project with probability $F(\theta^T(i, \alpha_{\mathrm{A}}))$. Throughout this chapter, I assume that $F(\theta^S(1)) = F(\theta^T(1, 1)) = F(\theta_H) < 1$.

4.3.2. Ability Development

Next, I analyze the ability development decision. First, suppose that the principal tells the good news($\hat{s} = \phi$). Then the agent has no ability development opportunity, and his expected benefit is calculated as follows:

$$U^S(r) = \int_0^{\theta^S(r)} (\theta^S(r) - c) dF(c) = \int_0^{\theta^S(r)} F(c) dc.$$

Next, suppose the principal tells the bad news ($\hat{s} = B$). Then, the agent has the ability development opportunity. The agent's expected benefit differs with i and is expressed by

$$U^T(i, \alpha_{\mathrm{A}}) = \begin{cases} U^T(1, \alpha_{\mathrm{A}}) & \text{if } i = 1 \\ U^T(0) & \text{if } i = 0, \end{cases}$$

where $U^T(1, \alpha_{\mathrm{A}})$ and $U^T(0)$ are calculated as follows:

$$U^T(1, \alpha_{\mathrm{A}}) = \int_0^{\theta^T(1, \alpha_{\mathrm{A}})} (\theta^T(1, \alpha_{\mathrm{A}}) - c) dF(c) = \int_0^{\theta^T(1, \alpha_{\mathrm{A}})} F(c) dc,$$
$$U^T(0) = \int_0^{\theta_L} (\theta_L - c) dF(c) = \int_0^{\theta_L} F(c) dc.$$

The agent chooses $i = 1$ if and only if $U^T(1, \alpha_{\text{A}}) - U^T(0) \geq d$ holds. The following lemma shows the condition under which the agent, observing $\hat{s} = B$, chooses $i = 1$.

Lemma 4. *Suppose $\hat{s} = B$. Then, there exists $d^T(\alpha_{\text{A}}) \geq 0$ such that the agent chooses $i = 1$ if and only if $d^T(\alpha_{\text{A}}) \geq d$, where $d^T(\alpha_{\text{A}})$ is increasing in α_{A}.*

Proof. I can rewrite $U^T(1, \alpha_{\text{A}}) - U^T(0) \geq d$ as

$$\int_0^{\theta^T(1,\alpha_{\text{A}})} F(c)dc - \int_0^{\theta_L} F(c)dc \geq d,$$
$$\Longleftrightarrow d^T(\alpha_{\text{A}}) \equiv \int_{\theta_L}^{\theta^T(1,\alpha_{\text{A}})} F(c)dc \geq d.$$

Since $\theta^T(1, \alpha_{\text{A}}) \geq \theta_L$, for all α_{A}, $d^T(\alpha_{\text{A}}) \geq 0$, for all α_{A}. □

This is an intuitive result. The agent develops his ability level if the development cost is sufficiently low. The threshold level of the development cost depends on the agent's belief regarding learnability and which is increasing in α_{A}. Hence, the agent with higher learnability confidence is more likely to learn after receiving the bad news.

4.3.3. Feedback

In this section, I shows the optimal feedback strategy. Since the principal always tells $\hat{s} = \phi$ after observing $s = \phi$, I focus on the case where she observes the bad news ($s = B$).

First, suppose the principal suppresses the bad news ($h = 0$) and transmits $\hat{s} = \phi$. Then, the agent does not develop and his expected ability level is given by $\theta^S(r)$. The principal's expected benefit is written as follows:

$$V^S(r) = F(\theta^S(r))\theta_L.$$

If the principal suppresses the bad news, she cannot induce the agent to develop his ability and increase the success probability of the implemented project. However, she can increase the probability of the project implementation. This is because, by suppressing the bad news, the agent's expected ability level perceived by the agent increases from θ_L to $\theta^S(r)$. I call this the *status effect.* The benefit from the status effect depends on, and is increasing in the reliability of the transmitted signal.

Next, suppose the principal tells the bad news truthfully ($\hat{s} = B$). Then the principal's expected benefit differs with i and is given by

$$V^T(i, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) = \begin{cases} V^T(1, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) & \text{if } i = 1 \\ V^T(0) & \text{if } i = 0, \end{cases}$$

where

$$V^T(1, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) = F(\theta^T(1, \alpha_{\mathrm{A}}))\theta^T(1, \alpha_{\mathrm{P}}),$$
$$V^T(0) = F(\theta_L)\theta_L.$$

If the principal tells the bad news truthfully, she can induce the agent to develop his ability level. Although it depends on the assumption, I call this the *motivational effect.* In Section 4.4.1, I derive this effect endogenously. When the agent develops, both the probability of the project implementation ($e = 1$) and the success probability of the implemented project as perceived by the principal are increased. This is the principal's benefit from the motivational effect, which is increasing in the principal's and the agent's belief regarding learnability.

On the other hand, without the ability development($i = 0$), by telling the bad news($\hat{s} = B$), the probability of the project implementation goes down to $F(\theta_L)$.

The principal's optimal feedback strategy, given i, α_{A}, α_{P} and r, is a solution to the following maximization:

$$h \in \arg\max[hV^T(i, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) + (1 - h)V^S(r)].$$

I focus on a perfect Bayesian equilibrium (PBE) which satisfies the following conditions:

- The principal's feedback strategy is optimal, given the agent's estimation of the signal's reliability.
- The agent estimates the reliability of the signal according to Bayes' rule and using the principal's feedback strategy.

In the main analysis, I assume the ability development is costless($d = 0$), for analytical simplicity. Under this assumption, the agent, observing the bad news, develops for all α_{A}. In Section 4.4.1, I derive the optimal feedback strategy when the ability development is costly.

Benchmark: Common Prior Belief

Since it will be helpful to understand the main result, I first show the optimal feedback strategy under a common prior assumption. To this end, instead suppose that the principal and the agent share a common prior belief regarding the learnability, denoted by α.

Only after transmitting $\hat{s} = B$, some notations are changed. The agent, observing $\hat{s} = B$, implements the project if and only if $\theta^T(i, \alpha) \geq c$, and the principal expects the project to be implemented with probability $F(\theta^T(i, \alpha))$. Following Lemma 4, the agent, observing $\hat{s} = B$, chooses $i = 1$ if and only if $d \leq d^T(\alpha)$. The principal's expected benefit when she tells the bad news ($\hat{s} = B$) is rewritten as follows:

$$V^T(i, \alpha) = \begin{cases} V^T(1, \alpha) & \text{if } i = 1 \\ V^T(0) & \text{if } i = 0, \end{cases}$$

where

$$V^T(1, \alpha) = V^T(1, \alpha, \alpha) = F(\theta^T(1, \alpha))\theta^T(1, \alpha).$$

In the following proposition, I derive and characterize the set of equilibria under a common prior assumption.

Proposition 13. *Suppose $d = 0$ and the principal and the agent share a common prior belief. Then, there exist $\underline{A}$ and $\overline{A}$, satisfying $0 < \underline{A} < \overline{A} < 1$, such that*

Case 1: *For $\alpha > \overline{A}$, the unique PBE is $h = 1$.*

Case 2: *For $\alpha < \underline{A}$, the unique PBE is $h = 0$.*

Case 3: *For $\alpha \in [\underline{A}, \overline{A}]$, the unique PBE is $h = h(\alpha)$, where $h(\alpha)$ is increasing in α.*

The optimal feedback strategy depends on the belief regarding learnability, α. The relevant comparison is between $V^T(1, \alpha)$ and $V^S(r)$. The net gain from telling the truth is given by

$$V^T(1, \alpha) - V^S(r) = F(\theta^T(1, \alpha))\theta^T(1, \alpha) - F(\theta^S(r))\theta_L.$$

By telling the bad news truthfully, the success probability perceived by the principal is increased from θ_L to $\theta^T(1, \alpha)$. Thus, the optimal feedback strategy is telling the truth ($h = 1$), for sufficiently high α (Case 1). On the other hand, after suppressing the bad news, the principal can increase the probability of project implementation by the status effect. Thus, for low α (Case 2), the benefit from the status effect dominates, and telling the good news becomes beneficial. Hence, the principal may suppress the bad news even if the ability development is costless.

For the intermediate value of α (Case 3), a pure-strategy equilibrium does not exist, and the bad news is partially revealed. In this case, the principal prefers to tell the bad news ($h = 1$) if the reliability, r is low. However, the reliability is increasing in h, and $r = 1$ under $h = 1$. For high r, the principal prefers to suppress the bad news ($h = 0$), but under $h = 0$, r decreases to q. Hence, there exists only the mixed-strategy equilibrium($h = h(\alpha)$). Since $h(\alpha)$ is increasing in α, the principal is more likely to tell the bad news for higher α.

Differing Prior Beliefs

I move on to the analysis under the differing prior assumption. From now, I adopt the following assumption for analytical simplicity,

Assumption 4. *$\theta_H/\theta_L \geq F(\theta_H)/F(\theta_L)$.*

For example, if c is distributed uniformly on $[0, 1]$, then this assumption is satisfied.

I first present the result in the following proposition and then discuss intuition later.

Proposition 14. *Suppose $d = 0$ and Assumption 1. Then there exist $\overline{A}(\alpha_{\mathrm{A}}) \in [0, 1]$ and $\underline{A}(\alpha_{\mathrm{A}}) \in [0, 1]$, satisfying $\underline{A}(\alpha_{\mathrm{A}}) < \overline{A}(\alpha_{\mathrm{A}})$, for all α_{A}, such that the optimal feedback strategy is given as follows:*

Case 1: *For $\alpha_{\mathrm{P}} > \overline{A}(\alpha_{\mathrm{A}})$, the unique PBE is $h = 1$.*

Case 2: *For $\alpha_{\mathrm{A}} < q$ and $\alpha_{\mathrm{P}} < \underline{A}(\alpha_{\mathrm{A}})$, the unique PBE is $h = 0$. (For $\alpha_{\mathrm{A}} \geq q$, $\underline{A}(\alpha_{\mathrm{A}}) = 0$, and Case 2 does not exist.)*

Case 3: *For $\alpha_{\mathrm{P}} \in [\underline{A}(\alpha_{\mathrm{A}}), \overline{A}(\alpha_{\mathrm{A}})]$, the unique PBE is $h = h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$, where $h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ is increasing in $(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$.*

Under the differing prior assumption, the agent's belief and the principal's belief regarding learnability are separated. The effect of the ability development on the success probability perceived by the principal depends only on α_{P}. Thus, if α_{P} is high (Case 1), the benefit from the motivational effect dominates. Hence, for high α_{P}, telling the bad news ($h = 1$) is the only equilibrium, even if the agent's belief α_{A} is low. This result differs from the previous analysis. Of course, telling the bad news ($h = 1$) is more likely to be optimal for higher α_{A} .

On the other hand, for low α_{P} (Case 2), the principal suppresses the bad news if α_{A} is also sufficiently low. This result is aligned with the benchmark case. If both α_{P} and α_{A} are low, the benefit from the status effect dominates. Note that for $\alpha_{\mathrm{A}} > q$, the benefit from the motivational effect is so large that suppressing the bad new($h = 0$) cannot be optimal.

Lastly, for the intermediate values of α_{P} (Case 3), the principal partially reveals the bad news, and there is no equilibrium with a pure strategy. The intuition is similar to the corresponding case under a common prior assumption.

Role of Differing Prior Assumption

Now, I discuss the role of the differing prior assumption. To this end, I compare the threshold levels of beliefs. For analytical simplicity, I assume c is uniformly distributed over $[0, 1]$. The following corollary shows the result.

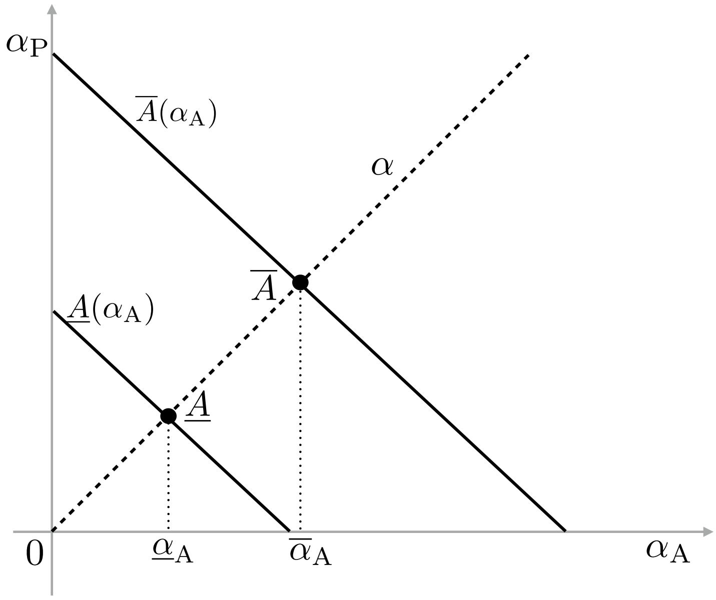
Corollary 4. *Suppose $d = 0$ and c is uniformly distributed on $[0, 1]$. Then there exist $\underline{\alpha}_{\mathrm{A}} \in (0, q)$ and $\overline{\alpha}_{\mathrm{A}} \in (0, 1)$ such that*

- $\overline{A}(\alpha_{\mathrm{A}}) \leq \overline{A}$ *holds if* $\alpha_{\mathrm{A}} \geq \overline{\alpha}_{\mathrm{A}}$.
- $\underline{A}(\alpha_{\mathrm{A}}) \leq \underline{A}$ *holds if* $\alpha_{\mathrm{A}} \geq \underline{\alpha}_{\mathrm{A}}$.

Figure 4.1 illustrates the result. The dashed line(the 45-degree line) represents the level of common prior belief $\alpha = \alpha_{\mathrm{P}} = \alpha_{\mathrm{A}}$. The upper solid line displays $\overline{A}(\alpha_{\mathrm{A}})$, and the lower solid line displays $\underline{A}(\alpha_{\mathrm{A}})$. First, the principal is more likely to tell bad news under differing priors. For example, if the principal and the agent share a common prior $\alpha' \in (\underline{A}, \overline{A})$, then the principal reveals bad news partially. However, suppose the principal and the agent openly disagree, and the agent has sufficiently high learnability confidence($\alpha_{\mathrm{A}} > \overline{\alpha}_{\mathrm{A}}$). Then, the principal tells the bad news ($h = 1$) even if her prior belief is given by α'. Instead, suppose that the agent's belief is given by α'. Then the principal tells the bad news ($h = 1$) if her belief is high. Since the benefit from motivational effect is increasing in the principal's and the agent's belief, their strong learnability confidence induces telling the truth.

Next, the principal is less likely to suppress bad news under differing priors. If the principal and agent share a common prior, denoted by α'', which is lower than $\underline{A}$. Then the principal suppresses bad news. Under the differing priors, the principal who has α'' will reveal bad news partially if the agent's belief is sufficiently high. Instead, if the agent's belief is given by α'', then the principal tells the bad news with positive probability if her belief regarding learnability is high.

Figure 4.1.: Comparison between Common Prior and Differing Priors



4.4. Extension

In this section, I extend my model. In Section 4.4.1, I show the optimal feedback strategy when the ability development is costly. In Section 4.4.2, I discuss the alternative specification of the ability development. Since it clearly illustrates the result, I adopt the common prior assumption in this section.

4.4.1. Costly Ability Development

In the main analysis, I focus on the optimal feedback strategy when the ability development is costless. Now, instead I derive the optimal feedback strategy when the ability development is costly ($d > 0$).

As I showed, the agent, observing the bad news, chooses $i = 1$ if and only if $d \geq d^T(\alpha)$. I can define A as the solution to $d = d^T(\alpha)$. Thus, the agent chooses $i = 1$ for $\alpha \geq A$ and $i = 0$ for $\alpha < A$. Note that A can be greater 1. By comparing $\underline{A}$, $\overline{A}$, and A, I can obtain the optimal feedback strategy.

Corollary 5. *Suppose $d > 0$. There exist $\underline{A}^*$ and $\overline{A}^*$, satisfying $0 < \underline{A}^* < \overline{A}^*$, such that the optimal feedback strategy is given as follows:*

Case 1: *For $\alpha > \overline{A}^*$, the unique PBE is $h = 1$.*

Case 2: *For $\alpha < \underline{A}^*$, the unique PBE is $h = 0$.*

Case 3: *For $\alpha \in [\underline{A}^*, \overline{A}^*]$, then there exist following three PBEs: (i) $h = 0$; (ii) $h = 1$; and (iii) $h = h(\alpha)$.*

When the ability development is costly, the result is similar to the main analysis. The principal suppresses the bad news for the low value of α (Case 2), and tells the bad news for the high value of α (Case 1). For the intermediate value of α (Case 3), there are three PBEs. Since the ability development is costly, the agent does not develop for $\alpha < A$. Thus, for $\alpha < A$, the agent chooses $i = 0$, and hence the benefit from the status effect dominates. If the ability development cost is low ($A < \underline{A}$), then for $\alpha \in [\underline{A}, \overline{A}]$, the agent chooses $i = 1$, and the principal partially reveals the bad news. If A is so high that $A > \overline{A}$, then at $\alpha = A$, the agent develops ($i = 1$), and the principal prefers to tell the bad news.

4.4.2. Alternative Specification

In the main analysis, I assume that the agent has the ability development opportunity if and only if the principal tells the bad news. In this section, I derive the motivational effect endogenously. To this end, suppose instead that the agent can develop his ability level regardless of the transmitted signal. Since, after observing the bad news ($\hat{s} = B$), there is no difference in the project implementation and the ability development from the main analysis, I revisit both after the agent observes the good news ($\hat{s} = \phi$).

First, I examine the project implementation. Now, after observing $\hat{s} = \phi$, the agent has the ability development opportunity, and thus, his expected ability level is rewritten as follows:

$$\tilde{\theta}^S(i, r, \alpha) = \begin{cases} \tilde{\theta}^S(1, r, \alpha) & \text{if } i = 1 \\ \theta^S(r) & \text{if } i = 0, \end{cases}$$

where

$$\tilde{\theta}^S(1, r, \alpha) = r\theta_H + (1 - r)(\theta_L + \alpha\Delta_\theta).$$

Then, given i, the agent, observing $\hat{s} = \phi$, chooses $e = 1$ if and only if $\theta^S(i, r, \alpha) \geq c$. The principal expects the agent to implement the project with probability $F(\theta^S(i, r, \alpha))$.

Next, I analyze the ability development when $\hat{s} = \phi$. After observing $\hat{s} = \phi$, the agent's expected benefit differs with i and is rewritten as

$$\tilde{U}^S(i, r, \alpha) = \begin{cases} \tilde{U}^S(1, r, \alpha) & \text{if } i = 1 \\ U^S(r) & \text{if } i = 0, \end{cases}$$

where $\tilde{U}^S(1, r, \alpha)$ is calculated as follows

$$\tilde{U}^S(1, r, \alpha) = \int_0^{\tilde{\theta}^S(1,r,\alpha)} (\tilde{\theta}^S(1, r, \alpha) - c)dF(c) = \int_0^{\tilde{\theta}^S(1,r,\alpha)} F(c)dc.$$

After observing $\hat{s} = \phi$, the agent chooses $i = 1$ if and only if $\tilde{U}^S(1, r, \alpha) - d \geq U^S(r)$, which is satisfied if d is sufficiently low. The following lemma shows the threshold level of the ability development cost.

Lemma 5. *Suppose $\hat{s} = \phi$. Then there exists $d^S(r, \alpha) \geq 0$, such that the agent chooses $i = 1$ if and only if $d \leq d^S(r, \alpha)$.*

Proof. $\tilde{U}^S(1, r, \alpha) - d \geq U^S(r)$ is rewritten as follows:

$$\int_0^{\tilde{\theta}^S(1,r,\alpha)} F(c)dc - d \geq \int_0^{\theta^S(r)} F(c)dc,$$
$$\iff d^S(r, \alpha) \equiv \int_{\theta^S(r)}^{\tilde{\theta}^S(1,r,\alpha)} F(c)dc \geq d.$$

Since $\tilde{\theta}^S(1, r, \alpha) \geq \theta^S(r)$, for all $r \in [q, 1]$ and $\alpha \in [0, 1]$, $d^S(r, \alpha) \geq 0$ for all r, α. $\square$

Now, I compare the threshold levels of d. For analytical simplicity, I assume that c is uniformly distributed over $[0, 1]$.

Proposition 15. *Suppose c is uniformly distributed on $[0, 1]$. Then, $d^T(\alpha) \geq d^S(r, \alpha)$ holds for all r, α, if $\theta_L \geq \frac{\theta_H}{2}$.*

Under this alternative setting, the agent is more likely to develop his ability after observing $\hat{s} = B$ if $\theta_L \geq \theta_H/2$. Hence, *the motivational effect arises endogenously.* In the proof, I define the difference between $d^T(\alpha)$ and $d^S(r, \alpha)$ by $\Delta_d(\alpha, r) = d^T(\alpha) - d^S(r, \alpha)$. Both $\Delta_d(1, r) > 0$ and $\Delta_d(0, r) = 0$ hold for all r, and if $\theta_L \geq \theta_H/2$, $\Delta_d(\alpha, r)$ is increasing in α. Hence, $\Delta_d(\alpha, r) \geq 0$ for all r and α if $\theta_L \geq \theta_H/2$.

Finally, I discuss the optimal feedback strategy under the alternative specification. I can define A^T as the solution to $d = d^T(\alpha)$ and $A^S(r)$ as the solution to $d = d^S(r, \alpha)$. Suppose $\theta_L \geq \theta_H/2$. Then, following from Proposition 15, $A^T \leq A^S(r)$ for all r. Thus, there exists a non-empty interval $[A^T, A^S(r)]$ such that, for $\alpha \in [A^T, A^S(r)]$, the agent develops if and only if he observes the bad news. In this interval, the net benefit from telling the bad is written by $V^T(1, \alpha) - V^S(r)$. Hence, under the alternative specification, with some conditions, I can obtain the same result as in the main analysis.

4.5. Concluding Remarks

This study examines the interaction between feedback and human capital acquisition in organizations. I derive the condition under which the principal, observing the bad news, tells the bad news truthfully. Telling the bad news has the following two effects: (1) it may hurt the agent's incentive to implement the project; but (2) it can induce the agent's ability development. Under the common prior assumption, if the belief regarding learnability is sufficiently high, then the benefit from the motivational effect dominates and the principal tells the bad news. Under the differing priors, the principal tells the bad news truthfully if her belief regarding learnability is high. Furthermore, the principal is more likely to tell the bad news under the differing priors.

Chapter 5.

Conclusion

In this dissertation, I have shown the incentive effects of heterogeneous preferences and priors in organizations. In this chapter, I summarize the results and discuss some possible extensions.

Information Acquisition, Decision Making, and Implementation in Organizations

In chapter 2, we show the three reasons why the preference diversity is optimal under the assumption of symmetric information. Under the heterogeneous organization, (i) DM is more likely to be reactive to the signal and select her unfavorite project; (ii) IM has a stronger incentive to gather information to avoid ending up with no additional information under the heterogeneous organization; (iii) the interaction between reactivity effect and the ignorance-avoiding effect.

If the additional information is so informative that DM is reactive, the heterogeneous organization has an additional advantage from IM's stronger incentive to gather information. Hence, the owner prefers the heterogeneous organization if the quality of additional information is high and the marginal cost of information acquisition is low.

In this study, the owner cannot offer any contingent wages. If the owner can offer an incentive contract to induce project implementation or information acquisition, does the heterogeneous organization still have information advantage? The contract design by the owner is an interesting direction for future research.

Optimal Contracts for Human Capital Acquisition and Organizational Beliefs

In chapter 3, I examine the effect of differing priors on the incentive contract in the dynamic moral hazard model and derive the conflicting effects of the agent's belief regarding the learnability. First, the optimal wage after failure is decreasing in the agent's belief regarding learnability by the positive incentive effect. Second, the optimal wage in the first period is increasing in the agent's belief regarding learnability. The principal's belief regarding learnability determines which effect dominates.

The principal prefers the agent with similar learnability confidence. Hence, the main result shows that organizations tend to share the homogenous beliefs regarding the learnability. However, under some condition, the principal who does not believe in the learnability prefers the agent with higher learnability confidence. This result implies the heterogeneous priors can be optimal for organizations.

I focus on the contract design to induce the human capital acquisition. In the related literature, for example, Prendergast (1993) investigates the effect of promotions on the incentive to acquire human capital. For future research, it is an interesting direction to examine the effect of heterogeneous beliefs regarding the learnability in a promotion model.

Furthermore, in my model, the levels of the principal's and the agent's beliefs regarding the learnability are fixed. In reality, workers can learn about the learnability, and their disagreement may disappear. It is natural extension to study the learning about the learnability in organizations.

Optimality of Straight Talk: Information Feedback and Human Capital Acquisition

In chapter 4, I study the incentive effect of differing priors when the principal cannot offer any monetary incentive. Instead, the principal has superior information about the agent's ability and can provide feedback. I first show the effect of the belief regarding learnability on the project implementation and the ability development. After observing bad news, the agent with higher learnability confidence is more likely to develop his ability. On the other hand, the agent, observing good news, highly estimates his ability level, and thus, is more likely to implement the project.

The principal's optimal feedback strategy is determined by her belief regarding learnability. The principal with strong learnability confidence, tells bad news truthfully even if the agent has less learnability confidence. Instead, if both the principal and the agent have low learnability confidence, then the principal prefers to suppress bad news.

In this study, I assume the signal is hard information. Then the principal can suppress but cannot fabricate the signal. However, in organizations, a supervisor may have soft information. Thus, it must be a fruitful extension to study an optimal feedback strategy when a signal is soft information.

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Appendix A.

Appendix to Chapter 2

A1. Proofs

Proof of Lemma 2

We first show $\alpha_{\text{hom}} \geq \alpha_\gamma \equiv \gamma/(1+\gamma)$, where $\alpha_\gamma \in (1/2, 1)$ is the solution to $\alpha b_L = (1-\alpha)b_H$. By the definition of α_{hom}, the claim is true if

$$\alpha_\gamma \leq (1-\alpha_\gamma)\Gamma,$$

which is equivalent to $\Gamma \geq \gamma$, that is, Assumption 2.

Now for all $\alpha > \alpha_{\text{hom}} \geq \alpha_\gamma$,

$$\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K(\alpha b_L) - K\left(\frac{b_H}{2}\right) > \frac{1}{2}K(\alpha b_H) + \frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right) > 0,$$

by the convexity of $K(\cdot)$, which completes the proof.

Proof of Proposition 1

First suppose $\alpha \leq \alpha_{\text{het}}$ so that DM is non-reactive under either organization. In this case, the only difference between $\pi^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\pi^{\text{N}}_{\text{het}}(\alpha, k)$ is in IM's private benefit b. For $b \in \{b_L, b_H\}$,

$$\begin{aligned}
&\frac{\partial}{\partial b}\left(\frac{1}{2}K(\alpha b) + \frac{1}{2}K((1-\alpha)b) - K\left(\frac{b}{2}\right)\right) \\
&= \frac{1}{2}\left[\alpha F(\alpha b) + (1-\alpha)F((1-\alpha)b) - F\left(\frac{b}{2}\right)\right] \\
&> 0
\end{aligned}$$

holds for $\alpha > 1/2$ because $\alpha F(\alpha b) + (1-\alpha)F((1-\alpha)b) - F(b/2)$ is strictly increasing in α by Assumption 3. Hence $\pi^{\text{N}}_{\text{hom}}(\alpha, k) \geq \pi^{\text{N}}_{\text{het}}(\alpha, k)$ holds, with strict inequality if $\pi^{\text{N}}_{\text{het}}(\alpha, k) < 1$, which is equivalent to $k < \overline{k}^{\text{N}}_{\text{het}}(\alpha)$.

Second suppose $\alpha > \alpha_{\text{hom}}$. From the definitions, it is easy to see $\pi^{\text{R}}_{\text{het}}(\alpha, k) \geq \pi^{\text{R}}_{\text{hom}}(\alpha, k)$ holds, with strict inequality if $\pi^{\text{R}}_{\text{hom}}(\alpha, k) < 1$, which is equivalent to $k < \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$.

Finally, suppose $\alpha_{\text{het}} < \alpha \leq \alpha_{\text{hom}}$. The relevant comparison is then between $\pi^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\pi^{\text{R}}_{\text{het}}(\alpha, k)$. Suppose $\pi^{\text{R}}_{\text{het}}(\alpha, k) < 1$ and $\pi^{\text{N}}_{\text{hom}}(\alpha, k) < 1$. Then the sign of $\pi^{\text{R}}_{\text{het}}(\alpha, k) - \pi^{\text{N}}_{\text{hom}}(\alpha, k)$ is equal to that of

$$\begin{aligned}
&\left[\frac{1}{2}K(\alpha b_L) - K\left(\frac{b_L}{2}\right)\right] - \left[\frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right)\right] \\
&\quad > \frac{1}{2}K\left(\frac{b_L}{2}\right) - \frac{1}{2}K\left(\frac{b_H}{2}\right) + K\left(\frac{b_H}{2}\right) - K\left(\frac{b_L}{2}\right) = \frac{1}{2}\left[K\left(\frac{b_H}{2}\right) - K\left(\frac{b_L}{2}\right)\right] > 0,
\end{aligned}$$

and hence $\pi^{\text{R}}_{\text{het}}(\alpha, k) \geq \pi^{\text{N}}_{\text{hom}}(\alpha, k)$ holds, with strict inequality if $k < \overline{k}^{\text{N}}_{\text{hom}}(\alpha)$. This completes the proof.

Proof of Proposition 2

The exact formulas of $V_{\text{hom}}(\alpha, k)$ and $V_{\text{het}}(\alpha, k)$, the success probability of homogeneous organization and heterogenous organization, respectively, are given as follows:

$$
\begin{aligned}
&V_{\text{hom}}(\alpha, k) \\
&\quad = \begin{cases} V_{\text{hom}}^{\text{N}}(\alpha, k) & \text{if } \alpha \le \alpha_{\text{hom}} \\ V_{\text{hom}}^{\text{R}}(\alpha, k) & \text{if } \alpha > \alpha_{\text{hom}} \end{cases} \\
&\quad = \begin{cases} \pi_{\text{hom}}^{\text{N}}(\alpha, k)\frac{1}{2}\left[p(b_H, 1, \sigma = 1) + p(b_H, 1, \sigma = 2)\right] + (1 - \pi_{\text{hom}}^{\text{N}}(\alpha, k))p(b_H, 1, \sigma = \phi) & \text{if } \alpha \le \alpha_{\text{hom}} \\ \pi_{\text{hom}}^{\text{R}}(\alpha, k)\frac{1}{2}\left[p(b_H, 1, \sigma = 1) + p(b_L, 2, \sigma = 2)\right] + (1 - \pi_{\text{hom}}^{\text{R}}(\alpha, k))p(b_H, 1, \sigma = \phi) & \text{if } \alpha > \alpha_{\text{hom}} \end{cases} \\
&\quad = \begin{cases} \frac{1}{2}\left(F\left(\frac{b_H}{2}\right) + \pi_{\text{hom}}^{\text{N}}(\alpha, k)\left[\alpha F(\alpha b_H) + (1-\alpha)F((1-\alpha)b_H) - F\left(\frac{b_H}{2}\right)\right]\right) & \text{if } \alpha \le \alpha_{\text{hom}} \\ \frac{1}{2}\left(F\left(\frac{b_H}{2}\right) + \pi_{\text{hom}}^{\text{R}}(\alpha, k)\left[\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\right]\right) & \text{if } \alpha > \alpha_{\text{hom}} \end{cases}
\end{aligned}
$$

$$
\begin{aligned}
&V_{\text{het}}(\alpha, k) \\
&\quad = \begin{cases} V_{\text{het}}^{\text{N}}(\alpha, k) & \text{if } \alpha \le \alpha_{\text{het}} \\ V_{\text{het}}^{\text{R}}(\alpha, k) & \text{if } \alpha > \alpha_{\text{het}} \end{cases} \\
&\quad = \begin{cases} \pi_{\text{het}}^{\text{N}}(\alpha, k)\frac{1}{2}\left[p(b_L, 1, \sigma = 1) + p(b_L, 1, \sigma = 2)\right] + (1 - \pi_{\text{het}}^{\text{N}}(\alpha, k))p(b_L, 1, \sigma = \phi) & \text{if } \alpha \le \alpha_{\text{het}} \\ \pi_{\text{het}}^{\text{R}}(\alpha, k)\frac{1}{2}\left[p(b_L, 1, \sigma = 1) + p(b_H, 2, \sigma = 2)\right] + (1 - \pi_{\text{het}}^{\text{R}}(\alpha, k))p(b_L, 1, \sigma = \phi) & \text{if } \alpha > \alpha_{\text{het}} \end{cases} \\
&\quad = \begin{cases} \frac{1}{2}\left(F\left(\frac{b_L}{2}\right) + \pi_{\text{het}}^{\text{N}}(\alpha, k)\left[\alpha F(\alpha b_L) + (1-\alpha)F((1-\alpha)b_L) - F\left(\frac{b_L}{2}\right)\right]\right) & \text{if } \alpha \le \alpha_{\text{het}} \\ \frac{1}{2}\left(F\left(\frac{b_L}{2}\right) + \pi_{\text{het}}^{\text{R}}(\alpha, k)\left[\alpha F(\alpha b_L) + \alpha F(\alpha b_H) - F\left(\frac{b_L}{2}\right)\right]\right) & \text{if } \alpha > \alpha_{\text{het}} \end{cases}
\end{aligned}
$$

The proof consists of three lemmas.

Lemma A1. *Under Assumptions 1–3,* $V_{\text{het}}(\alpha, k) < V_{\text{hom}}(\alpha, k)$ *for all* $\alpha \in (1/2, \alpha_{\text{het}}]$

and $k > 0$

Proof. Obvious from the definitions of the owner's expected profits. This proves Case 1 of Proposition 2. $\square$

Lemma A2. *Suppose Assumptions 1–3 and* $\alpha \in (\alpha_{\text{hom}}, 1]$*. There exists* $k(\alpha) \in (0, \bar{k}^{\text{R}}_{\text{het}}(\alpha))$ *such that* $V_{\text{het}}(\alpha) < V_{\text{hom}}(\alpha)$ *for all* $k < k(\alpha)$*, and* $V_{\text{het}}(\alpha) \geq V_{\text{hom}}(\alpha)$ *for all* $k \geq k(\alpha)$*, with strict inequality if* $k \in (k(\alpha), \bar{k}^{\text{R}}_{\text{hom}}(\alpha))$*.*

Proof. Since DM is reactive under either organization for $\alpha \in (\alpha_{\text{hom}}, 1]$, the relevant comparison is between $V^{\text{R}}_{\text{hom}}(\alpha, k)$ and $V^{\text{R}}_{\text{het}}(\alpha, k)$. Define $\Delta^{\text{R}}_{V}(\alpha, k)$ by

$$\begin{aligned} \Delta^{\text{R}}_{V}(\alpha, k) &= V^{\text{R}}_{\text{het}}(\alpha, k) - V^{\text{R}}_{\text{hom}}(\alpha, k) \\ &= \frac{1}{2}\Bigg(\Delta^{\text{R}}_{\pi}(\alpha, k)\left[\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\right] \\ &\qquad - (1 - \pi^{\text{R}}_{\text{het}}(\alpha, k))\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right]\Bigg), \end{aligned} \tag{A1}$$

where $\Delta^{\text{R}}_{\pi}(\alpha, k) \equiv \pi^{\text{R}}_{\text{het}}(\alpha, k) - \pi^{\text{R}}_{\text{hom}}(\alpha, k)$, which, by definition, does not depend on α if $k < \bar{k}^{\text{R}}_{\text{het}}(\alpha)$. The expression in the first square bracket is positive since $\alpha F(\alpha b_L) > (1-\alpha)F((1-\alpha)b_H)$ at $\alpha = \alpha_{\text{hom}}$ and by Assumption 3. The expression in the second bracket is obviously positive.

Fix $\alpha \in (\alpha_{\text{hom}}, 1]$. $\Delta^{\text{R}}_{V}(\alpha, k)$ is negative as $k \downarrow 0$ (and hence $\pi^{\text{R}}_{h}(\alpha, k) \downarrow 0$, $h = \text{hom}, \text{het}$), increasing in k since both $\pi^{\text{R}}_{\text{het}}(\alpha, k)$ and $\Delta^{\text{R}}_{\pi}(\alpha, k)$ are increasing in k, and positive at $k = \bar{k}^{\text{R}}_{\text{het}}(\alpha)$. Hence there exists $k(\alpha)$ satisfying $0 < k(\alpha) < \bar{k}^{\text{R}}_{\text{het}}(\alpha)$ such that $\Delta^{\text{R}}_{V}(\alpha, k(\alpha)) = 0$. The conclusion then follows. $\square$

Lemma A3. *Suppose Assumptions 1–3 and* $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$*. There exists* $k(\alpha) \in (0, \bar{k}^{\text{R}}_{\text{het}}(\alpha))$ *such that* $V_{\text{het}}(\alpha) < V_{\text{hom}}(\alpha)$ *for all* $k < k(\alpha)$*, and* $V_{\text{het}}(\alpha) \geq V_{\text{hom}}(\alpha)$ *for all* $k \geq k(\alpha)$*, with strict inequality if* $k \in (k(\alpha), \bar{k}^{\text{N}}_{\text{hom}}(\alpha))$*.*

Proof. DM is non-reactive (reactive) under the homogeneous (respectively, heterogenous) organization for $\alpha \in (\hat{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$. The relevant comparison is hence between

$V^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)$ and $V^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k)$. Define $\Delta^{\mathrm{RN}}_{V}(\alpha, k)$ by

$$\begin{aligned}
\Delta^{\mathrm{RN}}_{V}(\alpha, k) &= V^{\mathrm{R}}_{\mathrm{het}}(\alpha, k) - V^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k) \\
&= \frac{1}{2}\Bigg(\pi^{\mathrm{R}}_{\mathrm{het}}(\alpha, k) \left[\alpha F(\alpha b_L) - (1-\alpha) F((1-\alpha) b_H) + F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right) \right] \\
&\quad - \left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right) \right] \\
&\quad + \Delta^{\mathrm{RN}}_{\pi}(\alpha, k) \left[\alpha F(\alpha b_H) + (1-\alpha) F((1-\alpha) b_H) - F\left(\frac{b_H}{2}\right) \right] \Bigg),
\end{aligned} \tag{A2}$$

where $\Delta^{\mathrm{RN}}_{\pi} \equiv \pi^{\mathrm{R}}_{\mathrm{het}}(\alpha, k) - \pi^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k)$. The expressions in three square brackets are all positive: the expression in the first square bracket following $\pi^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)$ is positive because it is increasing in α and is positive at $\alpha = 1/2$, and the expression in the third square bracket is positive by Assumption 3.

Fix $\alpha \in (\hat{\alpha}_{\mathrm{het}}, \alpha_{\mathrm{hom}}]$. $\Delta^{\mathrm{RN}}_{V}(\alpha, k)$ is negative as $k \downarrow 0$, increasing in k since both $\pi^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)$ and $\Delta^{\mathrm{RN}}_{\pi}(\alpha, k)$ are increasing in k. And $\Delta^{\mathrm{RN}}_{V}(\alpha, k)$ is positive at $k = \overline{k}^{\mathrm{R}}_{\mathrm{het}}(\alpha)$. Hence there exists $k(\alpha) \in (0, \overline{k}^{\mathrm{R}}_{\mathrm{het}}(\alpha))$ such that $\Delta^{\mathrm{RN}}_{V}(\alpha, k(\alpha)) = 0$. The conclusion then follows. $\square$

Proof of Corollary 1

Define $\underline{k}_1, \overline{k}_1$ by $\underline{k}_1 = k(\alpha_{\mathrm{hom}})$ and $\overline{k}_1 = k(\alpha_{\mathrm{het}})$, respectively. Then $\underline{k}_1 < \overline{k}_1 < \overline{k}_{\mathrm{het}}(\alpha_{\mathrm{het}})$, and $\underline{k}_1 < k(\alpha)$ and $k(\alpha) < \overline{k}_1$ hold for all $\alpha \in (\alpha_{\mathrm{het}}, \alpha_{\mathrm{hom}})$. Hence if $k < \underline{k}_1$, $V_{\mathrm{het}}(\alpha, k) < V_{\mathrm{hom}}(\alpha, k)$ for all $\alpha \in (\alpha_{\mathrm{het}}, \alpha_{\mathrm{hom}}]$; and if $k > \overline{k}_1$, $V_{\mathrm{het}}(\alpha, k) \geq V_{\mathrm{hom}}(\alpha, k)$ for all $\alpha \in (\alpha_{\mathrm{het}}, \alpha_{\mathrm{hom}}]$, with strict inequality if $k \in (\overline{k}_1, \overline{k}_{\mathrm{hom}}(\alpha))$.

Next, define $\underline{k}_2, \overline{k}_2$ by $\underline{k}_2 = k(1)$ and $\overline{k}_2 = k(\alpha_{\mathrm{hom}})$, respectively. Then $\underline{k}_2 < \overline{k}_2 < \overline{k}_{\mathrm{het}}(\alpha_{\mathrm{hom}}) < \overline{k}_{\mathrm{het}}(\hat{\alpha}_{\mathrm{het}})$, and $\underline{k}_2 < k(\alpha)$ and $k(\alpha) < \overline{k}_2$ hold for all $\alpha \in (\alpha_{\mathrm{hom}}, 1)$. Hence if $k < \underline{k}_2$, $V_{\mathrm{het}}(\alpha, k) < V_{\mathrm{hom}}(\alpha, k)$ for all $\alpha \in (\alpha_{\mathrm{hom}}, 1]$; and if $k > \overline{k}_2$, $V_{\mathrm{het}}(\alpha, k) \geq V_{\mathrm{hom}}(\alpha, k)$ for all $\alpha \in (\alpha_{\mathrm{hom}}, 1]$, with strict inequality if $k \in (\overline{k}_2, \overline{k}_{\mathrm{hom}}(\alpha))$.

The conclusion then follows from $\underline{k} \equiv \min\{\underline{k}_1, \underline{k}_2\}$ and $\overline{k} \equiv \max\{\overline{k}_1, \overline{k}_2\}$.

Proof of Proposition 3

Proof of (a)

First suppose $\alpha \leq \alpha_{\text{hom}}$ and hence $V_{\text{hom}}(\alpha, k) = V^{\text{N}}_{\text{hom}}(\alpha, k)$. The proof is obvious if $k \geq \overline{k}^{\text{N}}_{\text{hom}}(\alpha)$, and thus assume $k < \overline{k}^{\text{N}}_{\text{hom}}(\alpha)$. It is easy to show $\partial \pi^{\text{N}}_{\text{hom}}(\alpha, k)/\partial k > 0$ and $\partial^2 \pi^{\text{N}}_{\text{hom}}(\alpha, k)/\partial k \partial \alpha > 0$. Then

$$\begin{aligned}\frac{\partial^2 V^{\text{N}}_{\text{hom}}}{\partial k \partial \alpha}(\alpha, k) &= \frac{1}{2} \frac{\partial^2 \pi^{\text{N}}_{\text{hom}}}{\partial k \partial \alpha}(\alpha, k) \left[\alpha F(\alpha b_H) + (1-\alpha) F((1-\alpha) b_H) - F\left(\frac{b_H}{2}\right)\right] \\ &\quad + \frac{1}{2} \frac{\partial \pi^{\text{N}}_{\text{hom}}}{\partial k}(\alpha, k) \left[F(\alpha b_H) - F((1-\alpha) b_H) + \alpha b_H f(\alpha b_H) - (1-\alpha) b_H f((1-\alpha) b_H)\right] \\ &> 0.\end{aligned}$$

Suppose next $\alpha > \alpha_{\text{hom}}$ and hence $V_{\text{hom}}(\alpha, k) = V^{\text{R}}_{\text{hom}}(\alpha, k)$. The proof is obvious if $k \geq \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$, and thus assume $k < \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$. It is easy to show $\partial \pi^{\text{R}}_{\text{hom}}(\alpha, k)/\partial k > 0$ and $\partial^2 \pi^{\text{R}}_{\text{hom}}(\alpha, k)/\partial k \partial \alpha > 0$. Then

$$\begin{aligned}\frac{\partial^2 V^{\text{R}}_{\text{hom}}}{\partial k \partial \alpha}(\alpha, k) &= \frac{1}{2} \frac{\partial^2 \pi^{\text{R}}_{\text{hom}}}{\partial k \partial \alpha}(\alpha, k) \left[\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\right] \\ &\quad + \frac{1}{2} \frac{\partial \pi^{\text{R}}_{\text{hom}}}{\partial k}(\alpha, k) \left[F(\alpha b_H) + F(\alpha b_L) + \alpha b_H f(\alpha b_H) + \alpha b_L f(\alpha b_L)\right] \\ &> 0.\end{aligned}$$

Finally suppose $\alpha > \alpha_{\text{hom}} > \alpha' > \max\{\alpha_{\text{het}}, \alpha_\gamma\}$ and $k < \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$. Then

$$
\begin{aligned}
&\frac{\partial V^{\text{R}}_{\text{hom}}}{\partial k}(\alpha, k) - \frac{\partial V^{\text{N}}_{\text{hom}}}{\partial k}(\alpha', k) \\
&\quad = \frac{1}{2}\frac{\partial \pi^{\text{R}}_{\text{hom}}}{\partial k}(\alpha, k)\left[\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\right] \\
&\qquad - \frac{1}{2}\frac{\partial \pi^{\text{N}}_{\text{hom}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_H) + (1-\alpha')F((1-\alpha')b_H) - F\left(\frac{b_H}{2}\right)\right] \\
&\quad \geq \frac{1}{2}\frac{\partial \pi^{\text{R}}_{\text{hom}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_H) + \alpha' F(\alpha' b_L) - F\left(\frac{b_H}{2}\right)\right] \\
&\qquad - \frac{1}{2}\frac{\partial \pi^{\text{N}}_{\text{hom}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_H) + (1-\alpha')F((1-\alpha')b_H) - F\left(\frac{b_H}{2}\right)\right] \\
&\quad > 0,
\end{aligned}
$$

where the first inequality is due to $\alpha > \alpha'$ and the second inequality follows from $\alpha' > \alpha_\gamma$. This completes the proof of (a).

Proof of (b)

First suppose $\alpha \leq \alpha_{\text{het}}$ and hence $V_{\text{het}}(\alpha, k) = V^{\text{N}}_{\text{het}}(\alpha, k)$. The proof is obvious if $k \geq \overline{k}^{\text{N}}_{\text{het}}(\alpha)$, and thus assume $k < \overline{k}^{\text{N}}_{\text{het}}(\alpha)$. It is easy to show $\partial \pi^{\text{N}}_{\text{het}}(\alpha, k)/\partial k > 0$ and $\partial^2 \pi^{\text{N}}_{\text{het}}(\alpha, k)/\partial k \partial \alpha > 0$. Then

$$
\begin{aligned}
\frac{\partial^2 V^{\text{N}}_{\text{het}}}{\partial k \partial \alpha}(\alpha, k) &= \frac{1}{2}\frac{\partial^2 \pi^{\text{N}}_{\text{het}}}{\partial k \partial \alpha}(\alpha, k)\left[\alpha F(\alpha b_L) + (1-\alpha)F((1-\alpha)b_L) - F\left(\frac{b_L}{2}\right)\right] \\
&\quad + \frac{1}{2}\frac{\partial \pi^{\text{N}}_{\text{het}}}{\partial k}(\alpha, k)\left[F(\alpha b_L) - F((1-\alpha)b_L) + \alpha b_L f(\alpha b_L) - (1-\alpha)b_L f((1-\alpha)b_L)\right] \\
&> 0.
\end{aligned}
$$

Suppose next $\alpha > \alpha_{\text{het}}$ and hence $V_{\text{het}}(\alpha, k) = V^{\text{R}}_{\text{het}}(\alpha, k)$. The proof is obvious if $k \geq \overline{k}^{\text{R}}_{\text{het}}(\alpha)$, and thus assume $k < \overline{k}^{\text{R}}_{\text{het}}(\alpha)$. It is easy to show $\partial \pi^{\text{R}}_{\text{het}}(\alpha, k)/\partial k > 0$ and

$\partial^2 \pi^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)/\partial k \partial \alpha > 0$. Then

$$
\begin{aligned}
\frac{\partial^2 V^{\mathrm{R}}_{\mathrm{het}}}{\partial k \partial \alpha}(\alpha, k) = \frac{1}{2}\frac{\partial^2 \pi^{\mathrm{R}}_{\mathrm{het}}}{\partial k \partial \alpha}(\alpha, k) &\left[\alpha F(\alpha b_L) + \alpha F(\alpha b_H) - F\left(\frac{b_L}{2}\right)\right] \\
&+ \frac{1}{2}\frac{\partial \pi^{\mathrm{R}}_{\mathrm{het}}}{\partial k}(\alpha, k)\left[F(\alpha b_L) + F(\alpha b_H) + \alpha b_L f(\alpha b_L) + \alpha b_H f(\alpha b_H)\right] \\
&> 0.
\end{aligned}
$$

Finally suppose $\alpha > \alpha_{\mathrm{het}} > \alpha'$ and $k < \overline{k}^{\mathrm{R}}_{\mathrm{het}}(\alpha)$. Then

$$
\begin{aligned}
&\frac{\partial V^{\mathrm{R}}_{\mathrm{het}}}{\partial k}(\alpha, k) - \frac{\partial V^{\mathrm{N}}_{\mathrm{het}}}{\partial k}(\alpha', k) \\
&= \frac{1}{2}\frac{\partial \pi^{\mathrm{R}}_{\mathrm{het}}}{\partial k}(\alpha, k)\left[\alpha F(\alpha b_L) + \alpha F(\alpha b_H) - F\left(\frac{b_L}{2}\right)\right] \\
&\quad - \frac{1}{2}\frac{\partial \pi^{\mathrm{N}}_{\mathrm{het}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_L) + (1-\alpha')F((1-\alpha')b_L) - F\left(\frac{b_L}{2}\right)\right] \\
&\geq \frac{1}{2}\frac{\partial \pi^{\mathrm{R}}_{\mathrm{het}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_L) + \alpha' F(\alpha' b_H) - F\left(\frac{b_L}{2}\right)\right] \\
&\quad - \frac{1}{2}\frac{\partial \pi^{\mathrm{N}}_{\mathrm{het}}}{\partial k}(\alpha', k)\left[\alpha' F(\alpha' b_L) + (1-\alpha')F((1-\alpha')b_L) - F\left(\frac{b_L}{2}\right)\right] \\
&> 0.
\end{aligned}
$$

This completes the proof of (b).

Proof of (c)

First suppose $\alpha > \alpha_{\mathrm{hom}}$ and hence $V_{\mathrm{het}}(\alpha, k) - V_{\mathrm{het}}(\alpha, k) = \Delta^{\mathrm{R}}_V(\alpha, k)$. It is easy to show $\Delta^{\mathrm{R}}_V(\alpha, k)$ is increasing in (α, k). Next suppose $\alpha \in (\alpha_{\mathrm{het}}, \alpha_{\mathrm{hom}}]$ and hence $V_{\mathrm{het}}(\alpha, k) - V_{\mathrm{het}}(\alpha, k) = \Delta^{\mathrm{RN}}_V(\alpha, k)$. It is again easy to show $\Delta^{\mathrm{RN}}_V(\alpha, k)$ is increasing in (α, k).

Finally suppose $\alpha > \alpha_{\mathrm{hom}} > \alpha' > \alpha_{\mathrm{het}}$. Then

$$
\Delta^{\mathrm{R}}_V(\alpha, k) - \Delta^{\mathrm{RN}}_V(\alpha', k) > \Delta^{\mathrm{R}}_V(\alpha', k) - \Delta^{\mathrm{RN}}_V(\alpha', k) > 0.
$$

This completes the proof of (c).

Proof of Proposition 5

Suppose $\alpha > \alpha_{\text{het}}$ and consider IM's reporting strategy first, given DM's strategy $d^*_{\text{het}}(\sigma) = \sigma$ for $\sigma \in \{1, 2\}$ and $d^*_{\text{het}}(\phi) = 1$. IM, observing $\sigma = 1$, chooses to report $\tilde{\sigma} = 1$ if and only if $\alpha > \alpha_\gamma$ holds as shown in the discussion preceding Proposition 4. Second, it is obvious to show that IM's optimal reporting choice is $\tilde{\sigma} = 2$ when he observes $\sigma \in \{\phi, 2\}$.

Next, consider DM's project choice given IM's reporting strategy and optimal information-gathering effort. $d^*_{\text{het}}(1) = 1$ is obviously optimal, and hence suppose DM receives $\tilde{\sigma} = 2$. Her posterior beliefs are $\mathbb{P}[\sigma = 2 \mid \tilde{\sigma} = 2] = \tilde{\pi}/(2 - \tilde{\pi})$ and $\mathbb{P}[\sigma = \phi \mid \tilde{\sigma} = 2] = 2(1 - \tilde{\pi})/(2 - \tilde{\pi})$ where $\tilde{\pi} \in (0, 1)$ is DM's belief of IM's information-gathering effort. In an equilibrium, $\tilde{\pi}$ must be equal to IM's optimal level of information-gathering effort. If DM chooses project 1, her expected benefit is

$$\begin{aligned}
&\mathbb{P}[\sigma = 2 \mid \tilde{\sigma} = 2](1-\alpha)F((1-\alpha)b_L)B_H + \mathbb{P}[\sigma = \phi \mid \tilde{\sigma} = 2]\frac{1}{2}F\left(\frac{b_L}{2}\right)B_H \\
&= \frac{B_H}{2-\tilde{\pi}}\left[\tilde{\pi}(1-\alpha)F((1-\alpha)b_L) + (1-\tilde{\pi})F\left(\frac{b_L}{2}\right)\right].
\end{aligned}$$

If DM chooses project 2, her expected benefit is

$$\begin{aligned}
&\mathbb{P}[\sigma = 2 \mid \tilde{\sigma} = 2]\alpha F(\alpha b_H)B_L + \mathbb{P}[\sigma = \phi \mid \tilde{\sigma} = 2]\frac{1}{2}F\left(\frac{b_H}{2}\right)B_L \\
&= \frac{B_L}{2-\tilde{\pi}}\left[\tilde{\pi}\alpha F(\alpha b_H) + (1-\tilde{\pi})F\left(\frac{b_H}{2}\right)\right].
\end{aligned}$$

Then DM does not deviate from $d^*_{\text{het}}(2) = 2$ if and only if the following condition is satisfied:

$$\alpha F(\alpha b_H) - (1-\alpha)F((1-\alpha)b_L)\Gamma > \frac{1-\tilde{\pi}}{\tilde{\pi}}F\left(\frac{b_L}{2}\right)\left(\Gamma - \frac{F(b_H/2)}{F(b_L/2)}\right). \tag{A3}$$

The left-hand side of (A3) is strictly decreasing in Γ and strictly increasing in α, and is equal to zero at $\alpha = \alpha_{\text{het}}$. The right-hand side is strictly increasing in Γ and is zero if Assumption 1 holds with equality. Hence for each $\alpha > \alpha_{\text{het}}$, there exists an upper bound on Γ, denoted by $\tilde{\Gamma}(\tilde{\pi}, \alpha) > 1$, such that (A3) holds if and only if $\Gamma < \tilde{\Gamma}(\tilde{\pi}, \alpha)$: $\tilde{\Gamma}(\tilde{\pi}, \alpha)$ is DM's bias that satisfies (A3) with equality, and is strictly increasing in $\tilde{\pi}$ and α, with $\tilde{\Gamma}(\tilde{\pi}, \alpha) \downarrow F(b_H/2)/F(b_L/2) > 1$ as $\alpha \downarrow \alpha_{\text{het}}$.

Finally, consider IM's optimal information-gathering effort. Suppose $\alpha > \tilde{\alpha}_{\text{het}} = \max\{\alpha_{\text{het}}, \alpha_\gamma\}$ (as defined in Proposition 4). Since DM is reactive, IM's expected payoff from information acquisition under the heterogeneous organization is written as

$$\frac{\pi}{2}\left[K(\alpha b_L) + K(\alpha b_H)\right] + (1-\pi)K\left(\frac{b_H}{2}\right) - \eta(\pi; k).$$

Then IM's optimal level of information-gathering effort, denoted by $\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$, is obtained as follows:

$$\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k) = \min\left\{k\left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K(\alpha b_H) - K\left(\frac{b_H}{2}\right)\right), 1\right\} = \pi^{\text{R}}_{\text{hom}}(\alpha, k).$$

Note that $\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha) > 0$ is satisfied for all $\alpha > \tilde{\alpha}_{\text{het}}$ since $\tilde{\alpha}_{\text{het}} \geq \alpha_\gamma$. IM prefers to report $\tilde{\sigma} = 2$ following uninformative signal $\sigma = \phi$ because by reporting $\tilde{\sigma} = 2$, he can induce his favorite project to be selected. In other words, the informational advantage of the heterogeneous organization due to the ignorance-avoiding effect identified by Proposition 1 no longer exists, and hence IM's incentive to avoid no additional information becomes weaker and his optimal effort decreases from $\pi^{\text{R}}_{\text{het}}(\alpha, k)$ to $\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$.

Since $\tilde{\pi} = \tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ must hold in equilibrium, we rewrite $\tilde{\Gamma}(\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k), \alpha)$ as $\tilde{\Gamma}(\alpha, k)$, which is increasing in α and k. Condition $\tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k) = \pi^{\text{R}}_{\text{hom}}(\alpha, k) < 1$ yields $k < \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$. This completes the proof.

Note that if $k \geq \overline{k}^{\text{R}}_{\text{hom}}(\alpha)$, the condition on Γ would become $\alpha F(\alpha b_H) > (1-\alpha)F((1-\alpha)b_L)\Gamma$, which is always satisfied for $\alpha > \alpha_{\text{het}}$ by the definition of α_{het}. In this case, the partial communication equilibrium is in fact identical to the full communication equilibrium.

Proof of Proposition 6

Both Cases 1 and 3 are obvious, and hence suppose $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$. All we need to show is $\pi^{\text{R}}_{\text{hom}}(\alpha, k) \geq \pi^{\text{N}}_{\text{hom}}(\alpha, k)$, which is satisfied since the inequality holds for $\alpha \geq \alpha_\gamma > \alpha_{\text{het}}$ (see the discussion following Lemma 2).

Proof of Proposition 7

Cases (a) and (c) are obvious from the definition of $\tilde{V}_{\text{het}}(\alpha, k)$. In Case (b) where $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$, the relevant comparison is between $\tilde{V}_{\text{het}}(\alpha, k) = V^{\text{R}}_{\text{hom}}(\alpha, k)$ and $V^{\text{N}}_{\text{hom}}(\alpha, k)$:

$$\begin{aligned}
\tilde{\Delta}^{\text{RN}}_{V}(\alpha, k) &\equiv V^{\text{R}}_{\text{hom}}(\alpha, k) - V^{\text{N}}_{\text{hom}}(\alpha, k) \\
&= \frac{1}{2}\bigg(\tilde{\Delta}^{\text{RN}}_{\pi}(\alpha, k)\left[\alpha F(\alpha b_H) + (1-\alpha)F((1-\alpha)b_H) - F\left(\frac{b_H}{2}\right)\right] \\
&\quad + \tilde{\pi}^{\text{R}}_{\text{het}}(\alpha, k)(\alpha F(\alpha b_L) - (1-\alpha)F((1-\alpha)b_H))\bigg) > 0,
\end{aligned} \tag{A4}$$

where $\tilde{\Delta}^{\text{RN}}_{\pi}(\alpha, k) \equiv \pi^{\text{R}}_{\text{hom}}(\alpha, k) - \pi^{\text{N}}_{\text{hom}}(\alpha, k)$. The expression in the square bracket is positive for all $\alpha > 1/2$ (see the proof of Proposition 1), and $\alpha F(\alpha b_L) - (1-\alpha)F((1-\alpha)b_H) > 0$ as well as $\tilde{\Delta}^{\text{RN}}_{\pi}(\alpha, k) > 0$ holds by $\alpha > \alpha_\gamma > \hat{\alpha}$. Hence $\tilde{\Delta}^{\text{RN}}_{V}(\alpha, k) > 0$ for all $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$ and $k > 0$, which completes the proof.

A2. Additional Results

Less Biased Decision Maker

DM's Project Choice

In the main analysis we adopt Assumption 1, $\Gamma \geq F(b_H/2)/F(b_L/2)$, implying that without additional information DM's optimal project choice is her favorite project 1 under heterogenous organization. In this section we instead assume

$$\Gamma < \frac{F(b_H/2)}{F(b_L/2)} \tag{A5}$$

so that under heterogenous organization, DM, observing $\sigma = \phi$, prefers to select project 2 because it is more important for DM to induce IM to implement the project than to choose her favorite one.

DM's optimal project choice under homogeneous organization is the same as in the main text, and hence we focus on the heterogenous organization. We have already seen $d^*_{\text{het}}(\phi) = 2$. Suppose next $\sigma = 1$. DM chooses her favorite project 1 ($d^*_{\text{het}}(1) = 1$) if and only if

$$\alpha F(\alpha b_L) B_H \geq (1-\alpha) F((1-\alpha) b_H) B_L$$

Note the left-hand side is increasing and the right-hand side is decreasing in α, and (A5) implies that the condition does not hold when $\alpha = 1/2$. Therefore there exists $\breve{\alpha}_{\text{het}} \in (1/2, 1)$ such that $d^*_{\text{het}}(1) = 2$ for $\alpha < \breve{\alpha}_{\text{het}}$ and $d^*_{\text{het}}(1) = 1$ for $\alpha \geq \breve{\alpha}_{\text{het}}$, where $\breve{\alpha}_{\text{het}}$ is defined by

$$\breve{\alpha}_{\text{het}} F(\breve{\alpha}_{\text{het}} b_L)\Gamma = (1-\breve{\alpha}_{\text{het}}) F((1-\breve{\alpha}_{\text{het}}) b_H)$$

It is easy to show $\breve{\alpha}_{\text{het}} < \alpha_{\text{hom}}$ holds.

Suppose finally $\sigma = 2$. DM then always chooses project 2 which is more likely to be implemented and succeed. The project choice by DM is then summarized as follows.

Lemma A4. *Under* (A5)*, there exist thresholds* α_{hom} *and* $\breve{\alpha}_{\text{het}}$ *satisfying* $1/2 < \breve{\alpha}_{\text{het}} < \alpha_{\text{hom}} < 1$*, such that DM's optimal project choice is* $d^*_{\text{hom}}(\phi) = 1$ *and* $d^*_{\text{het}}(\phi) = 2$ *for all* $\alpha \in (1/2, 1]$*; and for informative signals, it is given as follows:*

Case 1: *If* $\alpha \in (1/2, \breve{\alpha}_{\text{het}})$*, then* $d^*_{\text{hom}}(\sigma) = 1$ *and* $d^*_{\text{het}}(\sigma) = 2$ *for* $\sigma \in \{1, 2\}$*;*

Case 2: *If* $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$*, then* $d^*_{\text{hom}}(\sigma) = 1$ *and* $d^*_{\text{het}}(\sigma) = \sigma$ *for* $\sigma \in \{1, 2\}$*;*

Case 3: *If* $\alpha \in (\alpha_{\text{hom}}, 1]$*, then* $d^*_{\text{hom}}(\sigma) = d^*_{\text{het}}(\sigma) = \sigma$ *for* $\sigma \in \{1, 2\}$*.*

IM's Incentive to Gather Additional Information

While IM's optimal information-gathering effort under homogeneous organization is the same as $\pi_{\text{hom}}(\alpha, k)$, we need to make an important remark. In the main analysis we also make Assumption 2 ($\Gamma \geq \gamma$), which is implied by Assumption 1 if $F(\cdot)$ is convex, and is equivalent to Assumption 1 if $F(x) = x$, that is, $\tilde{c}$ is uniformly distributed over $[0, 1]$. In this section we may alternatively assume

$$\Gamma < \gamma. \tag{A6}$$

If (A6) is satisfied, $\alpha_\gamma > \alpha_{\text{hom}}$ must hold, and hence $\pi_{\text{hom}}(\alpha, k)$ jumps *down* at $\alpha = \alpha_{\text{hom}}$ in contrast to the case of $\Gamma > \gamma$ in which $\alpha_\gamma < \alpha_{\text{hom}}$ and hence $\pi_{\text{hom}}(\alpha, k)$ jumps up. Intuitively, under (A6) DM's reaction to signal $\sigma = 1$ leading to her project choice against IM's implementation motive damages his incentive to gather information more than DM's choice of the project more likely to succeed raises his incentive.

Suppose that the organization is heterogenous. IM's optimal information-gathering effort $\breve{\pi}_{\text{het}}(\alpha, k)$ is derived as follows.

$$\breve{\pi}_{\text{het}}(\alpha, k) = \begin{cases} \breve{\pi}^{\text{N}}_{\text{het}}(\alpha, k) & \text{if } \alpha < \breve{\alpha}_{\text{het}} \\ \breve{\pi}^{\text{R}}_{\text{het}}(\alpha, k) & \text{if } \alpha \geq \breve{\alpha}_{\text{het}} \end{cases}$$

where $\breve{\pi}^{\text{N}}_{\text{het}}(\alpha, k)$ and $\breve{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ are obtained as follows.

$$\breve{\pi}^{\text{N}}_{\text{het}}(\alpha, k) = \pi^{\text{N}}_{\text{hom}}(\alpha, k) = \min\left\{k\left(\frac{1}{2}K(\alpha b_H) + \frac{1}{2}K((1-\alpha)b_H) - K\left(\frac{b_H}{2}\right)\right), 1\right\};$$
$$\breve{\pi}^{\text{R}}_{\text{het}}(\alpha, k) = \pi^{\text{R}}_{\text{hom}}(\alpha, k) = \min\left\{k\left(\frac{1}{2}K(\alpha b_L) + \frac{1}{2}K(\alpha b_H) - K\left(\frac{b_H}{2}\right)\right), 1\right\}$$

Note that since $\breve{\alpha}_{\text{het}} < \alpha_\gamma$ holds, $\breve{\pi}_{\text{het}}(\alpha, k)$ also drops discontinuously at $\alpha = \breve{\alpha}_{\text{het}}$, possibly to zero.

Proposition A1. *Under* (A5)*, IM's incentive to gather additional information differs between homogeneous and heterogeneous organizations as follows.*

Case 1: *Suppose $\alpha \in (1/2, \breve{\alpha}_{\text{het}})$. Then $\pi_{\text{hom}}(\alpha, k) = \breve{\pi}_{\text{het}}(\alpha, k)$ holds for all $k > 0$.*

Case 2: *Suppose $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$. If $\Gamma < \gamma$, then $\pi_{\text{hom}}(\alpha, k) > \breve{\pi}_{\text{het}}(\alpha, k)$ holds for all $k > 0$. If instead $\Gamma > \gamma$, then $\pi_{\text{hom}}(\alpha, k) > \breve{\pi}_{\text{het}}(\alpha, k)$ for $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_\gamma)$ and $\pi_{\text{hom}}(\alpha, k) < \breve{\pi}_{\text{het}}(\alpha, k)$ for $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$ hold for all $k > 0$.*

Case 3: *Suppose $\alpha \in (\alpha_{\text{hom}}, 1]$. Then $\pi_{\text{hom}}(\alpha, k) = \breve{\pi}_{\text{het}}(\alpha, k)$ holds for all $k > 0$.*

Proof. Cases 1 and 3 are obvious from the definition. Hence suppose $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$ and compare $\breve{\pi}_{\text{het}}(\alpha, k) = \pi^{\text{R}}_{\text{hom}}(\alpha, k)$ with $\pi^{\text{N}}_{\text{hom}}(\alpha, k)$.

If $\Gamma < \gamma$, then $\alpha_{\text{hom}} < \alpha_\gamma$ and hence $\alpha b_L < (1-\alpha)b_H$ holds for all $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$. Therefore $\pi_{\text{hom}}(\alpha, k) > \breve{\pi}_{\text{het}}(\alpha, k)$ for all $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}}]$.

If $\Gamma > \gamma$, then $\alpha_\gamma \in (\breve{\alpha}_{\text{het}}, \alpha_{\text{hom}})$ must be true, and hence $\pi_{\text{hom}}(\alpha, k) > \breve{\pi}_{\text{het}}(\alpha, k)$ for $\alpha \in [\breve{\alpha}_{\text{het}}, \alpha_\gamma)$ and $\pi_{\text{hom}}(\alpha, k) < \breve{\pi}_{\text{het}}(\alpha, k)$ for $\alpha \in (\alpha_\gamma, \alpha_{\text{hom}}]$. $\square$

Note that as we assert in Section 4 of the paper, IM's optimal effort under heterogenous organization is never higher than that under homogeneous organization if $\Gamma < \gamma$.

Information Acquisition by the Decision Maker

In the model in the main text, IM gathers additional information. In this section, we instead suppose that DM gathers additional information. Note that DM's project choice and IM's implementation decision do not change from those in the main analysis.

Under the homogeneous organization, DM's optimal information-gathering effort is solved as follows.

$$\hat{\pi}_{\text{hom}}(\alpha, k) = \begin{cases} \hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) & \text{if } \alpha \leq \alpha_{\text{hom}} \\ \hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) & \text{if } \alpha > \alpha_{\text{hom}} \end{cases}$$

where $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k)$ are defined by

$$\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) = \min\left\{k\frac{B_L}{2}\left(\alpha F(\alpha b_H)\Gamma + (1-\alpha)F((1-\alpha)b_H)\Gamma - F\left(\frac{b_H}{2}\right)\Gamma\right), 1\right\};$$
$$\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) = \min\left\{k\frac{B_L}{2}\left(\alpha F(\alpha b_H)\Gamma + \alpha F(\alpha b_L) - F\left(\frac{b_H}{2}\right)\Gamma\right), 1\right\}.$$

Both of them are strictly increasing in α and k (unless they are equal to one) and positive for all $\alpha > 1/2$ and k. *Note that in contrast to the case where IM gathers information, there is no discontinuity at* $\alpha = \alpha_{\text{hom}}$.

Under the heterogeneous organization, DM's optimal information-gathering effort is obtained as follows.

$$\hat{\pi}_{\text{het}}(\alpha, k) = \begin{cases} \hat{\pi}^{\text{N}}_{\text{het}}(\alpha, k) & \text{if } \alpha \leq \alpha_{\text{het}} \\ \hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) & \text{if } \alpha > \alpha_{\text{het}} \end{cases}$$

where $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha,k)$ and $\hat{\pi}^{\mathrm{R}}_{\mathrm{hom}}(\alpha,k)$ are defined by

$$\hat{\pi}^{\mathrm{N}}_{\mathrm{het}}(\alpha,k)=\min\left\{k\frac{B_L}{2}\left(\alpha F(\alpha b_L)\Gamma+(1-\alpha)F((1-\alpha)b_L)\Gamma-F\left(\frac{b_L}{2}\right)\Gamma\right),1\right\};$$
$$\hat{\pi}^{\mathrm{R}}_{\mathrm{het}}(\alpha,k)=\min\left\{k\frac{B_L}{2}\left(\alpha F(\alpha b_L)\Gamma+\alpha F(\alpha b_H)-F\left(\frac{b_L}{2}\right)\Gamma\right),1\right\}.$$

Both of them are strictly increasing in α and k (unless they are equal to one) and positive for all $\alpha > 1/2$ and k. *Note again that in contrast to the case where IM gathers information, there is no discontinuity at $\alpha = \alpha_{\mathrm{het}}$.*

First suppose $\tilde{c}$ is uniformly distributed over $[0,1]$. Then we show that DM's information-gathering effort under the homogeneous organization is *always* higher than that under the heterogenous organization if DM's bias is large.

Proposition A2. *Suppose $\tilde{c}$ is uniformly distributed over $[0,1]$. Then there exists a threshold $\overline{\Gamma}$ such that DM's incentive to gather information differs with homogeneous and heterogenous organizations as follows.*

Case 1: *Suppose $\alpha \in (1/2, \alpha_{\mathrm{het}}]$. Then $\hat{\pi}_{\mathrm{hom}}(\alpha,k) \geq \hat{\pi}_{\mathrm{het}}(\alpha,k)$ holds for all $k > 0$. The inequality is strict if $\hat{\pi}_{\mathrm{het}}(\alpha,k) < 1$.*

Case 2: *Suppose $\alpha \in (\alpha_{\mathrm{het}}, 1]$. Then $\hat{\pi}_{\mathrm{hom}}(\alpha,k) \geq \hat{\pi}_{\mathrm{het}}(\alpha,k)$ holds for all $k > 0$ if $\Gamma > \overline{\Gamma}$. The inequality is strict if $\hat{\pi}_{\mathrm{het}}(\alpha,k) < 1$.*

Proof. First, suppose $\alpha \in (1/2, \alpha_{\mathrm{het}}]$. Then the relevant comparison is between $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha,k)$ and $\hat{\pi}^{\mathrm{N}}_{\mathrm{het}}(\alpha,k)$. Suppose $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha,k) < 1$ and $\hat{\pi}^{\mathrm{N}}_{\mathrm{het}}(\alpha,k) < 1$. Then the sign of $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha,k) - \hat{\pi}^{\mathrm{N}}_{\mathrm{het}}(\alpha,k)$ is equivalent to that of

$$\left(\alpha^2+(1-\alpha)^2-\frac{1}{2}\right)(b_H-b_L).$$

Since $\alpha^2+(1-\alpha)^2 > 1/2$ for all $\alpha > 1/2$ and $b_H > b_L$, $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha,k) > \hat{\pi}^{\mathrm{N}}_{\mathrm{het}}(\alpha,k)$ holds for all $\alpha > 1/2$, which completes the proof of Case 1.

Second, suppose $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$. Then the relevant comparison is between $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$. Suppose $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) < 1$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) < 1$. Then the sign of $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) - \hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ is equal to that of

$$\begin{aligned}
&\alpha^2\gamma\Gamma + (1-\alpha)^2\gamma\Gamma - \frac{1}{2}\gamma\Gamma - \alpha^2\Gamma - \alpha^2\gamma + \frac{1}{2}\Gamma \\
&\quad \geq \alpha^2\gamma\Gamma + \alpha^2 - \frac{1}{2}\gamma\Gamma - \alpha^2\Gamma - \alpha^2\gamma + \frac{1}{2}\Gamma \\
&\quad = \alpha^2(\gamma-1)(\Gamma-1) - \frac{1}{2}(\gamma-1)\Gamma,
\end{aligned}$$

where the inequality follows from $\alpha \leq \alpha_{\text{hom}}$. Thus $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) > \hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ holds if

$$\alpha^2 > \frac{\Gamma/2}{\Gamma-1}. \tag{A7}$$

If (A7) holds at $\alpha = \alpha_{\text{het}}$, then it holds for all $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$. Using $\alpha_{\text{het}} = \sqrt{\Gamma}/(\sqrt{\Gamma} + \sqrt{\gamma})$ yields the condition under which (A7) holds at $\alpha = \alpha_{\text{het}}$ as follows:

$$\Gamma > \left(\sqrt{\gamma} + \sqrt{2+2\gamma}\right)^2.$$

Denote the right-hand side by $\overline{\Gamma}$. It is easy to show $\overline{\Gamma} > \gamma$.

Finally, suppose $\alpha \in (\alpha_{\text{hom}}, 1]$. Then the relevant comparison is between $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$. If the following condition is satisfied, then $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) > \hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ holds, supposing $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) < 1$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) < 1$.

$$\alpha^2(\gamma-1)(\Gamma-1) - \frac{1}{2}(\gamma-1)\Gamma > 0.$$

We have already shown that this condition holds for all $\alpha \in (\alpha_{\text{hom}}, 1]$ if $\Gamma > \overline{\Gamma}$. This completes the proof of Case 3. □

Next, we extend the result to the case of the general distribution function. To simplify the analysis, we make the following assumption.

Assumption 5. *$xf(x)$ is (weakly) convex in $x > 0$.*

Under this assumption, we show that DM exerts more information-gathering effort under the homogeneous organization than under the heterogenous organization if DM's bias is sufficiently large. The following proposition summarizes the result.

Proposition A3. *Under Assumption 5, there exists a threshold $\overline{\Gamma}_g$ such that DM's incentive to gather information differs with homogeneous and heterogeneous organizations as follows.*

Case 1: *Suppose $\alpha \in (1/2, \alpha_{\text{het}}]$. Then $\hat{\pi}_{\text{hom}}(\alpha, k) \geq \hat{\pi}_{\text{het}}(\alpha, k)$ holds for all $k > 0$. The inequality is strict if $\hat{\pi}^{\text{N}}_{\text{het}}(\alpha, k) < 1$.*

Case 2: *Suppose $\alpha \in (\alpha_{\text{het}}, 1]$. Then $\hat{\pi}_{\text{hom}}(\alpha, k) \geq \hat{\pi}_{\text{het}}(\alpha, k)$ holds for all $k > 0$ if $\Gamma > \overline{\Gamma}_g$. The inequality is strict if $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) < 1$.*

Proof. First, suppose $\alpha \in (1/2, \alpha_{\text{het}}]$. Then the relevant comparison is between $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{N}}_{\text{het}}(\alpha, k)$.

$$\begin{aligned}
&\frac{\partial}{\partial b}\left(\alpha F(\alpha b) + (1-\alpha)F((1-\alpha)b) - F\left(\frac{b}{2}\right)\right) \\
&\quad = \alpha^2 f(\alpha b) + (1-\alpha)^2 f((1-\alpha)b) - \frac{1}{2} f\left(\frac{b}{2}\right) > 0.
\end{aligned}$$

The left-hand side is positive at $\alpha = 1$ and is equal to 0 at $\alpha = 1/2$, and it is increasing in α under Assumption 5. Hence, for all $\alpha > 1/2$, $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) \geq \hat{\pi}^{\text{N}}_{\text{het}}(\alpha, k)$ holds under (5), and the inequality is strict if $\hat{\pi}^{\text{N}}_{\text{het}}(\alpha, k) < 1$. This complete the proof of Case 1.

Next, suppose $\alpha \in (\alpha_{\text{het}}, \alpha_{\text{hom}}]$. Then the relevant comparison is between $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$. Suppose $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k) < 1$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) < 1$. Then the sign of $\hat{\pi}^{\text{N}}_{\text{hom}}(\alpha, k)-$

$\hat{\pi}^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)$ is equal to that of

$$\begin{aligned}
&(\Gamma-1)\alpha F(\alpha b_H) + (1-\alpha)F((1-\alpha)b_H)\Gamma - \alpha F(\alpha b_L)\Gamma - \Gamma\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \\
&\quad \geq (\Gamma-1)\alpha F(\alpha b_H) + \alpha F(\alpha b_L) - \alpha F(\alpha b_L)\Gamma - \Gamma\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \\
&\quad\quad = (\Gamma-1)\left[\alpha F(\alpha b_H) - \alpha F(\alpha b_L)\right] - \Gamma\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right],
\end{aligned}$$

where the inequality follows from $\alpha \leq \alpha_{\mathrm{hom}}$. Thus $\hat{\pi}^{\mathrm{N}}_{\mathrm{hom}}(\alpha, k) \geq \hat{\pi}^{\mathrm{R}}_{\mathrm{het}}(\alpha, k)$ holds if

$$D(\Gamma, \alpha) \equiv (\Gamma-1)\left[\alpha F(\alpha b_H) - \alpha F(\alpha b_L)\right] - \Gamma\left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \geq 0.$$

Since $D(\Gamma, \alpha)$ is increasing in α, $D(\Gamma, \alpha) > 0$ holds for all $\alpha > \alpha_{\mathrm{het}}$ if $D(\Gamma, \alpha_{\mathrm{het}}) \geq 0$. We hence derive the condition under which $D(\Gamma, \alpha_{\mathrm{het}}) \geq 0$ holds. From the definition, α_{het} is increasing function in Γ and thus we can write α_{het} as $\alpha(\Gamma)$ and $D(\Gamma, \alpha_{\mathrm{het}})$ as

$$D(\Gamma, \alpha(\Gamma)) \equiv \Gamma\left(L(\Gamma) - \left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right]\right) - L(\Gamma).$$

where $L(\Gamma) \equiv \alpha(\Gamma)F(\alpha(\Gamma)b_H) - \alpha(\Gamma)F(\alpha(\Gamma)b_L)$. $L(\Gamma)$ is increasing in $\alpha(\Gamma)$ and Γ, and $L(\Gamma) < 1$ for all Γ. Note that $D(\Gamma, \alpha(\Gamma)) < 0$ at $\Gamma = 1$. By differentiating $D(\Gamma, \alpha(\Gamma))$ with respect to Γ, we obtain

$$\frac{dD(\Gamma, \alpha(\Gamma))}{d\Gamma} = L(\Gamma) - \left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] + (\Gamma-1)L'(\Gamma).$$

which is positive if $L(\Gamma) \geq [F(b_H/2) - F(b_L/2)]$. Since $L(\Gamma)$ is increasing in $\alpha(\Gamma)$ and both $L(\Gamma) < [F(b_H/2) - F(b_L/2)]$ at $\alpha(\Gamma) = 1/2$ and $L(\Gamma) > [F(b_H/2) - F(b_L/2)]$ at $\alpha(\Gamma) = 1$ hold, $L(\Gamma) \geq [F(b_H/2) - F(b_L/2)]$ if $\alpha(\Gamma)$ is sufficiently high. $\alpha(\Gamma)$ is increasing in Γ and $\alpha(\Gamma) \to 1$ as $\Gamma \to +\infty$, and thus there exists Γ^* such that $L(\Gamma) \geq [F(b_H/2) - F(b_L/2)]$ holds if $\Gamma \geq \Gamma^*$. Note that Γ^* can be smaller than γ. Define $\Gamma^+ \equiv \max\{\Gamma^*, \gamma\}$. Then $D(\Gamma, \alpha(\Gamma)) < 0$ at $\Gamma = 1$ and for $\Gamma > \Gamma^+$, $D(\Gamma, \alpha(\Gamma)) > 0$ as

$\Gamma \to +\infty$. Hence there exists $\overline{\Gamma}_g \in (\Gamma^+, +\infty)$ such that $D(\Gamma, \alpha(\Gamma)) \geq 0$ holds if $\Gamma \geq \overline{\Gamma}_g$.

Finally, suppose $\alpha \in (\alpha_{\text{hom}}, 1]$. Then the relevant comparison is between $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k)$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$. Suppose $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) < 1$ and $\hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k) < 1$. Then $\hat{\pi}^{\text{R}}_{\text{hom}}(\alpha, k) \geq \hat{\pi}^{\text{R}}_{\text{het}}(\alpha, k)$ holds if

$$D(\Gamma, \alpha) = (\Gamma - 1)\left[\alpha F(\alpha b_H) - \alpha F(\alpha b_L)\right] - \Gamma \left[F\left(\frac{b_H}{2}\right) - F\left(\frac{b_L}{2}\right)\right] \geq 0.$$

We have shown that this condition holds for all $\alpha \geq \alpha_{\text{het}}$ if $\Gamma \geq \overline{\Gamma}_g$. This completes the proof of Case 2. $\square$

Appendix B.

Appendix to Chapter 3

B1. Proof of Lemma 3

First, I show the renegotiation-proof contract. Note that (PC) is not effective due to (LL), and thus I can ignore it. Since the principal renegotiates after the first-period outcome is realized and implements $e_t = 1$ for all t with probability one, the renegotiation-proof contract is quit simple as Ma (1991) points out. That is, in the second period, the principal offers wages that are optimal in the corresponding one-shot model.

The optimal wages after success correspond to the optimal wages without learning opportunity in the one-shot model. As in the one-shot model, $w_{sf} = 0$ must be hold at the optimum. Then the incentive compatibility constraint is rewritten by

$$\Delta_p w_{ss} \geq c. \tag{IC2$'_{\mathrm{s}}$}$$

There is no uncertainty in the agent's ability level after success, and then at $r = 1$. Thus, the corresponding wage in the one-shot model is rewritten as $w^*_{ss} = \frac{c}{\Delta_p}$. The constraint (IC2$'_{\mathrm{s}}$) binds at the wages $(w_{ss}, w_{fs}) = (w^*_{ss}, 0)$.

The optimal wages after failure correspond to the optimal wages with the learning opportunity in the one-shot model. As in the one-shot model, $w_{ff} = 0$ must be satisfied at the optimum. Then, given $e_1 = 1$, the incentive compatibility constraint is rewritten as follows.

$$[(q_1 + (1 - q_1)\alpha_{\mathrm{A}})\, p_1 - q_1 p_0]\, w_{fs} \geq c. \tag{IC2$'_{\mathrm{f}}$}$$

While in the one-shot model, the probability that the agent's ability level is high is given by $\mathbb{P}[\theta = \theta_H] = r$, it will be updated after the first-period outcome is realized. After failure, the probability that the agent has high ability level is written as $\mathbb{P}[\theta = \theta_H \mid x_1 = f, 1] = q_1$. Hence, by replacing r with q_1, the optimal wages after failure are given by $(w_{fs}, w_{ff}) = (w^*_{fs}(\alpha_{\mathrm{A}}), 0)$ where $w^*_{fs}(\alpha_{\mathrm{A}})$ is defined by $w^*_{fs}(\alpha_{\mathrm{A}}) = \frac{c}{q_1\Delta_p + (1-q_1)\alpha_{\mathrm{A}} p_1}$. Under the optimal wages $(w^*_{fs}(\alpha_{\mathrm{A}}), 0)$, (IC2$'_{\mathrm{f}}$) holds with equality. It is obvious that the expected implementation cost in the second period is minimized if the principal offers the wages $\{(w^*_{ss}, 0), (w^*_{fs}(\alpha_{\mathrm{A}}), 0)\}$. There are no other contracts under which both the principal and the agent are mutually better off.

Given the effort decisions and the optimal wages in the second period. In the first period, $w_f = 0$ must be hold. Then I can rewrite the incentive compatibility constraint as follows:

$$r\Delta_p w_s + \Delta_{u_2}(\alpha_{\mathrm{A}}) \geq c \tag{IC1$'$}$$

The optimal wage, $w^*_s(\alpha_{\mathrm{A}})$ is determined at (IC1$'$) binds.

Next, I show that $w^*_s(\alpha_{\mathrm{A}}) > 0$ holds. If $\Delta_{u_2}(\alpha_{\mathrm{A}}) < 0$, then $w^*_s(\alpha_{\mathrm{A}}) > 0$, and thus I show $\Delta_{u_2}(\alpha_{\mathrm{A}}) < 0$ below. To this end, I first derive the optimal wages and the agent's expected rent after failure and shirking ($e_1 = 0$). In this case, the incentive compatibility constraint is written as follows.

$$q_0\Delta_p(w_{fs} - w_{ff}) \geq c.$$

At the optimum, $w_{ff} = 0$ holds. Under $w_{ff} = 0$, the optimal wage after shirking and failure is determined at the incentive compatibility constrain binds. Denote $w^0_{fs} = \frac{c}{q_0\Delta_p}$ as the optimal wage. By substituting the optimal wages, the agent's expected rent is written by

$$u_f(0,1) = \frac{p_0}{\Delta_p} c = u_s(1; l^*(\alpha_{\mathrm{A}})),$$

which equals to the expected rent after success. Thus, the net expected rent in the second period is rewritten as follows:

$$\begin{aligned}
\Delta_{u_2}(\alpha_{\mathrm{A}}) &= r\Delta_p u_s(1; l^*(\alpha_{\mathrm{A}})) + (1 - rp_1) u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) - (1 - rp_0) u_f(0, 1) \\
&= (1 - rp_1) \left[u_f(1, 1, \tilde{\alpha}; l^*(\tilde{\alpha})) - u_s(1; l^*(\tilde{\alpha})) \right] \\
&= (1 - rp_1) \left[\frac{q_1 p_0}{q_1 \Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1} - \frac{p_0}{\Delta_p} \right] c \\
&= -(1 - rp_1) \left[\frac{(1 - q_1)\alpha_{\mathrm{A}} p_1 p_0}{(q_1 \Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1)\, \Delta_p} \right] c \\
&< 0,
\end{aligned}$$

which is satisfied for all $\alpha_{\mathrm{A}} \geq 0$. Hence, $w_s^*(\alpha_{\mathrm{A}}) > 0$ for all α_{A}. This completes the proof.

B2. Proof of Corollary 2

$w_{fs}^*(\alpha_{\mathrm{A}}) \geq w_{s1}(\alpha_{\mathrm{A}})$ holds if and only if

$$\frac{c}{q_1 \Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1} \geq \frac{c}{r\Delta_p + (1 - r)\alpha_{\mathrm{A}} p_1} \iff \alpha_{\mathrm{A}}^* \equiv \frac{\Delta_p}{p_1} \geq \alpha_{\mathrm{A}}.$$

Note that $0 < \alpha_{\mathrm{A}}^* < 1$. This completes the proof.

B3. Proof of Proposition 8

Suppose the principal offers $l^*(\alpha_{\mathrm{A}})$. Then the principal's expected profit is written as $V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))$. Differentiating $V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))$ with respect to α_{A}, I obtain

$$\begin{aligned}\frac{\partial V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} &= -\left[rp_1\frac{\partial w_s^*(\alpha_{\mathrm{A}})}{\partial \alpha_{\mathrm{A}}} + (1-rp_1)(q_1+(1-q_1)\alpha_{\mathrm{P}})p_1\frac{\partial w_{fs}^*(\alpha_{\mathrm{A}})}{\partial \alpha_{\mathrm{A}}}\right]\\ &= -\frac{\partial W(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}}.\end{aligned}$$

Thus, I can find the optimal level of the agent's learnability confidence by analyzing its impact on the expected payment. Differentiation yields

$$\begin{aligned}\frac{\partial W(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))}{\partial \alpha_{\mathrm{A}}} &= rp_1\left[\frac{1}{r\Delta_p}(1-rp_1)\frac{(1-q_1)p_1q_1p_0c}{(q_1\Delta_p+(1-q_1)\alpha_{\mathrm{A}}p_1)^2}\right]\\ &\quad -(1-rp_1)(q_1+(1-q_1)\alpha_{\mathrm{P}})p_1\left[\frac{(1-q_1)p_1c}{(q_1\Delta_p+(1-q_1)\alpha_{\mathrm{A}}p_1)^2}\right]\\ &= (1-rp_1)\frac{(1-q_1)p_1^2c}{(q_1\Delta_p+(1-q_1)\alpha_{\mathrm{A}}p_1)^2}\left[\frac{p_0}{\Delta_p}q_1-(q_1+(1-q_1)\alpha_{\mathrm{P}})\right].\end{aligned}$$

The sign of which is positive if and only if

$$\frac{p_0}{\Delta_p}q_1 \geq q_1+(1-q_1)\alpha_{\mathrm{P}} \Longleftrightarrow \frac{q_1(2p_0-p_1)}{(1-q_1)\Delta_p} \equiv \alpha_{\mathrm{P}}^* \geq \alpha_{\mathrm{P}}.$$

The value of α_{P}^* can be lower than 0. Since $\alpha_{\mathrm{P}}^*<0$ at $p_0=0$ and

$$\frac{\partial \alpha_{\mathrm{P}}^*}{\partial p_0} = \frac{q_1p_1}{(1-q_1)\Delta_p^2} > 0,$$

holds for all $p_0 \in (0,p_1)$, there exits a lower bound on p_0, denoted by $\underline{p}_0$, such that $\alpha_{\mathrm{P}}^*>0$ if $p_0>\underline{p}_0=\frac{p_1}{2}$ where I define $\underline{p}_0$ as the solution to $\alpha_{\mathrm{P}}^*=0$. Notice that $\alpha_{\mathrm{P}}^*>1$ as $p_0 \to p_1$. Then there exits an upper bound on p_0, denoted by $\overline{p}_0$, such that $\alpha_{\mathrm{P}}^*<1$ if $p_0<\overline{p}_0=\frac{p_1}{1+q_1}$. I define $\overline{p}_0$ as the solution to $\alpha_{\mathrm{P}}^*=1$. Note that $p_1>\overline{p}_0>\underline{p}_0>0$. This completes the proof.

B4. Proof of Proposition 9

By differentiating $W(1,1,1,\alpha;l^*(\alpha))$, I obtain

$$\begin{aligned}
\frac{\partial W(1,1,1,\alpha;l^*(\alpha))}{\partial\alpha} &= rp_1\frac{\partial w_s^*(\alpha)}{\partial\alpha} + (1-rp_1)p_1\left[(1-q_1)w_{fs}^*(\alpha) + (q_1+(1-q_1)\alpha)\frac{\partial w_{fs}^*(\alpha)}{\partial\alpha}\right] \\
&= rp_1\left(\frac{1}{r\Delta_p}(1-rp_1)\frac{(1-q_1)p_1q_1p_0c}{(q_1\Delta_p+(1-q_1)\alpha p_1)^2}\right) \\
&\quad + (1-rp_1)p_1\left(\frac{(1-q_1)c}{q_1\Delta_p+(1-q_1)\alpha p_1} - \frac{(q_1+(1-q_1)\alpha)(1-q_1)p_1c}{(q_1\Delta_p+(1-q_1)\alpha p_1)^2}\right) \\
&= \frac{p_1(1-rp_1)(1-q_1)q_1p_0c}{(q_1\Delta_p+(1-q_1)\alpha p_1)^2}\left(\frac{p_1}{\Delta_p}-1\right) \\
&> 0,
\end{aligned}$$

which holds for all $\alpha \geq 0$. This completes the proof.

B5. Proof of Proposition 10

First, I derive the threshold level of V. Recall that the principal's expected profit is given by

$$V(1,1,1,\alpha;l^*(\alpha)) = \left[rp_1 + rp_1^2 + (1-rp_1)(q_1+(1-q_1)\alpha)p_1\right]V - W(1,1,1,\alpha;l^*(\alpha)).$$

Differentiation yields,

$$\frac{\partial V(1,1,1,\alpha;l^*(\alpha))}{\partial\alpha} = (1-rp_1)(1-q_1)p_1V - \frac{\partial W(1,1,1,\alpha;l^*(\alpha))}{\partial\alpha}.$$

Since the sign of $\partial V(1,1,1,\alpha;l^*(\alpha))/\partial\alpha$ is negative at $V=0$ and increasing in V and positive as $V\to\infty$, there exists a threshold $V^*(\alpha)>0$ such that $\partial V(1,1,1,\alpha;l^*(\alpha))/\partial\alpha > 0$ if $V > V^*(\alpha)$. I define $V^*(\alpha)$ as the solution to $\partial V(1,1,1,\alpha;l^*(\alpha))/\partial\alpha = 0$ and which is given by

$$V^*(\alpha) = \frac{1}{(1-rp_1)(1-q_1)p_1}\frac{\partial W(1,1,1,\alpha;l^*(\alpha))}{\partial \alpha} > 0.$$

Following from Proposition 9, the inequality holds for all $\alpha \geq 0$.

Next, I show that $V^*(\alpha)$ is decreasing in α. By differentiating $V^*(\alpha)$, I obtain

$$\frac{\partial V^*(\alpha)}{\partial \alpha} = \frac{1}{(1-rp_1)(1-q_1)p_1}\frac{\partial^2 W(1,1,1,\alpha;l^*(\alpha))}{\partial \alpha^2}.$$

The sign of $\partial V^*(\alpha)/\partial\alpha$ is equivalent to the sign of $\partial^2 W(1,1,1,\alpha;l^*(\alpha))/\partial\alpha^2$. I can write $\partial^2 W(1,1,1,\alpha;l^*(\alpha))/\partial\alpha^2$ as

$$\begin{aligned}\frac{\partial^2 W(1,1,1,\alpha;l^*(\alpha))}{\partial \alpha^2} &= -\frac{(1-rp_1)p_1^2(1-q_1)^2 q_1 p_0(\frac{p_1}{\Delta_p}-1)2c}{(q_1\Delta_p + (1-q_1)\alpha p_1)^3}, \\ &< 0,\end{aligned}$$

which holds for all α. To complete the proof, define $\underline{V} \equiv V^*(0) > 0$.

B6. Proof of Proposition 11

Suppose the principal implements the effort profile $e = (1,1,0)$ and offers the contract l^{**}. Then her expected profit is written as follows.

$$V(1,1,0;l^{**}) = \left[rp_1 + rp_1^2 + (1-rp_1)q_0p_0\right]V - \left[rp_1 w_s^{**} + rp_1^2 w_{ss}^*\right].$$

Since the agent chooses $e_f = 0$ after failure, the success probability after failure is given by q_0p_0 and the optimal wage after failure is equal to zero. Next, I derive the condition under which the principal prefers $e = (1,1,1)$ to $e = (1,1,0)$ by comparing

$V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}}))$ and $V(1,1,0;l^{**})$. Define $\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}})$ by

$$\begin{aligned}\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) &= V(1,1,1,\alpha_{\mathrm{P}};l^*(\alpha_{\mathrm{A}})) - V(1,1,0;l^*)\\ &= (1-rp_1)\left[(q_1+(1-q_1)\alpha_{\mathrm{P}})p_1 - q_0p_0\right]V\\ &\quad - \left[rp_1(w_s^*(\alpha_{\mathrm{A}})-w_s^{**}) + (1-rp_1)(q_1+(1-q_1)\alpha_{\mathrm{P}})p_1w_{fs}^*(\alpha_{\mathrm{A}})\right].\end{aligned}$$

$\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}})$ is increasing in V and $\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) > 0$ as $V \to \infty$. If $w_s^*(\alpha_{\mathrm{A}}) \geq w_s^{**}$, then $\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) < 0$ at $V = 0$. I can rewrite $w_s^{**} - w_s^*(\alpha_{\mathrm{A}})$ as

$$\begin{aligned}w_s^{**} - w_s^*(\tilde{\alpha}) &= \frac{c-\Delta_{u_2}}{r\Delta_p} - \frac{(c-\Delta_{u_2}(\alpha_{\mathrm{A}}))}{r\Delta_p},\\ &= \frac{1}{r\Delta_p}\left(\Delta_{u_2}(\alpha_{\mathrm{A}}) - \Delta_{u_2}\right),\\ &= \frac{1}{r\Delta_p}\left((1-rp_1)u_f(1,1,\tilde{\alpha};l^*(\alpha_{\mathrm{A}})) - (1-rp_0)u_f(0,1)\right),\\ &= -\frac{p_0c}{r\Delta_p}\left[\frac{rq_1\Delta_p^2 + (1-rp_0)(1-q_1)\alpha_{\mathrm{A}}p_1}{\Delta_p(q_1\Delta_p+(1-q_1)\alpha_{\mathrm{A}}p_1)}\right],\\ &< 0,\end{aligned}$$

which holds for all α_{A}. Then there exits a threshold level of V, denoted by $V^*(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}})$, such that $\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) > 0$ if and only if $V > V^*(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}})$. I define $V^*(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}})$ as the solution to $\Delta_V(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) = 0$ and which is written by

$$V^*(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) \equiv \frac{(1-rp_1)(q_1+(1-q_1)\alpha_{\mathrm{P}})p_1w_{fs}(\alpha_{\mathrm{A}}) - rp_1(w_s^* - w_s^*(\alpha_{\mathrm{A}}))}{(1-rp_1)[q_1\Delta_p + (1-q_1)\alpha_{\mathrm{P}}p_0]}.$$

The sign of $V^*(\alpha,\tilde{\alpha})$ is positive since $w_s^* - w_s^*(\alpha_{\mathrm{A}}) < 0$. Hence $V^*(\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}) > 0$ for all $\alpha_{\mathrm{P}},\alpha_{\mathrm{A}}$. This completes the proof.

B7. Proof of Proposition 12

Under this alternative specification, the net expected rent in the second period is written as follows.

$$\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}}) = r\Delta_p u_s(1; l^*(\alpha_{\mathrm{A}})) + (1 - rp_1)u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) - (1 - rp_0)\hat{u}_f(0, 1, \alpha_{\mathrm{A}}).$$

$\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}})$ depends on α_{A} only though the difference $(1 - rp_1)u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) - (1 - rp_0)\hat{u}_f(0, 1, \alpha_{\mathrm{A}})$. I can write the difference as follows.

$$\begin{aligned}
&(1 - rp_1)u_f(1, 1, \alpha_{\mathrm{A}}; l^*(\alpha_{\mathrm{A}})) - (1 - rp_0)\hat{u}_f(0, 1, \alpha_{\mathrm{A}}) \\
&= p_0 c \left[\frac{(1 - rp_1)q_1}{q_1\Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1} - \frac{(1 - rp_0)q_0}{q_0\Delta_p + (1 - q_0)\alpha_{\mathrm{A}} p_1} \right].
\end{aligned}$$

Define $D(\tilde{\alpha})$ as the expression in the square bracket. The sign of $\partial\hat{\Delta}_{u_2}(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}}$ is equivalent to the sign of $\partial D(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}}$. I show that $\partial D(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} < 0$ below. $D(\alpha_{\mathrm{A}})$ is written as follows.

$$D(\alpha_{\mathrm{A}}) = \frac{(1 - rp_1)q_1(q_0\Delta_p + (1 - q_0)\alpha_{\mathrm{A}} p_1) - (1 - rp_0)q_0(q_1\Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1)}{(q_1\Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1)(q_0\Delta_p + (1 - q_0)\alpha_{\mathrm{A}} p_1)}.$$

Let $f(\alpha_{\mathrm{A}})$ as the numerator and $g(\alpha_{\mathrm{A}})$ as the denominator of $D(\alpha_{\mathrm{A}})$. Then $\partial D(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} < 0$ if both $\partial f(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} < 0$ and $\partial g(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} > 0$ hold. By differentiating, I obtain

$$\begin{aligned}
\frac{\partial f(\alpha_{\mathrm{A}})}{\partial\alpha_{\mathrm{A}}} &= p_1 \left[(1 - rp_1)q_1(1 - q_0) - (1 - rp_0)q_0(1 - q_1) \right], \\
&= p_1 r(1 - r) \left[\frac{(1 - p_1)(1 - rp_1) - (1 - p_0)(1 - rp_0)}{(1 - rp_0)(1 - rp_1)} \right] < 0, \\
\frac{\partial g(\alpha_{\mathrm{A}})}{\partial\alpha_{\mathrm{A}}} &= p_1 \left[(1 - q_1)(q_0\Delta_p + (1 - q_0)\alpha_{\mathrm{A}} p_1) + (1 - q_0)(q_1\Delta_p + (1 - q_1)\alpha_{\mathrm{A}} p_1) \right] > 0.
\end{aligned}$$

The second inequality holds for all α_{A}. Hence $\partial D(\alpha_{\mathrm{A}})/\partial\alpha_{\mathrm{A}} < 0$ for all α_{A}. This completes the proof.

Appendix C.

Appendix to Chapter 4

C1. Proof of Proposition 13

Suppose $d = 0$. Then, the agent, observing $\hat{s} = B$, always develops, and thus the relevant comparison is between $V^T(1, \alpha)$ and $V^S(r)$. Define $\Delta_V(\alpha, r)$ by

$$\begin{aligned}\Delta_V(\alpha, r) &= V^T(1, \alpha) - V^S(r), \\ &= F(\theta^T(1, \alpha))\theta^T(1, \alpha) - F(\theta^S(r))\theta_L\end{aligned}$$

Both $\Delta_V(0, r) < 0$ and $\Delta_V(1, r) > 0$ hold for all $r \in [q, 1]$, and differentiation yields

$$\frac{\partial \Delta_V(\alpha, r)}{\partial \alpha} = \left[f(\theta^T(1, \alpha))\theta^T(1, \alpha) + F(\theta^T(1, \alpha))\right] \frac{\partial \theta^T(1, \alpha)}{\partial \alpha} > 0,$$

thus there exists $A(r) \in (0, 1)$ such that $\Delta_V(A(r), r) = 0$. Since

$$\frac{\partial \Delta_V(\alpha, r)}{\partial r} = -f(\theta^S(r))\Delta_\theta \theta_L < 0,$$

by the implicit function theorem, $A(r)$ is increasing in r. To prove Proposition 13, consider the following cases.

- For $\alpha > A(1)$, I have $\Delta_V(\alpha, r) > 0$ for all r, and hence the principal's optimal feedback strategy is $h = 1$.

- For $\alpha < A(q)$, I have $\Delta_V(\alpha, r) < 0$ for all r, and hence the principal's optimal feedback strategy is $h = 0$. Note that $A(q) \in (0, q)$.

- For $\alpha \in [A(q), A(1)]$, there exists a unique inverse function $R(\alpha) \equiv A^{-1}(\alpha) \in [q, 1]$ such that $\Delta_V(\alpha, R(\alpha)) = 0$ where $R(\alpha)$ is increasing in α. Since $\Delta_V(\alpha, r)$ is decreasing in r, the sign of $\Delta_V(\alpha, r)$ is equal to the sign of $R(\alpha) - r$. If $r < R(\alpha)$, the principal's optimal feedback strategy is $h = 1$, but under $h = 1$, $r = 1$ which contradicts with $r < R(\alpha)$. Instead if $r > R(\alpha)$, the principal's optimal feedback strategy is $h = 0$, but under $h = 0$, $r = q$ which contradicts with $r > R(\alpha)$. Hence, a pure-strategy equilibrium does not exist, and the unique PBE is $r = R(\alpha)$ with $h = h(\alpha)$ where $h(\alpha)$ is defined by

$$h(\alpha) = \frac{1 - \frac{q}{R(\alpha)}}{1 - q}.$$

  Note that $h(\alpha)$ is increasing in α.

To complete the proof, define $\underline{A} = A(q)$ and $\overline{A} = A(1)$.

C2. Proof of Proposition 14

Suppose $d = 0$. Then, the relevant comparison is between $V^T(1, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ and $V^S(r)$. Define $\Delta_V(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}, r)$ by

$$\begin{aligned}\Delta_V(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}, r) &= V^T(1, \alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) - V^S(r), \\ &= F(\theta^T(1, \alpha_{\mathrm{A}}))\theta^T(1, \alpha_{\mathrm{P}}) - F(\theta^S(r))\theta_L.\end{aligned}$$

I can rewrite $\Delta_V(\alpha_{\text{A}}, \alpha_{\text{P}}, r) \geq 0$ as

$$\alpha_{\text{P}} \geq \frac{\theta_L[F(\theta^S(r)) - F(\theta^T(1, \alpha_{\text{A}}))]}{\Delta_\theta F(\theta^T(1, \alpha_{\text{A}}))} \equiv A(r, \alpha_{\text{A}}).$$

Differentiation yields

$$\frac{\partial A(r, \alpha_{\text{A}})}{\partial \alpha_{\text{A}}} = -\frac{\theta_L f(\theta^T(1, \alpha_{\text{A}}))\frac{\partial \theta^T(1,\alpha_{\text{A}})}{\partial \alpha_{\text{A}}} \Delta_\theta F(\theta^S(r))}{[\Delta_\theta F(\theta^T(1, \alpha_{\text{A}}))]^2} \leq 0,$$

which holds for all $r \in [q, 1]$. Since $A(r, \alpha_{\text{A}})$ is increasing in r, $\Delta_V(\alpha_{\text{A}}, \alpha_{\text{P}}, r) > 0$ for all $r \in [q, 1]$ if $\alpha_{\text{P}} > A(1, \alpha_{\text{A}})$. Now, I prove the existence of $A(1, \alpha_{\text{A}}) \in [0, 1]$. $A(1, \alpha_{\text{A}})$ is decreasing in α_{A} and $A(1, 1) = 0$ holds, and $A(1, 0) \leq 1$ if

$$\frac{\theta_H}{\theta_L} \geq \frac{F(\theta_H)}{F(\theta_L)}.$$

Under Assumption 1, this inequality holds. Note that $A(1, 0) = 1$ if c is uniformly distributed over $[0, 1]$. Thus, under Assumption 1, there exists $A(1, \alpha_{\text{A}}) \in [0, 1]$ such that $\Delta_V(\alpha_{\text{A}}, \alpha_{\text{P}}, r) > 0$ for all $r \in [q, 1]$ if $\alpha_{\text{P}} > A(1, \alpha_{\text{A}})$. Hence, the principal's optimal feedback strategy is $h = 1$. To complete the proof of Case 1, define $\overline{A}(\alpha_{\text{A}}) = A(1, \alpha_{\text{A}})$.

Since $A(r, \alpha_{\text{A}})$ is increasing in r, $\Delta_V(\alpha_{\text{A}}, \alpha_{\text{P}}, r) < 0$ holds for all $r \in [q, 1]$ if $\alpha_{\text{P}} < A(q, \alpha_{\text{A}})$. I prove the existence of $A(q, \alpha_{\text{A}}) \in [0, 1]$ below. The sign of $A(q, \alpha_{\text{A}})$ is equal to $F(\theta^S(q)) - F(\theta^T(1, \alpha_{\text{A}}))$. Thus, $A(q, \alpha_{\text{A}}) \geq 0$ for $\alpha_{\text{A}} \leq q$. Since $A(q, \alpha_{\text{A}})$ is decreasing in α_{A}, for all $\alpha_{\text{A}} \leq q$, $A(q, \alpha_{\text{A}}) \leq 1$ if $A(q, 0) \leq 1$. If the following condition holds, then $A(q, 0) \leq 1$.

$$\frac{\theta_H}{\theta_L} \geq \frac{F(\theta^S(q))}{F(\theta_L)}.$$

Since $F(\theta_H)/F(\theta_L) \geq F(\theta^S(q))/F(\theta_L)$, this inequality holds under Assumption 1. Note that if c is uniformly distributed over $[0, 1]$, then $A(q, 0) = q \leq 1$. Thus, for all $\alpha_{\text{A}} \leq q$, $A(q, \alpha_{\text{A}}) \in [0, 1]$. Hence, for $\alpha_{\text{A}} \leq q$, there exists $A(q, \alpha_{\text{A}}) \in [0, 1]$ such that $\Delta_V(\alpha_{\text{A}}, \alpha_{\text{P}}, r) < 0$ holds for all $r \in [q, 1]$ if $\alpha_{\text{P}} < A(q, \alpha_{\text{A}})$. Therefore, the principal's optimal feedback strategy is $h = 0$. Define $\underline{A}(\alpha_{\mathrm{A}}) = \max\{0, A(q, \alpha_{\mathrm{A}})\}$. Note that $\underline{A}(\alpha_{\mathrm{A}}) = 0$ for $\alpha_{\mathrm{A}} > q$, and thus Case 2 does not exists for $\alpha_{\mathrm{A}} > q$. This proves the claim of Case 2.

Suppose $\alpha_{\mathrm{P}} \in [\underline{A}(\alpha_{\mathrm{A}}), \overline{A}(\alpha_{\mathrm{A}})]$. Then, given α_{A}, there exists a unique inverse function $R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) \equiv A^{-1}(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) \in [q, 1]$ such that $\Delta_V(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}, R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})) = 0$ where $R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ is increasing in $(\alpha_{\mathrm{P}}, \alpha_{\mathrm{A}})$. Since $\Delta_V(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}, r)$ is decreasing in r, the sign of $\Delta_V(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}, r)$ is equal to the sign of $R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) - r$. If $r > R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$, the principal's optimal feedback strategy is $h = 0$, but under $h = 0$, $r = q$ which contradicts with $r > R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$. Instead if $r < R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$, the principal's optimal feedback strategy is $h = 1$, but under $h = 1$, $r = 1$ which contradicts with $r < R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$. Hence, a pure-strategy equilibrium does not exist, and the unique PBE is $r = R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ with $h = h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ where $h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ is defined by

$$h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}}) = \frac{1 - \frac{q}{R(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})}}{1 - q}.$$

Note that $h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$ is increasing in $(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$. This completes the proof of Case 3.

C3. Proof of Corollary 4

First, I compare $\overline{A}$ and $\overline{A}(\alpha_{\mathrm{A}})$. $\overline{A}(\alpha_{\mathrm{A}})$ is decreasing in α_{A} and $\overline{A}(1) = 0$ and $\overline{A}(0) = 1$ holds under a uniform distribution. Since $\overline{A} \in (0, 1)$, there exists $\overline{\alpha}_{\mathrm{A}}$, satisfying $0 < \overline{\alpha}_{\mathrm{A}} < 1$, such that $\overline{A} \geq \overline{A}(\alpha_{\mathrm{A}})$ if $\alpha_{\mathrm{A}} \geq \overline{\alpha}_{\mathrm{A}}$. I define $\overline{\alpha}_{\mathrm{A}}$ as the solution to $\overline{A} = \overline{A}(\alpha_{\mathrm{A}})$.

Next, I compare $\underline{A}$ and $\underline{A}(\alpha_{\mathrm{A}})$. $\underline{A}(\alpha_{\mathrm{A}})$ is decreasing in α_{A} and $\underline{A}(q) = 0$ and $\underline{A}(0) = q$ under a uniform distribution. Since $\underline{A} \in (0, q)$, there exists $\underline{\alpha}_{\mathrm{A}}$, satisfying $0 < \underline{\alpha}_{\mathrm{A}} < q$, such that $\underline{A} \geq \underline{A}(\alpha_{\mathrm{A}})$ if $\alpha_{\mathrm{A}} \geq \underline{\alpha}_{\mathrm{A}}$. I define $\underline{\alpha}_{\mathrm{A}}$ as the solution to $\underline{A} = \underline{A}(\alpha_{\mathrm{A}})$. This completes the proof.

C4. Proof of Corollary 5

Define $\underline{A}^* = \min\{A, \underline{A}\}$ and $\overline{A}^* = \max\{A, \overline{A}\}$. Then, from Proposition 14, it is obvious that the unique PBE is $h = 0$ for $\alpha < \underline{A}^*$, and $h = 1$ for $\alpha > \overline{A}^*$. For intermediate value of α, $\alpha \in [\underline{A}^*, \overline{A}^*]$, there are following cases.

- First, suppose $\underline{A}^* = A$. Then, for $\alpha \in [A, \underline{A})$, the principal's optimal feedback strategy is $h = 0$, and for $\alpha \in [\underline{A}, \overline{A}]$, the principal's optimal feedback strategy is $h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$.

- Second, suppose $\underline{A}^* = \underline{A}$. Then, for $\alpha \in [\underline{A}, A)$, the principal's optimal feedback strategy is $h = 0$, and for $\alpha \in [A, \overline{A}]$, the principal's optimal feedback strategy is $h = h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$.

- Third, suppose $\overline{A}^* = A$. Then, for $\alpha \in [\underline{A}, A)$, the principal's optimal feedback strategy is $h = 0$, and at $\alpha = A$, the principal's optimal feedback strategy is $h = 1$.

Hence for $\alpha \in [\underline{A}^*, \overline{A}^*]$, there are three PBEs: (i) $h = 0$; (ii) $h = 1$; and (iii) $h = h(\alpha_{\mathrm{A}}, \alpha_{\mathrm{P}})$. This completes the proof.

C5. Proof of Proposition 15

Define the deference between $d^T(\alpha)$ and $d^S(r, \alpha)$ by

$$\begin{aligned}\Delta_d(\alpha, r) &= d^T(\alpha) - d^S(r, \alpha), \\ &= \int_{\theta_L}^{\theta^T(1,\alpha)} F(c)dc - \int_{\theta^S(r)}^{\tilde{\theta}^S(1,r,\alpha)} F(c)dc.\end{aligned}$$

Since both $\Delta_d(0,r) = 0$ and $\Delta_d(1,r) = \int_{\theta_L}^{\theta^S(r)} F(c)dc > 0$ hold for all $r \in [q,1]$, $\Delta_d(\alpha,r) \geq 0$ if $\Delta_d(\alpha,r)$ is increasing in α. By differentiating, I obtain

$$\begin{aligned}\frac{\partial \Delta_d(\alpha,r)}{\partial \alpha} &= \frac{\partial d^T(\alpha)}{\partial \alpha} - \frac{\partial d^S(r,\alpha)}{\partial \alpha}, \\ &= \Delta_\theta \left[F(\theta^T(1,\alpha)) - F(\theta^S(1,r,\alpha))(1-r) \right].\end{aligned}$$

Let $D(\alpha,r)$ be the expression in the square bracket. The sign of $\partial \Delta_d(\alpha,r)/\partial \alpha$ is equal to the sign of $D(\alpha,r)$. Both $D(\alpha,1) > 0$ and $D(\alpha,0) = 0$ holds, and thus for all $r \in [q,1]$, $D(\alpha,r) \geq 0$ if $\partial D(\alpha,r)/\partial r \geq 0$. Under the uniform distribution assumption, $\partial D(\alpha,r)/\partial r$ is written as follows.

$$\begin{aligned}\frac{\partial D(\alpha,r)}{\partial r} &= \theta^S(1,r,\alpha) - (1-r)\frac{\partial \theta^S(1,r,\alpha)}{\partial r}, \\ &= r\theta_H + (1-r)(2\theta_L - \theta_H + 2\alpha\Delta_\theta).\end{aligned}$$

Hence, for all α and r, $D(\alpha,r)$ is increasing in r if $2\theta_L \geq \theta_H$ which is rewritten as $\theta_L \geq \theta_H/2$. This completes the proof.