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The Allocation of Authority and Information Revelation*

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We study the allocation of authority and the possibility of information revelation in a principal-agent model where the principal faces both problems of adverse selection and moral hazard. We find that the consideration for information asymmetry and effort incentive for the agent makes the principal more likely delegate. Interestingly, we find that the informed agent has an ex-ante incentive to commit to reveal his information to the principal voluntarily if the information is hard.

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I. Introduction

Within an organization, delegation of authority to subordinates is easily observed. Why does delegation occur within an organization? Although there are various reasons for delegation, we consider two main motives for delegation in this paper: informational motive and effort-incentive motive. First, a superordinate (she) can benefit by delegating her authority to a subordinate (he) who has more decision-relevant information or knowledge than herself and having him make a decision on behalf of herself. That is, delegation can be used as a means of addressing the problem of adverse selection within an organization. Second, delegation can be also

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used as a way to solve the moral hazard problem. This is because, under delegation, the subordinate makes his own decision and hence he may work harder for the success of his decision than when he is forced to work on the superordinate's decision. In a sense, the subordinate becomes self-motivated in implementing his decision under delegation. However, along with these benefits of delegation, delegation entails a cost on the superordinate. Once authority is given to the subordinate, the superordinate cannot control the subordinate's decision, and hence the subordinate will make his most favorite decision that may be different from the superordinate's most favorite one. Hence, the two benefits of delegation come along with a cost, the loss of control. In this work, considering the two benefits of delegation and its cost, we study the allocation of authority within an organization, i.e., the question of whether a superordinate in an organization should delegate or not. We also examine the possibility of the subordinate's revealing its private information voluntarily to the superordinate.

For example, consider the problem of project choice within a firm that consists of a firm owner and several branch managers. The firm owner wants to select and implement a project that maximizes the firm's economic profit or its market value but she may not have sufficient information about the economic environment that would affect the return of each project. That is, given the economic situation, the firm owner does not know which project generates the maximum profit for the firm. Unlike the firm owner, each of the branch managers is well-experienced and so well-informed about the economic circumstances. However, each manager is self-interested, i.e., he wants to undertake a project that maximizes the benefit of his branch rather than a project that maximizes the firm's profit, because he is far more concerned about his professional careers and reputation. So, if the firm owner delegates her authority of selecting a project to one of the branch managers, she then can avoid a risky situation where she would have to choose a project without any information about the economic environment but the manager will undertake a project that is best for himself and not for the firm owner. Along with the benefit of reducing the risk to the firm owner, there will be another benefit of delegation. Since the manager will select a project that potentially generates the greatest benefit to himself, he will exert high effort in implementing that project. In other words, in case of delegation, the manager may be highly self-motivated to expend his effort on the project. Then, should the firm owner delegate her authority to one of the branch managers or not? On the other hand, from the viewpoint of the informed branch manager, is it really good for him to keep its private information secret? Namely, which one is better, keeping the information private or revealing it to the firm owner?

We try to answer these questions in a principal-agent setting in which an uninformed principal (firm owner) and an informed agent (branch manager) select a project and implement it through a contract that specifies the allocation of decision right over project selection and the wage schedule for the agent. Following the incomplete contracts approach, we assume that the principal and the agent cannot make a contract on the agent's private information, the selection of a project, or their payoffs.[1] Only the allocation of the decision right over project selection is contractible. The wage schedule cannot be conditioned on the selection of a project or the principal's payoff, and hence it is only contingent on the outcome of the project, that is, whether the project succeeds or fails. The decision right is initially given to the principal and the principal has an option to retain the decision right or delegate it to the agent. If the principal decides to keep its decision right, she chooses a project that maximizes her expected payoff given her prior information, and the agent implements the project. If the principal delegates to the agent its decision right, the agent selects and implements a project without interacting with the principal.[2]

Many papers study the allocation of authority within an organization, i.e., the choice between retaining the authority or delegating it to someone, in a principal-agent setting. Focusing on the informational benefits of delegation, some papers consider a trade-off between the loss of control resulting from delegation and the loss of information coming from centralization: Dessein (2002), Harris and Raviv (2005), and Acemoglu et at. (2007). Some papers, on the other hand, consider the trade-off between delegation and centralization, focusing on increasing the agent's effort incentive as the benefit of delegation: Aghion and Tirole (1997), Stein (2002), Zábojník (2002), and Bester and Krähmer (2008). However, there is few work on the allocational issue of authority with consideration for both benefits of delegation. So, we try to fill in the gap between these two streams of literatures by taking both the informational and the effort-incentive benefit of delegation into account and investigating the principal's choice between delegation and centralization. Basically, our work borrows from Bester and Krähmer (2008). We extend the model of Bester and Krähmer (2008), that has a moral hazard problem under symmetric information between the principal and the agent, to the asymmetric information case as examined in Dessein (2002) and Harris and Raviv (2005) that do not have a moral hazard issue.

Our main findings are as follows. First, consideration on the asymmetric information and the effort incentive for the agent makes the principal more likely delegate its decision right to the agent as the information asymmetry becomes severe and than the case where the principal considers only the information asymmetry as

[1] See Aghion, Dewatripont, and Rey (2002) for the incomplete contract literature.

[2] According to the principal's commitment to different decision rules, Alonso and Matouschek (2007) define different types of relational delegation: complete delegation, threshold delegation, menu delegation, and centralization. In this paper, we use the concepts of centralization and complete delegation of Alonso and Matouschek (2007) for each case of the principal's keepting the authorty and delegating it, respectively.

in Dessein (2002). Second, however, that consideration also makes the well-informed agent have an ex-ante incentive to reveal his information voluntarily to the principal, and thus may bring in centralization more likely.

The first finding is understandable. Since, in the current paper, the principal gains two benefits by delegating authority to the agent, the informational benefit ("solving adverse selection") and the effort-incentive benefit ("solving moral hazard"), and the benefits increase as the information asymmetry between the principal and the agent becomes large, the principal delegates more likely as the information asymmetry increases and than the case where there does not exist the effort-incentive benefit of delegation. It means that the concern about the moral hazard problem of the agent, which is added to the concern about the information asymmetry, in the current paper makes the principal delegate more. Interestingly, this principal's concern on the agent's effort incentive further makes the agent reveal its information to the principal voluntarily. The intuition behind this (the second finding) is the following. Suppose that the principal delegates her decision right to the agent. The agent will then choose his most favorite decision and, consequently, he will be highly self-motivated in exerting his efforts. Having perfect foresight about this, under delegation, the principal does not offer a high level of wage schedule to the agent, because the agent is already self-motivated. On the other hand, suppose that the principal retains its decision right (centralization) and makes a decision for herself. Since the principal considers the effect of her decision-making on the agent's effort incentive, she won't select her most favorite choice, which weakens the agent's effort incentive, and will offer the agent a high level of wage schedule in order to encourage the agent to exert high efforts on the decision she makes. This principal's agent-regarding decision making and the (expected) high level of wage schedule offered under centralization causes the agent's willingness to reveal his information to the principal in order to make the principal informed and thus make her keep its authority. That is, making the principal informed results in centralization, and centralization gives better payoff to the agent. So, the agent will reveal his information to the principal voluntarily, if possible, and centralization may occur.

The rest of the paper proceeds as follows. In Section 2, we present the basic model and examine it in Section 3. Section 4 discusses, and finally, we conclude in Section 5.

II. The Basic Model

Consider an organization in which a principal and an agent should choose and implement a project $d \in D \subset \mathbb{R}$, where D is a set of projects. The right over project selection is initially given to the principal. We adopt an incomplete contracting approach by assuming that project selection cannot be contracted upon but the right over project selection can be assigned contractually either to the principal or the agent. We call this right over project selection *authority*. If the principal keeps authority, she retains the right to select a project. If she delegates her authority, she grants the right to the agent.

The success or failure of a project depends on the agent's effort e. The agent exerts his effort after a project is chosen. Thus, at the stage where the agent exerts his effort, he knows which project is chosen, i.e., a selected project d. If the agent chooses his effort level e, he incurs the effort cost $c(e)=e^2/2$ and the project succeeds with probability $p(e)=e\in[0,1]$.[3] Following a standard principal-agent model with moral hazard, we assume that the agent's effort is not observable.

If the project fails, both the principal and the agent get zero. If the project succeeds, the principal and the agent receive the private benefits u_P and u_A, respectively. These benefits depend on a state of the world described by a parameter $\theta\in\Theta=[-L,L]$. θ is uniformly distributed on $[-L,L]$ where $L>0$. We assume that only the agent observes the realization of θ and the principal only knows Θ and the distribution $F(\theta)$. The private benefits of the principal and the agent, when a project d succeeds, are defined as

$$u_P(d)=r_P-k_P(\theta-d)^2 \quad \text{and} \quad u_A(d)=r_A-k_A(\theta+b-d)^2,$$

where $b\neq 0$.[4] These benefits are not verifiable to the third party and hence are not contractible. $r_P(>0)$ and $r_A(>0)$ are large enough to make the private benefits nonnegative. The parameters $k_P(>0)$ and $k_A(>0)$ describe how much the principal and the agent care about project selection, respectively. Thus the principal's benefit reaches a unique maximum when the project $d=\theta$ is chosen and the agent's benefit is maximized when the project $d=\theta+b$ is chosen. We refer to b as the bias of the agent.

Let $w=(w_s,w_f)$ be an incentive scheme which is contingent on success and failure of a selected project. If the project succeeds, the principal pays the agent the wage w_s. If the project fails, the principal pays the agent the wage w_f. Then the expected payoffs of the principal and the agent, for given a state of the world θ, are

$$U_P(d,e,w;\theta)=e(r_P-k_P(\theta-d)^2-w_s)+(1-e)(-w_f)$$

and

[3] As the success probability function for a project, we can use an exponential form, $p(e)=1-\frac{1}{\exp(e)}$, which satisfies the following properties: $p(0)=0$, $\lim_{e\to\infty}p(e)=1$, $p'(e)>0$, and $p''(e)<0$. This form of probability function doesn't give us any qualitative change in our results and implications.

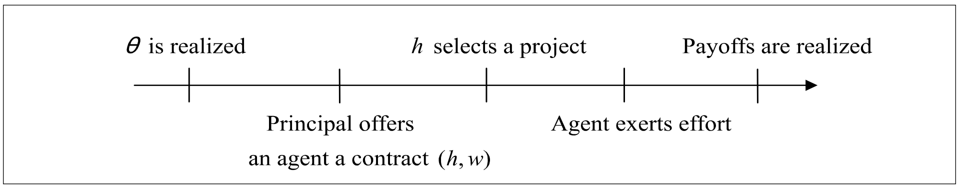
[4] This utility function is used in Crawford and Sobel (1982), Dessein (2002), and Bester and Krähmer (2008).

$$U_A(d,e,w;\theta) = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 .$$

The agent's outside option payoff, or reservation utility, is 0. We assume that the agent has limited liability, i.e., the agent cannot be paid a negative wage in any case.

Since the selection of a project is not contractible, the principal offers the agent a contract which specifies the allocation of the authority and the wage schedule w. We describe the allocation of authority by $h \in \{P, A\}$.[5] If $h = P$, the principal keeps the authority and selects a project that maximizes her expected payoff given her prior information about the state of the world. We call this case *centralization*. If $h = A$, she delegates the authority to the agent and the agent chooses a project. We call this case (*complete*) *delegation*.[6]

[Figure 1] The Sequence of Events



The time structure of the model is summarized in Figure 1: First, a state of the world (θ) is realized. Note that only the agent observes the realization of θ. Second, the principal offers the agent a contract (h, w) that specifies the allocation of authority and the wage schedule. If the agent does not accept the offer, the game ends and both the principal and the agent get nothing. If the agent accepts the principal's offer, according to the contract, the party h who has the authority selects a project at the subsequent stage. Next, the agent exerts his effort e after observing the selected project by the party h. The effort exerted by the agent affects the project's probability of success and failure and the payoffs of the principal and the agent are realized in the final stage.

III. The Analysis of the Game

3.1. Optimal Contracts when Information is Symmetric

As a benchmark case, we first consider a symmetric information case where both

[5] This notation is used in Bester and Krähmer (2008).

[6] We use the terms and concepts of *centralization and complete delegation* of Alonso and Matouschek (2007).

the principal and the agent can observe the realization of θ. To find out the optimal allocation of authority the principal chooses in equilibrium, we solve the optimal wage scheme the principal offers the agent, given the two scenarios: one case where the principal keeps her authority $(h = P)$ and the other case where the principal delegates her authority to the agent $(h = A)$.

3.1.1. The contract under centralizaton

Under centralization, the principal offers a contract $(h = P, w = (w_s, w_f))$ to the agent. After observing a state of the world θ, the principal solves the following contracting problem under moral hazard:

$$\max_{\{w_s, w_f\}} U_P = e(r_P - k_P(\theta - d)^2 - w_s) + (1-e)(-w_f) \tag{1}$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The incentive-compatibility constraint of the principal:
$d = \arg\max_d U_P = e(r_P - k_P(\theta - d)^2 - w_s) + (1-e)(-w_f)$

(c) The participation constraint of the agent:
$U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 \geq 0$

(d) The incentive-compatibility constraint of the agent:
$e = \arg\max_{e\in[0,1]} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$.

The incentive-compatibility constraint of the agent (d) can be simplified to:

$$e = r_A - k_A(\theta + b - d)^2 + w_s - w_f. \tag{2}$$

Substituting (2) into (1) and solving the principal's contracting problem with respect to w_s, w_f, and d, we obtain the following wage schedule and a project the principal chooses:

$$w_s = \frac{1}{2}\left(r_P - r_P + \frac{k_A k_P (k_P - k_A) b^2}{(k_A + k_P)^2} \right), w_f = 0 \text{ and } d = \theta + \frac{k_A b}{k_A + k_P}.^{7} \tag{3}$$

[7] After observing the contract $(h = P, w = (w_s, w_f))$, the agent decides whether to accept it or not. Note that the contract $(h = P, w = (w_s, w_f))$ does not say anything about the selection of project d. This means that the agent has to decide whether to accept it or not while only knowing the wage schedule (w_s, w_f) without any information about d to be chosen by the principal in the next stage. However, we can see that the agent's decision on whether to accept the contract or not does not depend on the information about d, because the agent can always obtain a non-negative payoff by choosing zero effort in case of accepting the contract. (See the participation constraint (c).) This

The following lemma summarizes these results. All proofs are presented in the Appendix.

Lemma 1 *The contract under centralization when the realization of* θ *is known to both the principal and the agent:*

(a) *The principal offers the agent the contract* $(h = P, w = (w_s^\circ, w_f^\circ))$ *such that* $w_s^\circ = \frac{1}{2}(r_P - r_A + \frac{k_A k_P (k_P - k_A) b^2}{(k_A + k_P)^2})$ *and* $w_f^\circ = 0$. *The principal selects a project* $d^\circ = \theta + \frac{k_A b}{k_A + k_P}$ *and the agent then exerts his effort* $e^\circ = \frac{1}{2}(r_P + r_A - \frac{k_A k_P b^2}{k_A + k_P})$.

(b) *The expected payoffs of the principal and the agent are* $U_P^\circ = \frac{1}{4}(r_P + r_A - \frac{k_A k_P b^2}{k_A + k_P})^2$ *and* $U_A^\circ = \frac{1}{8}(r_P + r_A - \frac{k_A k_P b^2}{k_A + k_P})^2$, *respectively.*

Lemma 1 says that the principal selects a project, $\theta + \frac{k_A b}{k_A + k_p}$, which is a weighted average of her ideal project, θ, and the agent's ideal project, $\theta + b$. This is intuitively understandable because the agent's effort in implementing a project depends on the project the principal selects and hence the principal does not select her ideal project (θ) which weakens the agent's effort incentive strongly. Instead, she selects an intermediate project between her most favorite project and the agent's, considering how much the agent cares about project selection relative to how much she does. We can also see that the wage w_s° increases with $|b|$ as long as $k_P > k_A$.

3.1.2. The contract under delegation

Under delegation, the principal offers a contract $(h = A, w = (w_s, w_f))$ to the agent. After observing θ, the principal solves the contracting problem under moral hazard:

$$\max_{\{w_s, w_f\}} U_P = e(r_P - k_P(\theta - d)^2 - w_s) + (1 - e)(-w_f) \tag{4}$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The participation constraint of the agent:
$U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1 - e)w_f - \frac{1}{2}e^2 \geq 0$

(c) The incentive-compatibility constraints:
$-d = \arg\max_{d \in D} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1 - e)w_f - \frac{1}{2}e^2$
$-e = \arg\max_{e \in [0,1]} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1 - e)w_f - \frac{1}{2}e^2$.

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implies that the agent will accept the contract $(h = P, w = (w_s, w_f))$ as long as it satisfies the limited-liability constraint (a), regardless of the project selection d. Therefore, having perfect foresight about this and considering the agent's incentive-compatibility constraint (d), the princial will choose w_s, w_f, and d simultaneously that maximize its expected payoff, although d is not known to the agent in the contracting stage.

The incentive-compatibility constraints (c) can be simplified to:

$$d = \theta + b \quad \text{and} \quad e = r_A + w_s - w_f \,. \tag{5}$$

Substituting (5) into (4) and solving the principal's contracting problem with respect to w_s and w_f, we obtain the following incentive scheme the principal makes:

$$w_s = \frac{1}{2}(r_P - r_A - k_P b^2) \quad \text{and} \quad w_f = 0 \,. \tag{6}$$

The following lemma summarizes the contract under delegation.

Lemma 2 *The contract under delegation when the realization of* θ *is known to both the principal and the agent:*

(a) The principal offers the agent the contract $(h = A, w = (w_s^{**}, w_f^{**}))$ *such that* $w_s^{**} = \frac{1}{2}(r_P - r_A - k_P b^2)$ *and* $w_f^{**} = 0$. *The agent selects a project* $d^{**} = \theta + b$ *and then exerts his effort* $e^{**} = \frac{1}{2}(r_P + r_A - k_P b^2)$.

(b) The expected payoffs of the principal and the agent are $U_P^{**} = \frac{1}{4}(r_P + r_A - k_P b^2)^2$ *and* $U_P^{**} = \frac{1}{8}(r_P + r_A - k_P b^2)^2$*, respectively.*

Lemma 2 says that the agent selects his most favorite project, $\theta + b$. It also says that the optimal incentive scheme w_s^{**}, effort level of the agent e^{**}, and the expected payoffs of the principal and the agent increase as $|b|$ decreases. This is intuitively true, because, as the agent's bias becomes small, the project the agent selects (d^{**}) is getting close to the ideal project of the principal and hence the private benefit of the principal in the case of project success increases. Therefore, the principal pays the agent more to induce him to exert more effort in implementing the project. In other words, this means that the principal differentiates the wages of the agent according to its bias. Finally, note that the expected payoffs of the principal and the agent, U_P^{**} and U_A^{**}, have the maximum values when $b = 0$, i.e., the preference of the agent is perfectly aligned with the principal's.

From Lemma 1 and Lemma 2, we obtain the following proposition that characterizes the optimal allocation of authority in the view of the principal when information is symmetric.

Proposition 1 *When information is symmetric, centralization is optimal. That is, delegation never happens under symmetric information.*[8]

[8] When information is symmetric between the principal and the agent, our model is the same as the one in Bester and Krähmer (2008). Since we assume the agent has the limited liability, Proposition 1 is

If the information about θ is symmetric between the principal and the agent, the principal's benefit resulting from delegation is only that she can provide the agent with a strong effort-incentive; the benefit from the information perspective of delegation does not exist. By the way, the principal has another instrument of inducing high effort from the agent without giving up her authority: the wage schedule. So, under centralization, the principal can still orchestrate the agent's effort incentive through the wage scheme without the loss of control she has to endure at the expense of effort-incentive benefit in case of delegation. Therefore, there is no reason for the principal to delegate her authority to the agent.

3.2. Optimal Contracts when Information is Asymmetric

Now we consider an asymmetric information circumstance where the agent can observe the realization of θ, while the principal cannot.

3.2.1. The contract under centralizaton

The principal, under centralization, offers a contract $(h=P, w=(w_s, w_f))$ to the agent. Since the principal cannot observe θ, the principal solves the following contracting problem under moral hazard:

$$\max_{\{w_s, w_f\}} U_P = \int_{-L}^{L} \{e(r_P - k_P(\theta - d)^2 - w_s) + (1-e)(-w_f)\} dF(\theta) \tag{7}$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The incentive-compatibility constraint of the principal:
$d = \arg\max_d U_P = \int_{-L}^{L} \{e(r_P - k_P(\theta - d)^2 - w_s) + (1-e)(-w_f)\} dF(\theta)$

(c) The participation constraint of the agent:
$U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 \geq 0$

(d) The incentive-compatibility constraint of the agent:
$e = \arg\max_{e \in [0,1]} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$.

The incentive-compatibility constraint (d) can be simplified to:

$$e = r_A - k_A(\theta + b - d)^2 + w_s - w_f. \tag{8}$$

Substituting (8) into (7) and solving the principal's contracting problem with respect to w_s, w_f, and d, we obtain the following first-order conditions for the optimal incentive scheme and the project the principal chooses:

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a replica of Proposition 4 in Bester and Krähmer (2008).

$$\left.\begin{aligned} w_s &= \frac{1}{2}\left(r_P - r_A + k_A\int_{-L}^{L}(\theta+b-d)^2\,dF(\theta) - k_P\int_{-L}^{L}(\theta-d)^2\,dF(\theta)\right), w_f = 0, \\ &\text{and } \frac{k_P\int_{-L}^{L}(\theta-d)(r_A - k_A(\theta+b-d)^2 + w_s)\,dF(\theta)}{k_A\int_{-L}^{L}(\theta+b-d)(r_P - k_P(\theta-d)^2 - w_s)\,dF(\theta)} = -1. \end{aligned}\right\} \quad (9)$$

Solving the first-order conditions in (9) simultaneously, we obtain the following incentive scheme and the project the principal chooses:

$$\left.\begin{aligned} w_s &= \frac{1}{2}\left(r_P - r_A + \frac{k_A k_P (k_P - k_A) b^2}{(k_A + k_P)^2} - \frac{4k_A k_P b}{k_A + k_P}\Delta - (k_p - k_A)(\Delta^2 + \frac{L^2}{3})\right), w_f = 0, \\ &\text{and } d = \frac{k_A b}{k_A + k_P} + \Delta, \end{aligned}\right\} \quad (10)$$

where $\Delta = \Delta(L,b) \equiv \frac{A-(B+\sqrt{A^3+B^2})^{2/3}}{3(k_A+k_P)^2(B+\sqrt{A^3+B^2})^{1/3}}$, $A = (k_A + k_P)^2(L^2(L(k_A - k_P)^2 + 12k_A k_P) - 3((r_A + r_P)(k_A + k_P) - b^2 k_A k_P))$ and $B = 9bL^2(3-L)k_A k_P (k_A - k_P)(k_A + k_P)^3$.

The following lemma summarizes the contract under centralization.

Lemma 3 *The contract under centralization when the realization of* θ *is known only to the agent:*

(a) The principal offers the agent the contract $(h = P, w = (w_s^\star, w_f^\star))$ *such that*

$$w_s^\star = \frac{1}{2}\left(r_P - r_A + \frac{k_A k_P (k_P - k_A) b^2}{(k_A + k_P)^2} - \frac{4k_A k_P b}{k_A + k_P}\Delta - (k_P - k_A)(\Delta^2 + \frac{L^2}{3})\right) \text{ and } w_f^\star = 0.$$

The principal selects a project $d^\star = \frac{k_A b}{k_A + k_P} + \Delta$ *and the agent then exerts his effort* $e^\star = r_A - k_A(\theta + b - d^\star)^2 + w_s^\star$.

(b) The expected payoffs of the principal and the agent are

$$U_P^\star = \int_{-L}^{L}(r_A - k_A(\theta+b-d^\star)^2 + w_s^\star)(r_P - k_P(\theta-d^\star)^2 - w_s^\star)\,dF(\theta)$$

and

$$U_A^\star = \frac{1}{2}(r_A - k_A(\theta+b-d^\star)^2 + w_s^\star)^2, \text{ respectively:}$$

3.2.2. The contract under delegation

Under delegation, the principal offers a contract $(h = A, w = (w_s, w_F))$ to the agent. Since the principal cannot observe the realized θ, the principal solves the following contracting problem under moral hazard:

$$\max_{\{w_s, w_f\}} U_P = \int_{-L}^{L} \{e(r_P - k_P(\theta - d)^2 - w_s) + (1-e)(-w_f)\} dF(\theta) \tag{11}$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The participation constraint of the agent:

$U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 \geq 0$

(c) The incentive-compatibility constraints:

$-d = \arg\max_{d \in D} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$

$-e = \arg\max_{e \in [0,1]} U_A = e(r_A - k_A(\theta + b - d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$.

The analysis of this principal's contracting problem can be done by the same way as in case of delegation under symmetric information. Consequently, we obtain Lemma 4.

Lemma 4 *The contract under delegation when the realization of θ is known only to the agent:*

(a) The principal offers the agent the contract $(h = A, w = (w_s^{\star\star}, w_f^{\star\star}))$ such that $w_s^{\star\star} = \frac{1}{2}(r_P - r_A - k_P b^2)$ and $w_f^{\star\star} = 0$. The agent selects a project $d^{\star\star} = \theta + b$ and then exerts his effort $e^{\star\star} = \frac{1}{2}(r_P + r_A - k_P b^2)$.

(b) The expected payoffs of the principal and the agent are $U_P^{\star\star} = \frac{1}{4}(r_P + r_A - k_P b^2)^2$ and $U_A^{\star\star} = \frac{1}{8}(r_P + r_A - k_P b^2)^2$, respectively.

From Lemma 3 and Lemma 4, we obtain the following proposition that characterizes the allocation of authority in the view of the principal when information is asymmetric.

Proposition 2 *When information is asymmetric, there exists a critical value of L, $\hat{L}(b)$, so that the principal delegates her authority to the agent as long as $L \geq \hat{L}(b)$.*

Note that L and b ($|b|$) in the model represent the degree of information asymmetry and the degree of preference difference between the principal and the agent, respectively, and they thus play an important role in the principal's decision-making on whether to keep her authority or delegate it to the agent. Proposition 2 reflects this. It says that delegation is more beneficial to the principal than centralization if L (the degree of information asymmetry) is greater than a certain level, $\hat{L}(b)$, which depends on b (the degree of preference difference). Intuitively, we can guess that $\hat{L}(b)$ increases (decreases) with the increase (decrease) of $|b|$. For example, suppose that $k_P = k_A = k$. Then we have the followings from Lemma 3 and Lemma 4:

$$w_s^{\star} = \frac{1}{2}(r_P - r_A), w_f^{\star} = 0, d^{\star} = \frac{1}{2}b, e^{\star} = \frac{1}{2}(r_P + r_A - 2k(\theta + \frac{1}{2}b)^2),$$
$$U_P^{\star} = \frac{1}{4}((r_P + r_A - \frac{1}{2}kb^2)^2 - \frac{4}{3}kL^2(r_P + r_A + \frac{1}{2}kb^2 - \frac{3}{5}kL^2)), U_P^{\star\star} = \frac{1}{4}(r_P + r_A - kb^2)^2$$

Comparing $U_P^{\star}$ and $U_P^{\star\star}$, we find $\hat{L}(b)$ in Proposition 2:

$$U_P^{\star} \leq U_P^{\star\star} \quad \text{for} \quad L \geq \hat{L}(b) \equiv \sqrt{\frac{5}{6k}\left(r_P + r_A + \frac{1}{2}kb^2 - \sqrt{(r_P + r_A - \frac{2}{5}kb^2)^2 + (\frac{6}{5}kb^2)^2}\right)}.$$

We see that $\frac{\partial \hat{L}(b)}{\partial |b|} > 0$, which means delegation occurs less likely as the degree of preference conflict increases. This also implies that the consideration of the agent's effort incentive as well as the informational asymmetry makes the principal more likely delegate its authority to the agent as the information asymmetry (L) increases and/or the bias of the agent ($|b|$) decreases and than when she considers the informational issue only.[9]

3.3. The Possibility of Information Revelation

Proposition 1 and 2 conclude that the optimal allocation of authority depends on the information structure. From these findings, we also have the following proposition that states the possibility of the agent's revealing his information to the principal.

Proposition 3 *If the information is hard (i.e., verifiable) and the agent is able to commit to revealing it ex ante, the agent will commit to reveal the information to the principal.*

Proposition 2 says that if the principal's uncertainty about a state of the world is greater than a certain level, delegation is more beneficial for the principal than centralization. This is because the benefit of delegation from the informational perspective becomes larger as the uncertainty the principal faces gets bigger. Then, which one is better for the agent between delegation and centralization? Interestingly, the agent prefers centralization to delegation in our model. In case of delegation, the agent will select his most favorite project and hence be highly self-motivated in implementing the project. The principal, having perfect foresight about this, offers a low level of wage schedule ($w_s^{\star\star}$) to the agent. On the other hand, in case of centralization, the principal chooses a project for herself while considering the effect of her project selection on the agent's effort incentive, and she

[9] I appreciate the referee's insightful comments and suggestions on Proposition 2.

offers the agent a high level of wage schedule (w_s°) in order to make him work hard on the project she chooses. Note that, obviously, $w_s^{\circ} > w_s^{**}$ holds. Thus, the principal's agent-regarding choice of a project and the high level of wage schedule offered under centralization causes the agent's willingness to reveal his information to the principal in order to make the principal informed and keep its authority. That is, the agent has an incentive to commit to reveal his information to the uninformed principal if the information is verifiable, because making the principal informed results in a better wage offer to him. However, if the information is not verifiable, i.e. soft, the agent's information revelation does not work well because the agent's commitment to reveal the information truthfully is unenforceable: the principal is aware of the incentive for the agent to lie or manipulate its information.

IV. Discussion and Further Research

In our model, we do not allow for the principal and the agent to communicate with each other. The analysis of communication under centralization was done in Dessein (2002) where the agent transmits its information to the principal through cheap talk. We cautiously guess that incorporating the communication structure into our model doesn't seem to make a qualitative change in Proposition 2, because the agent's project implementation stage in our model, which is absent in Dessein (2002), will result in the same structure of equilibrium as in Dessein (2002) (partition equilibrium). The only difference is that, because the principal in our model needs to take the agents' effort incentive into account when selecting a project, the effective conflict b between the principal and the agent reduces and it allows the agent to communicate more accurately with the principal than in Dessein (2002). In other words, the principal's consideration of the agent's effort incentive at the implementation stage enhances the communication and, consequently, it would lead to the increase of the principal's willingness to keep its authority (centralization). It means, in our model, the increase of the value of $\hat{L}(b)$ in Proposition 2. We believe the formal analysis on this, i.e., the communication game with the implementation stage, would be an interesting/potential research question.

There is another interesting/important question from the perspective of information asymmetry. We, in the current model, assume that the information about a state of the world (θ) is observable by only the agent and the information about the bias of the agent (b) is observable by both the principal and the agent. Changing or relaxing this assumption will give us different results with those we have in the current model. For example, suppose that there is no asymmetric information about θ, i.e., $L = 0$ in the current model, and instead the principal cannot observe the bias of the agent, b. She only knows that $b \in [-B, B]$ and its distribution $G(b)$: b is uniformly distributed on $[-B,B]$ where $B>0$. Then, under centralization, the principal solves the following contracting problem:

$$\max_{\{w_s,w_f\}} U_P = \int_{-B}^{B} \{e(r_P - k_P d^2 - w_s) + (1-e)(-w_f)\} dG(\theta)$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The incentive-compatibility constraint of the principal:
$d = \arg\max_d U_P = \int_{-B}^{B} \{e(r_P - k_P d^2 - w_s) + (1-e)(-w_f)\} dG(\theta)$

(c) The participation constraint of the agent:
$U_A = e(r_A - k_A(b-d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 \geq 0$

(d) The incentive-compatibility constraint of the agent:
$e = \arg\max_{e\in[0,1]} U_A = e(r_A - k_A(b-d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$.

Solving the principal's contracting problem above, we have the following outcomes under centralization:

$$w_s^C = \frac{1}{2}(r_P - r_A + \frac{1}{3}k_A B^2), w_f^C = 0, d^C = 0\text{, and } U_P^C = \frac{1}{4}(r_P + r_A + \frac{1}{3}k_A B^2)^2.$$

Under delegation, the principal solves the following contracting problem:

$$\max_{\{w_s,w_f\}} U_P = \int_{-B}^{B} \{e(r_P - k_P d^2 - w_s) + (1-e)(-w_f)\} dG(\theta)$$

subject to:

(a) The limited-liability constraint: $w_s \geq 0$ and $w_f \geq 0$

(b) The participation constraint of the agent:
$U_A = e(r_A - k_A(b-d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2 \geq 0$

(c) The incentive-compatibility constraints:
$-d = \arg\max_{d\in D} U_A = e(r_A - k_A(b-d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$
$-e = \arg\max_{e\in[0,1]} U_A = e(r_A - k_A(b-d)^2 + w_s) + (1-e)w_f - \frac{1}{2}e^2$.

We have the following outcomes under delegation by solving the principal's contracting problem:

$$w_s^D = \frac{1}{2}(r_P - r_A - \frac{1}{3}k_P B^2), w_f^D = 0, d^D = b\text{, and } U_P^D = \frac{1}{4}(r_P + r_A - \frac{1}{3}k_P B^2)^2.$$

Comparing U_P^C with U_P^D, we have $U_P^C \geq U_P^D$ if $k_P \geq k_A$. This implies that the principal's decision about whether to delegate its authority to the agent or not depends on only how much the principal cares about project selection (k_P) relative to the agent (k_A), not the degree of information asymmetry between the principal and the agent (B), and it is a strikingly different result with Proposition 2. The intuition behind this result is as follows. Since we assume that $L = 0$, i.e., there is no uncertainty about θ to the principal, the motive for the principal to delegate its decision right to the agent is only to provide the agent with strong effort incentive at the implementation stage. That is, through delegation, the principal can draw the maximum effort level from the agent (because the agent will select/implement his most favorite project), and thus the success probability of the project is maximized. However, she has to give up the opportunity of selecting a project for herself. On the other hand, if the principal retains her decision right, she can select her most favorite project while taking the agent's effort incentive into account, however, the project chosen by the principal will weaken the agent's effort incentive of implementing that project, comparing to the delegation case. So, the principal faces a tradeoff between selecting a project for herself (through centralization) and inducing the highest effort from the agent (through delegation). Therefore, the principal's decision depends on how much weight she puts on these relatively: if project selection matters to the principal more than the success of project (maximizing the agent's effort incentive), i.e., $k_P > k_A$, she decides to keep its decision right. Otherwise, i.e., $k_P < k_A$, she delegates it.

Finally, furthermore, if we assume that the principal cannot know exactly the realization of a state of the world (θ), i.e., $L \neq 0$, as well as the type of the agent (b), what results can we expect? This is also an interesting question, although it is more complicated to analyze this extended model. We leave this for our future work.

V. Conclusion

We have studied the contract problem between the principal and an agent that specifies which party has the authority over selecting a project and a wage scheme that is contingent on the outcome of the project. Our main findings are as follows: 1) The optimal allocation of authority depends on the information structure. If the information is asymmetric, the consideration of effort incentives and the information asymmetry between the principal and the agent makes the principal more likely delegate her authority to the agent as the degree of information asymmetry increases and/or the bias of the agent decreases. However, if the information is symmetric, centralization is an optimal choice of the principal. 2) If the information is asymmetric but verifiable (hard), there exists the ex-ante incentive of the agent to commit to revealing his information to the principal.

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Appendix. Mathematical Proofs

Proof of equations in (3) and Lemma 1. From (2) we know that $\frac{\partial e}{\partial w_f} < 0$ and $\frac{\partial U_P}{\partial w_f} < 0$. Then, by the limited-liability constraint $w_f \geq 0$, we obtain $w_f = 0$. Substituting (2) and $w_f = 0$ into (1), the principal's optimal contracting problem is written as follows:

$$\max_{\{w_s, d\}} U_P = (r_A - k_A(\theta + b - d)^2 + w_s)(r_P - k_P(\theta - d)^2 - w_s).$$

Solving the first-order conditions of maximizing U_P, i.e. $\frac{\partial U_P}{\partial w_s} = 0$ and $\frac{\partial U_P}{\partial d} = 0$, we have $w_s = \frac{1}{2}(r_P - r_A + \frac{k_A k_P (k_P - k_A) b^2}{(k_A + k_P)^2})$ and $d = \theta + \frac{k_A b}{k_A + k_P}$. The second-order condition is satisfied, that is, the Hessian of U_P at this solution is negative definite.

By substituting d, w_s, and w_f into (2), U_P, and U_A, we get the results in Lemma 1.

Proof of equations in (6) and Lemma 2. From (5) we know that $\frac{\partial e}{\partial w_f} < 0$ and $\frac{\partial U_P}{\partial w_f} < 0$. Then, by the limited-liability constraint $w_f \geq 0$, we obtain $w_f = 0$. Substituting (5) and $w_f = 0$ into (4), the principal's optimal contracting problem is written as follows:

$$\max_{w_s} U_P = (r_A + w_s)(r_P - k_P b^2 - w_s).$$

Solving the first-order conditions of maximizing U_P, i.e. $\frac{\partial U_P}{\partial w_s} = 0$, we have $w_s = \frac{1}{2}(r_P - r_A - k_P b^2)$. The second-order condition at this solution is satisfied.

By substituting d, w_s, and w_f into (5), U_P, and U_A, we get the results in Lemma 2.

Proof of Proposition 1. Let us compare the expected payoffs of the principal and the agent under centralization (in Lemma 1) with those under delegation (in Lemma 2). Since $k_P > 0$ and $k_A > 0$, we can easily show that $U_P^{\circ} > U_P^{**}$. This means that centralization is optimal for the principal. Trivially, we can also show that $U_A^{\circ} > U_A^{**}$.

Proof of equations in (9) and (10) and Lemma 3. From (8) we know that $\frac{\partial e}{\partial w_f} < 0$ and $\frac{\partial U_P}{\partial w_f} < 0$. Then, by the limited-liability constraint $w_f \geq 0$, we obtain $w_f = 0$. Substituting (8) and $w_f = 0$ into (7), the principal's optimal contracting problem is written as follows:

$$\max_{\{w_s, d\}} U_P = \int_{-L}^{L} (r_A - k_A(\theta + b - d)^2 + w_s)(r_P - k_P(\theta - d)^2 - w_s) dF(\theta).$$

The first-order conditions of maximizing U_P, i.e. $\frac{\partial U_P}{\partial w_s}=0$ and $\frac{\partial U_P}{\partial d}=0$, are as follows:

$$w_s = \frac{1}{2}\left(r_P - r_A + k_A \int_{-L}^{L} (\theta + b - d)^2 dF(\theta) - k_P \int_{-L}^{L} (\theta - d)^2 dF(\theta) \right)$$

and

$$-\frac{k_A}{k_P} = \frac{\int_{-L}^{L} (\theta - d)(r_A - k_A(\theta + b - d)^2 + w_s) dF(\theta)}{\int_{-L}^{L} (\theta + b - d)(r_P - k_P(\theta - d)^2 - w_s) dF(\theta)}.$$

The second-order condition is satisfied, that is, the Hessian of U_P at the solution satisfying the first-order conditions is negative definite.

By substituting the former first-order condition (w_s) into the latter, we get the following optimal condition for the project selection:

$$-\frac{k_A}{k_P} = \frac{\int_{-L}^{L} (\theta - d)\{r_P + r_A - 2k_A(\theta + b - d)^2 + k_A \int_{-L}^{L} (\theta + b - d)^2 dF(\theta) - k_P \int_{-L}^{L} (\theta - d)^2 dF(\theta)\} dF(\theta)}{\int_{-L}^{L} (\theta + b - d)\{r_P + r_A - 2k_P(\theta - d)^2 - k_A \int_{-L}^{L} (\theta + b - d)^2 dF(\theta) + k_P \int_{-L}^{L} (\theta - d)^2 dF(\theta)\} dF(\theta)}.$$

Solving the above equation with the assumption that θ is uniformly distributed on $[-L, L]$, we have $d = \frac{k_A b}{k_A + k_P} + \Delta$, Substituting d into w_s of the first-order condition, we obtain w_s in (10).

By substituting d, w_s, and w_f into (8), U_P, and U_A, we get the results in Lemma 3.

Proof of Proposition 2. From Lemma 3, we can see that $U_P^{\star}$ is continuous and decreasing in L, and that it converges to its maximum value U_P° (in Lemma 1) as L goes to 0, because $w_s^{\star} \to w_s^{\circ}$, $d^{\star} \to d^{\circ}$, and $e^{\star} \to e^{\circ}$ as $L \to 0$. That is, it holds that $U_P^{\circ} \geq U_P^{\star}$ where the equality holds when $L = 0$. By the way, since it always holds that $U_P^{\circ} > U_P^{\star\star}$, there exists $\hat{L}(b)$, a critical value of L, such that $U_P^{\star} \leq U_P^{\star\star}$ for $L \geq \hat{L}(b)$.

Proof of Proposition 3. By Proposition 2 the principal delegates her authority to the agent if the uncertainty she faces is large enough, or $L \geq \hat{L}(b)$. Consequently, when information is asymmetric, delegation happens and then the agent gets his expected payoff $U_A^{\star\star}$ (in Lemma 4), which is less than U_A° (in Lemma 1), the expected payoff he gets in the case of centralization under symmetric information. This implies that the agent is better off under centralization and symmetric information than under delegation and asymmetric information. Therefore, if the information is verifiable (hard), the agent will commit to reveal his information so that the principal can be informed and keep its authority.