Allocation of Authority when a Person is not a Robot [1]

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Abstract

We formalize a conception of authority, which is commonly defined as the right of controlling a person's actions embedded in human assets in sociology. Due to the inalienable property of human assets, the contractible formal authority is hard to verify and enforce, while real authority usually diverges from formal authority. Inefficiency tends to arise when a task is not routine or can not be done by a robot. Using a framework of incomplete contract, we show that allocation of formal authority, as an instrument to mitigate the inefficiency, is determined by features of tasks and specificity of assets, and the relationship between the resources. Monitoring is then introduced to fine tune value of delegation.

JEL classifications: *D23, J24, J41, L22.*

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1. INTRODUCTION

Fortunately or unfortunately, very few people are his or her own boss. Most people are employees. Division managers work under direction of CEOs. Entrepreneurs are usually subject to control rights of capitalists. Some workers enjoy a higher degree of freedom while many others complain they work like robots. Workers' control over their own actions also vary across industries, professions, divisions and positions inside an organization. Important questions arise: what is the control right of human assets? Why do different jobs result in different degree of freedom? What determines the allocation of authority in an organization?

The control rights of human assets correspond to the definition of authority over a person in sociology. James Coleman (Coleman (1994)) provides a well accepted definition:

> Individuals may, under threat or promise or because they otherwise see it as in their best interests to do so, give up the right to control certain of their actions. It is the right to control another's actions that is the usual definition of authority $\cdots$. One actor has authority over another in some domain of actions when the first holds the right to direct the actions of the second in that domain.

A formal economic treatment of authority was conducted in Simon (1951). His seminal paper investigated an employment relation where an employer exercises authority over an employee when the latter permits the former to select elements from a collection of specific actions (the area of acceptance) which the employee should perform on a job. That theory implies that even if human assets themselves are not observable or not verifiable, authority over actions which are embedded in human assets is contractible and transferrable.

Evidently, transfer of human assets is very different from that of physical assets due to the inalienability nature of human assets. First, social norms put strong constraints on usage of human assets. Usually, an employer can only control an employee's actions based on voluntary agreement. Second, the acceptance area is unlikely to be defined precisely unless the actions to be performed are very simple. Third, human assets such as knowledge and skills are embedded in human body. Even if they are observable and contractible, it is difficult to enforce the contractual right of using these resources.

These difficulties demand a careful inspection of the conception of authority. Consistent with Simon (1951) and Coleman (1994), an authority relation of one person over another exists when the former has rights of control over certain actions of the latter. Different from them, we find it necessary to distinguish nominal rights which are written down in a contract and actual implementation of these rights. We refer to the first as formal authority and the latter as real authority[1]. For convenience, we call a person who obtains formal authority as a principal (she) and the other subject to this formal authority an agent (he).

Sources of formal authority include legitimacy, institutions, forces, expertise, competency, ownership, etc.. Whatever sources, the formal authority does not guarantee ultimate authority over a person's actions. When a principal acquires (purchases in economic activities) formal authority, what she obtains is a promise from the agent to act in a certain way or the right to control

[1] These definitions correspond to nominal and functional authority in sociology.

his actions within certain limits. The transfer of actions is never complete. In particular, the required actions imbedded in a person's human assets may not be observable. A person can without being noticed take an action or a combination of actions different from what he is asked to do. Even when the actions are observable, they are not necessarily verifiable by a third party. Still in many cases, even when actions are observable and verifiable, an agent may choose not to honor the direction of his principal, when ex post punishment is infeasible or the agent is subject to limited liability or other institutional constraints. In an extreme case, a slave is still likely to shirk.

In this paper, we focus on a situation where a principal obtains formal authority because she controls critical physical resources for production, as in a paper on firm theory by Rajan and Zingales (1998). When the principal-agent relationship comes into being, centralization is the default authority regime. The principal chooses actions for the agent, but the agent can shirk within a certain limit such that he can not be punished because of such deviation.

However, if the principal delegates the authority back to the agent, both formal authority and real authority reside in the agent, who then has ultimate control over his own actions. This makes it possible for the agent to pick some actions that bring him private benefits. His enlarged freedom may be beneficial or detrimental to the principal's interest. [2]

Furthermore in order to employ the agent's skills or knowledge, the principal has to transfer the usage right of her physical assets to the agent, under centralisation or delegation. Under centralisation, since the principal chooses the actions for the agent, the threat of misusing assets is quite limited. However, under delegation, by allowing the agent freedom of choosing his own actions, the principal is likely to give to him more freedom in the usage of her assets. As a result, the agent obtains opportunities to use those resources to his own ends — possibly harmful to the principal's interests. Examples are numerous: the classic example of empire buildings, an employee's use of a company car for personal purposes, or exploitation of customer list to benefit oneself.

In consequence, although delegation may invite higher efforts from the agent, it also brings the principal a two-fold problem: 1) The agent may choose actions detrimental to the principal's interest; 2) The agent may divert a part of the physical assets. The tradeoff between losing control and improvement of incentive makes delegation a difficult decision for the principal.

Determinants of allocation of authority are the properties of the assets and features of the task. If the physical assets can be used for general purpose, it is easier for the agent to make use of the physical assets for his private benefits. If the physical assets are instead very specific to the task to be implemented, the agent's usage of the physical assets for his private benefits is restricted, and then his real authority is also limited. In the former case, the principal may choose not to delegate since the agent may use the physical assets against her benefits, while in the latter case, delegation may not give enough incentive since the agent has little chance of obtaining private benefits. Similarly, if the task is very simple, few private benefits can be realized by the agent under delegation and delegation would not be an effective instrument to provide incentives. Only when the task is complicated enough is delegation necessary and meaningful.

[2] One may argue under centralisation the principal may use revelation mechanisms to find out the actions that benefit the agent privately in order to improve the agent's effort. We do not argue that there is no other ways of reducing moral hazard problem. We rather argue that delegation is one practically used instrument, because the principal fails to choose a task which privately benefits the agent due to overload of the principal or costly communication.

We also explore the impact of monitoring on the allocation of authority. The principal, as the owner of the physical assets, has incentives to monitor their usage. By keeping the right of monitoring, she retains some real control over her assets, and to some extent also restricts the agent's actions and real authority. The possibility of monitoring improves the principal's payoff without reducing the feasible set of delegation. This explains that delegation always comes together with monitoring, as frequently observed in practice.

Our paper is related to three strands of literature.

PROPERTY RIGHT LITERATURE. Some authors (e.g. Grossman and Hart (1986)) suggest applying the property right theory of firm to authority, which would be defined as the purchase of residual rights over actions. This may be sensible when one compares an employment contract with a sales contract as the former is much more roughly specified. However, due to the inalienability of human actions, residual rights over actions will not be lost from human body even if they are sold, which makes the right of using residual rights hardly contractible. In contrast, we distinguish contractible formal authority from noncontractible real authority.

MORAL HAZARD LITERATURE. Standard treatment of the moral hazard problem emphasizes the non-observability of actions as the resource of inefficiency and thus design of optimal contract through information inference. Our explanation to this problem lies in the nature of authority and the separation of formal and real authority. We put more weights on the nonverifiability or non-enforceability feature of actions.

DECISION RIGHT LITERATURE. Our theory of formal and real authority is complementary to an influential stand of literature initiated by Aghion and Tirole (1997). A fundamental difference is that we define authority directly over human assets while their definition is referred to as decision right of project choice. Our key purpose is to discover the nature of transaction of human assets while theirs is to show the importance of information acquisition and revelation in decision making. In our paper, information collection itself is not a determinant of allocation of authority, rather the non-enforceability of the action is what causes the problem.

We also differ from the third strand of literature in another important aspect. In that literature, congruence in interests between the principal and the agent plays an important role and is usually assumed to come from an intrinsic difference in preferences. In our model, congruence is a result of the players' rational responses to economic activities, namely, sharing rule over final outcomes, productivity, features of tasks and characteristics of assets. In consequence, the principal has to deal with the delegation issue more carefully in our model, which contributes to a better understanding of the subtle real world.

The remaining of the paper is organized as follows. In Section 2 we formalize our general setup, and derive conditions under which delegation is a Pareto improvement over centralisation. In Section 3, we introduce monitoring into the model. In Section 4 we illustrate the most important results from previous sections with a simplified example. Section 5 summarizes our findings, and spell out potential applications and extensions of the general model.

2. GENERAL SETUP

In this section, we set up a general model and examine conditions of optimal allocation of authority to mitigate the inefficiency caused by the transaction of human assets. The principal, the owner of some critical physical assets, employs the agent, the owner of human assets, to perform production. The employment contract specifies roughly the task A. There are many ways of accomplishing the task, each is described by an action a_i. The principal's preferred action is a_P and that of the agent is a_A. In general, $a_P \neq a_A$, which reflects divergence of interests, however, a_P and a_A share some dimensions in common. Both players are risk neutral. When the employment contract is signed, the agent vests formal authority over the choice of action in the principal. However, in the implementation of the contract, the principal may delegate this authority back to the agent.

The task is characterized by $\theta := (\gamma, \xi)$, its complexity (γ) and the specificity (divisibility) of assets (ξ) used on the task. θ is exogenous and is revealed after the employment contract is signed. A higher γ refers to a more complicated task. A higher ξ means a more general usage of the assets.

γ and ξ capture the divergence of interest between the two players. If γ is big, a_P and a_A share very few dimensions in common. If ξ is big, the principal's assets can be easily adapted for personal benefits when the agent can choose the action.

To implement an action a_i, the agent's effort $e_i \in [0, \bar{e}]$ is required. However, the effort level mostly desired by the principal and the agent diverge. For example, under centralization, the principal chooses her preferred action a_P, the agent's optimal effort level is e_A^C while the principal prefers an effort level e_P^C.

The agent's behavior in implementing the action, in particular, the agent's effort, is partially verifiable. There exists an interval $E \subset [0, \bar{e}]$ such that if the agent is expected to exert effort $\tilde{e}$ but his actual effort level $\hat{e}$ falls outside that interval, such deviation is detected and verifiable to a third party. But if $\hat{e}$ falls in E, it is not verifiable to a third party. Interval E is exogenously given and may be determined by γ. If a task is very complicated, an agent's effort in implementing an action is more difficult to verify.

The production function of the firm depends on the chosen action and can be described by a real-valued function $V^R : (S, e; \theta) \to \mathbb{R}$, depending on the principal's physical assets $S \in \mathbb{R}_+$, the effort of implementing the action, and the state of world θ. Which action is chosen is determined by the authority regime $R \in \{C, D\}$, with C for centralization and D for delegation. Under centralization, the principal chooses her preferred action a_P, while under delegation, the agent chooses his preferred action a_A.

The sharing of output (firm value) is assumed to be predetermined: $(\lambda, 1-\lambda)$, with λ the share obtained by the principal. This structure deviates from standard incomplete contract literature by fixing sharing rule and excluding ex post renegotiation, since renegotiation is costly and not always feasible.[3] Such an exogenous fixed-share contract is well observed in reality: a fixed wage or (and) a sharing rule of final outcome is specified at the very beginning of an employment contract.

[3]Our theory still holds for other incomplete contract settings. We adopt such a game structure mainly for the purpose of convenience.

When the agent works for the principal, besides his share of final output, he also receives private benefits. Similar to Aghion and Tirole (1997), we interpret this as nonmonetary so as to preclude direct ex post transfer between the two players.[4] These benefits can come from social norms, team spirits or even personal empathy or pride when working in the firm. As our aim is to investigate the impact of authority allocation on the provision of incentives, we normalize the agent's private benefit under centralization to zero and denote that under delegation by $B : (S, e; \theta) \to \mathbb{R}$.

Cost of effort is assumed to be separable and is independent of factors other than e. Then the agent's cost of effort can be described by a function $C : [0, \bar{e}] \to \mathbb{R}$ or more condensely $C(e)$.

The principal and the agent behave noncooperatively, each with the aim of maximizing her (or his) own expected payoff. For simplicity, suppose the principal's investment in the critical assets S is irreversible and the costs are sunk. Then the principal's investment decision does not interact with the agent's behaviour.

We impose the following assumptions on the functional forms of $V(\cdot), B(\cdot)$ and $C(\cdot)$.

A1. $V(S, e; \gamma, \xi)$ is nondecreasing in S and e, but nonincreasing in γ and ξ. $B(S, e; \gamma, \xi)$ is nondecreasing in all arguments. Both functions are continuous and concave in e. The cost function $C(e)$ is nondecreasing, continuous and convex.

The nonincreasing of $V(\cdot)$ in $\theta = (\gamma, \xi)$ and nondecreasing of $B(\cdot)$ in $\theta = (\gamma, \xi)$ reflects an intrinsic conflict between the principal and the agent. The agent cares more about his private benefits if he is able to tunnel more effort and employ more assets for his personal purpose. And the agent's realization of private benefits through tunnelling and stealing is against the principal's benefits.

A2. The parameter $\theta = (\gamma, \xi)$ lies in a compact space $\Theta \subset \mathbb{R}^2$. In particular, $\gamma \in [\underline{\gamma}, \bar{\gamma}]$ and $\xi \in [\underline{\xi}, \bar{\xi}]$, where $\underline{\gamma}, \bar{\gamma}, \underline{\xi}, \bar{\xi}$ are some finite real numbers.

A3. $B(S, e; \gamma, \xi)$ and $V(S, e; \gamma, \xi)$ are continuous in γ and ξ.

Assumptions A2 and A3 are not necessary to obtain our main insights. But they will lead to much simplification and more explicit results.

Time structure of the game is summarized as follows.

At $t = 1$, features of the task are revealed and the principal reconsiders the authority regime (R): whether to retain the formal authority over the agent's actions herself (centralisation C) or delegate the formal authority to the agent (delegation D).

At $t = 2$, the agent implements the action chosen by the principal under centralisation or choose himself and implement an action from A under delegation.

At $t = 3$, the value of the firm is realized and shared according to the sharing rule $(\lambda, 1 - \lambda)$. The agent obtains private benefits as well.

[4] Actually the private benefits can be monetary as well. The key is that renegotiation is prevented (e.g. very costly) and the predetermined sharing rule can be committed to.

Before carrying out the analysis, we stress that the inefficiency arising from the transaction of human assets and separation of formal and real authority is fully embodied in the fixed sharing rule and the partial verifiability of effort. The agent deviates from the requirement of the principal because his marginal cost of effort is not fully compensated and this problem could have been solved if the principal had full authority over his actions.

2.1. *Centralisation*

Under centralisation, the principal holds the formal authority and chooses her preferred action a_P. Given the sharing rule $(\lambda, 1-\lambda)$ of the firm value, the principal expects a payoff equal to $\lambda V^C(S,e;\theta)$ and does not bear the cost of effort. The agent expects a payoff equal to $(1-\lambda)V^C(S,e;\theta)$ net of the effort cost $C(e)$. However, the agent still holds some real authority in choosing effort in the implementation of a_P. The agent can not choose action to realize his private benefits, therefore, we can drop θ out from the production function in this subsection.

Since the principal's payoff is monotone increasing in e, the effort level desired by the principal is $e_P^C = \bar{e}$. In an unusual case where the principal possesses both formal and real authority over the agent's actions, the principal would choose that effort level. Such slavery-like scheme may exist in very simple tasks, where E is very small. If the agent chooses effort outside the range E, he gets punished. In those situations, there is no need to delegate. This may explain why we rarely observe delegation in manual work in reality.

However, if the task is complicated, E is necessarily big, the real authority of the agent plays a role, and he may choose an effort level different from that desired by the principal without being detected. Then the agent's optimum effort level is to maximize the following objective function:

$$(1-\lambda)V^C(S,e) - C(e) \quad \text{subject to} \quad e \in E$$

Suppose e' is the unique maximizer of the unconstrained maximization problem. It is determined by

$$(1-\lambda)\frac{\partial V^C(S,e')}{\partial e} = \frac{dC(e')}{de} \tag{1}$$

Obviously when $\inf E > e'$, the agent will not choose an effort higher than $\inf E$ as he bears the cost alone but shares the output with the principal. In equilibrium, the effort chosen by the agent is $e^C := \max\{e', \inf E\}$. Such an effort is obviously lower than $\bar{e}$. We summarize the result in following proposition.

PROPOSITION 1 *Under centralisation, given sufficiently large E, the agent chooses an effort level that is lower than that preferred by the principal.*

The result is similar to the classical moral hazard problem in the literature. However, we stress that, rather than directly from the nonobservability of actions, the problem stems from the transaction of human assets and the separation of formal and real authority over actions. Nonverifiability and nonenforceability of the agent's action leads to the deviation of e^C from $\bar{e}$. If the principal had both formal and real authority, there would be no such deviation problem. If full compliance with the principal's direction is verifiable, then the problem is also easily solvable through contracting. However, in reality, most agents are not robots and always have some degree of freedom in the implementation of their actions.

Under centralisation, the payoffs of the principal and the agent are respectively

$$V_P^C := \lambda V^C(S, e^C); \qquad V_A^C := (1-\lambda)V^C(S, e^C) - C(e^C).$$

2.2. *Delegation and Optimal Allocation of Authority*

Alternative to retaining the formal authority over the agent's actions, the principal can delegate this authority back to the agent, and allow the agent to choose the action. Given this freedom, the agent chooses his preferred action a_A. Depending on the feature of the task, a_A may share little common feature with a_P, and the agent may even steal some assets for personal benefits, to the principal's dismay.

Now the agent's objective function becomes:

$$B(S, e; \gamma, \xi) + (1-\lambda)V^D(S, e; \gamma, \xi) - C(e)$$

where $B(\cdot)$ is the private benefits the agent obtains due to his freedom in the choice of action under delegation.

The agent will choose an equilibrium effort level e^D, which is determined by the first order condition

$$\frac{\partial B(S, e^D; \gamma, \xi)}{\partial e} + (1-\lambda)\frac{\partial V^D(S, e^D; \gamma, \xi)}{\partial e} = \frac{dC(e^D)}{de} \tag{2}$$

If $\frac{\partial B(S,e;\gamma,\xi)}{\partial e}$ is large enough while $\frac{\partial V^D(S,e;\gamma,\xi)}{\partial e}$ is not too small in comparison to $\frac{\partial V^C(S,e)}{\partial e}$, e^D is likely to exceed e^C.

Under delegation, the payoffs of the principal and the agent are respectively

$$\begin{aligned} V_P^D &:= \lambda V^D(S, e^D; \gamma, \xi) \\ V_A^D &:= B(S, e^D; \gamma, \xi) + (1-\lambda)V^D(S, e^D; \gamma, \xi) - C(e^D) \end{aligned}$$

Define $\Delta V_P^D := V_P^D - V_P^C$ and $\Delta V_A^D := V_A^D - V_A^C$. The principal, under centralisation, receives $V_P^C = \lambda V(S, e^C)$, while obtaining $V_P^D = \lambda V(S, e^D; \gamma, \xi)$ after delegation. We assume that S has no future use and the principal only cares about her monetary payoff at the end stage of the game. So as long as $V^D(S, e^D; \gamma, \xi) > V^C(S, e^C)$, ΔV_P^D is positive and the principal is willing to transfer formal authority (back) to the agent. This is possible when the increase of firm value from higher effort exceeds the detriment from loss of control over assets and actions.

To find the optimal set of delegation, we do not need to worry about the individual rationality constraint of the agent ($\Delta V_A^D \geq 0$). When $\Delta V_A^D < 0$, the principal is indifferent between centralisation and delegation since the principal could choose delegation but it will simply be ignored by the agent.

PROPOSITION 2 *Under delegation, the agent is never worse off in comparison to centralisation. Delegation is a Pareto improvement over centralisation iff $V^D(S, e^D; \gamma, \xi) > V^C(S, e^C)$. This is true only for a set of $\{\gamma, \xi\}$ with proper values.*

Evidently delegation is never a bad for the agent. Otherwise, he would just behave as if delegation had not taken place. For the principal, the situation is much more complicated. By delegation, she transfers formal authority back to the agent, and the agent can pick any actions in the acceptance area. Moreover, she allows the agent more freedom in the use of her critical assets.

Since a_A and a_P share some common features, if the agent's actual choice of effort increases, the principal may be better off because improved accomplishment of those common features. However, she may also be worse off if γ and ξ are too big, as there are too few common features or too many assets are diverted for the agent's private benefits.

Therefore, the principal faces the tradeoff between losing control over her assets and the agent's actions and incentivizing the agent to work harder. She has to choose carefully the authority regime that is better for her, by comparing her payoffs under centralisation and delegation, on the basis of her knowledge about the task, that is, the specificity of the assets and the complexity of the task.

Using assumptions A1-A3, one can find that the set of parameters under which delegation is feasible is well defined.

PROPOSITION 3 *If assumptions A1-A3 are satisfied and if Θ is sufficiently large, Θ can be partitioned into two sets F and F^c, each being a collection of subsets, such that $F \cup F^c = \Theta$. For $\theta \in F$, delegation is superior while centralisation dominates for $\theta \in F^c$.*

PROOF Define $\Delta V := V^D(S, e^D; \gamma, \xi) - V^C(S, e^C)$. Then ΔV is continuous in γ and ξ or more condensely in θ. For a sufficiently large parameter space Θ, there exist $\theta_1 \in \Theta$ and $\theta_2 \in \Theta$ such that $\Delta V(\theta_1) > 0$ and $\Delta V(\theta_2) < 0$. By continuity, there must exist at least some $\theta_3 \in \Theta$ such that $\Delta V(\theta_3) = 0$, under which the principal is indifferent between centralisation and delegation. This means that the space Θ can be partitioned into two sets F and F^c, each being a collection of subsets, such that $F \cup F^c = \Theta$, and $\Delta V(\theta) \geq 0$ for $\theta \in F$ and $\Delta V(\theta) < 0$ for $\theta \in F^c$. The boundary of the set F is well defined in the sense that the closure of F is continuous, by the continuity assumptions in B1-B3. □

A likely modelling form is that

$$V^C = V(S, e), \quad V^D = V((1-\xi)S, (1-\gamma)e), \quad B(.) = B(\xi S, \gamma e) \tag{3}$$

with $\gamma \in [0, 1]$ and $\xi \in [0, 1]$. In these functions, the assets are divisible and have general usage, with one portion $(1 - \xi)$ serving for the value of the firm and the other (ξ) for the agent's private purpose. The efforts devoted to private benefits and firm production are substitutes. Given total effort e, if the agent devotes more effort to the production of private benefits (portion γ), less efforts would be used in the firm production.

Suppose (3) holds, we can derive some more precise predictions about the effort levels and the feasible set of delegation.

PROPOSITION 4 *Suppose (3) holds, and E is sufficiently large that $e^C = e'$.*

1. If the principal's assets and agent's efforts are substitute or independent, delegation always leads to higher effort, $e^D > e^C$;

2. If the principal's assets and the agent's efforts are complements, $e^D > e^C$ only if γ and ξ are sufficiently big.

PROOF 1. Assets and efforts are substitute or independent means that $\frac{\partial V^2}{\partial S \partial e} \leq 0$. One has: $\frac{\partial V^D}{\partial e}|_{e=e^C} \geq \frac{\partial V^C}{\partial e}|_{e=e^C}$ since less assets are used in firm production under delegation. Recall that $\frac{\partial B}{\partial e} > 0$, the left-hand-side of equation (2) is bigger than that of equation (1) when evaluated at $e = e^C$, hence $e^D > e^C$.

2. Assets and efforts are complements means that $\frac{\partial V^2}{\partial S \partial e} > 0$. One has: $\frac{\partial V^D}{\partial e}|_{e=e^C} < \frac{\partial V^C}{\partial e}|_{e=e^C}$ since less assets are used in firm production under delegation. Recall the continuity assumptions and the fact that B is nondecreasing in θ, while V^D is nonincreasing in θ, there exists at least one pair $(\tilde{\gamma}, \tilde{\xi})$, such that if $\gamma \geq \tilde{\gamma}$ and $\xi \geq \tilde{\xi}$, $e^D > e^C$. □

PROPOSITION 5 *Suppose (3) holds, and E is sufficiently large that $e^C = e'$.*

1. If the principal's assets and agent's efforts are substitute or independent, delegation is only feasible if γ and ξ are not too big;

2. If the principal's assets and the agent's efforts are complements, delegation is only feasible if γ and ξ are neither too big nor too small.

If the assets and the efforts are substitutes or independent, delegation always improves the agent's incentives. Aghion and Tirole (1997) provides a good example. In their model, the principal's and agent's contributions to the firm are substitutable, as both players exert efforts to collect information on a same project. However, high effort from the agent does not necessarily mean that delegation is good for the principal. When γ and ξ are big, the agent's interest is too divergent from that of the principal and too much efforts and assets are diverted to the agent's private benefits. Consider the extreme case that $\gamma \to 1$ and $\xi \to 1$. Under delegation, the effort and assets devoted to the firm production are close to zero, and the principal's payoff is also close to zero, while under centralization, although the agent shirks, the principal receives strictly positive payoff. Hence, the principal will not delegate power to the agent.

If the assets and the efforts are highly complementary, for example, both $V(\cdot)$ and $B(\cdot)$ take the form of Cobb-Douglas production function or even more extreme Leontief production function, the decision about authority regime is more delicate. If γ and ξ are too big, the principal encounters the same problem as when S and e are substitutes. When γ and (or) ξ are small, delegation does not help very much to improve the agent's incentive as the agent's efforts are of little value to his private benefits without the principal's assets. If delegation does not improve the agent's effort, it is not optimal to the principal either. As a result, delegation is only feasible when γ and ξ lie in some intermediate range. This case will be illustrated with an example in section 4.

In this section, we started from a moral hazard problem due to separation of formal and real authority and suggested that through delegation, a process to reunite formal and real authority, the agent's incentive may be improved. However, delegation also imposes a cost on the principal since she loses control over the agent's actions and her own assets. The tradeoff is complicated by the subtle features of the task. In the next section, we will show that through monitoring, an increased real control over her assets, the principal can improve her control over the agent's actions indirectly.

3. DELEGATION WITH MONITORING

As stated in the introduction, monitoring is one part of ordinary life of almost every boss or manager in a firm. Under delegation, it is very often observed that a principal keeps the right of monitoring. In the context of our model, either the principal and the agent agree that the principal monitors or the principal automatically keeps the right of monitoring due to law or social norms. We will show that monitoring improves the principal's payoff without reducing her own action space and becomes a powerful instrument to induce desirable actions from the agent.

Monitoring can be written down at the contracting stage, together with an agreement of the acceptance area. Alternatively, the decision of monitoring can be made jointly with the choice of authority regime at stage $t = 1$. We will consider the second case in our model. That is, at stage $t = 1$, the principal's decision regime of organizational form is $R \in \{C, D, M\}$, where M refers to delegation with monitoring and D pure delegation (or delegation without monitoring). Then at stage $t = 2$, the principal monitors as the agent carries out the task. We do not consider the case of centralisation with monitoring, as monitoring, if there is, is always a part of the process of centralisation.

The principal's target of monitoring is to protect her own interest while inducing desirable actions from the agent. Monitoring activities can be classified into three groups. The first is to monitor the agent's actions directly. In other words, through monitoring, the principal may affect or even control the agent's real authority. The second one is to monitor the final outcome. According to the contractual arrangement of the sharing rule, both the principal and the agent have rights to benefit from the value of the firm. But there may be problems in realization of her or his revenue when the final outcome itself is unobservable or unverifiable. The third is to monitor the financial assets. As the owner of the critical assets, the principal holds the formal control rights over these assets. But she has to give away power of using these assets when delegating formal authority to the agent. To assure proper employment of the assets, the principal may have incentive to monitor these assets.

In our model, the working mechanisms of the three types of monitoring, direct supervision of the agent's behaviour, which is indicated by γ; examination of the final output, which can be captured by λ; and inspection of the principal's critical assets, measured by ξ, yields similar qualitative results. As stated in the introduction, we follow the third line here. This simplification is not far from reality, if not more realistic, taking into account failures of direct monitoring or imperfect monitoring due to the unobservability and nonverifiability of behaviour and outcomes. In large companies, the board of director usually can not observe the CEO's behaviour, let alone those activities conducted by lower level managers. In multinational firms, how can a CEO supervise a division manager thousand kilometers away? In looser principal-agent relations, for example a creditor and a debtor, it is almost unlikely to restrict the agent's actions directly. Even when actions are observable, due to the separation of formal and real authority, direct monitoring and monitoring of final outcome that depends on the actions may not be effective at all, since the agent always holds part of the real control over his own actions.

By delegation, the principal grants the agent the formal right of usage of her critical assets. However, she, as the owner of the assets, is always able to restrict the agent's actions by inspecting the usage of her critical assets and thus protect her own benefits. The inspection activities include requiring frequent reports, auditing financial statements and checking inventories etc.

To save notations, we let monitoring m enter ξ as if the principal's auditing can change the asset specificity. This is a realistic way of modelling as the divisibility of resources is a key feature of asset specificity. If $\xi(m)$ decreases with m, a more strict control of assets will reduce the degree of theft and yield a result similar to an increase in asset specificity. We maintain the basic assumptions A1-A3 and add some structures concerning the principal's monitoring behaviour.

B1. The cost function of monitoring is a continuous mapping $G(m) : [0, \bar{m}] \to \mathbb{R}_+$, with $G(0) = 0$. Moreover, $G'(m) > 0$ and $G''(m) \geq 0$.

B2. $\xi(m)$ is a continuous function from $[0, \bar{m}]$ onto $[0, \xi]$ with $\xi(\bar{m}) = 0$, $\xi(0) = \xi$ and $\xi'(m) \leq 0$.

Assumption B1 is to impose some regularity on the costly behaviour of monitoring. A fixed cost may be involved in supervision of the agent's actions. Since that is needed under centralisation as well, it can be normalized to zero. Assumption B2 concerns the impact of the principal's monitoring activity. The monitoring effort of the principal reduces the portion of assets that the agent can steal.

Since monitoring is costly, with imperfect monitoring, the agent can still steal part of the assets. His payoff now can be written as:

$$V_A^M(S, e, m) = B^M(S, e; \gamma, \xi(m)) + (1 - \lambda)V^M(S, e; \gamma, \xi(m)) - C(e)$$

and the principal's payoff function is

$$V_P^M(S, e, m) = \lambda V^M(S, e; \gamma, \xi(m)) - G(m)$$

In these equations, the major difference with delegation without monitoring is $\xi(m)$, which measures the effectiveness of monitoring. If the principal's monitoring is sufficiently effective, $\xi(m)$ may approach zero. Then just like under centralisation, the agent can not remove any part of the assets. But it is still possible for a delegated agent to tunnel his efforts even under monitoring due to the freedom he has in choosing his actions. When the principal chooses the authority regime, she takes her equilibrium monitoring into account. The functions $\xi(m)$ and $G(m)$ will play an important role in her delegation decision.

As we are considering the case in which the decision of monitoring takes place along with choice of authority regime, the game is like a sequential game in which the principal moves first by choosing the monitoring level. Therefore the principal

$$\max_m V_P^M(S, e, m)$$
$$\text{s.t. } e \in \arg\max_{\tilde{e}} V_A^M(S, \tilde{e}, m)$$

With the regular concavity assumptions, the agent's optimal effort $e(m)$ is determined by the following first order condition

$$\frac{\partial B^M(S,e;\gamma,\xi(m))}{\partial e} + (1-\lambda)\frac{\partial V^M(S,e;\gamma,\xi(m))}{\partial e} = \frac{dC(e)}{de}$$

Then the principal

$$\max_m V_P^M(m^M) := V_P^M(S,e(m);\gamma,\xi(m))$$

If interior solutions exist, the optimal level of monitoring is determined by

$$\lambda\frac{\partial V^M(S,e(m);\gamma,\xi(m))}{\partial m} = \frac{dG(m)}{dm}$$

Given the equilibrium$\{\bar{e}^M, \bar{m}^M\}$, the payoff of the two players are respectively:

$$\begin{aligned} V_P^M &= \lambda V^M\left(S,e(\bar{m}^M);\gamma,\xi(\bar{m}^M)\right) - G(\bar{m}^M) \\ V_A^M &= B^M\left(S,e(\bar{m}^M);\gamma,\xi(\bar{m}^M)\right) + (1-\lambda)V^M\left(S,e(\bar{m}^M);\gamma,\xi(\bar{m}^M)\right) - C(\bar{e}^M) \end{aligned}$$

We know immediately the principal will choose delegation with monitoring, and the agent will accept this formal power if the following conditions are satisfied:

$$V_P^M \geq \max\{V_P^C, V_P^D\}; \quad V_A^M \geq V_A^C$$

Similar to delegation without monitoring, the set of parameters $\{\gamma, \xi\}$ should take proper values to make delegation with monitoring feasible. The feasible set of parameters depends on interactions between actions of the principal and the agent and the functional forms.

There is an additional tradeoff faced by the principal with the option of monitoring. On the one hand, the principal can restrict the agent's misbehaviour by having a tighter control over the usage of her assets when the critical assets and the agent's action are highly complementary in the production of private benefits. On the other hand, her monitoring activities incur costs. If her inspection activities are not sufficiently effective or too expensive, the principal would not monitor at all, bringing us back to the case where monitoring is not possible at all.

3.1. *Monitoring vs. No Monitoring*

Even though few general statements can be made without further specifications of the model, a robust result is that the principal has a tendency to maintain the right of monitoring. Furthermore, the possibility of monitoring expands the feasible set of delegation.

The intuition is straightforward. Monitoring expands the principal's action space. Under a decision theory framework, it is always true that a decision maker with more possible actions is no worse off than one with less actions. This is indeed our case since the principal can move first and has right to design an enforceable contract. In a game theory framework, the result does not necessarily hold. We will discuss the difference as a caveat. The principal's expansion in action space can make delegation more desirable in some situations, and this may lead to an enlarged feasibility set of delegation. The proof is particularly easy with our continuity assumptions.

First of all we will show that $V_P^M \geq V_P^D$ always holds, and the principal only needs to choose between centralisation and delegation with monitoring (with pure delegation as special case), subject to the individual rationality constraint of the agent. Then we show that the individual rationality constraint of the agent never reduces the feasibility set of delegation when monitoring is possible.

LEMMA 1 *If delegation happens without monitoring, the principal is also willing to transfer formal authority to the agent with monitoring.*

PROOF Denote the value of delegation with monitoring to the principal as $\Delta_P^M = V_P^M - V_P^C$. What to be shown is if $\Delta_P^D \geq 0$, $\Delta_P^M \geq 0$. We only need to prove $\Delta_P^M \geq \Delta_P^D$. This can be easily done by contradiction.

Suppose $\Delta_P^M < \Delta_P^D$ and $\bar{m}^M > 0$, that implies $V_P^M < V_P^D$. The principal will then choose $m = 0$ as $V_P^M(\bar{e}^M, m = 0) = V_P^D$, which leads to a contradiction. Thus $\Delta_P^M \geq \Delta_P^D \geq 0$ if $\Delta_P^D \geq 0$. □

This lemma states that for the principal delegation with monitoring weakly dominates pure delegation even when monitoring is costly. The principal is never worse off when she can use monitoring as her strategic instrument. Of course, the principal would give up the right of monitoring or commit not to monitor if it is not in her favor.

LEMMA 2 *Under some given parameter values, even if delegation is not feasible without monitoring, it is feasible for the principal to delegate with monitoring.*

PROOF We want to prove there exists some $\hat{\theta} \in \Theta$, such that $\Delta_P^D(\hat{\theta}) < 0$, but $\Delta_P^M(\hat{\theta}) \geq 0$. By assumptions A2-A3 and B1-B2, $V_P(m^M) = V_P(S, e(m); \gamma, \xi(m)|M)$ is continuous in ξ. Define $\Delta V_P(m^M) = V_P(m^M) - V_P^C$. Obviously $\Delta V_P(m^M)$ is also continuous in ξ. We pick up a pair of parameter values $\{\gamma, \xi + \epsilon\}$ and $\{\gamma, \xi - \epsilon\}$ for a sufficiently small ϵ, such that $\Delta V_P(m^M = 0|\gamma, \xi + \epsilon) = \Delta V_P^D(\gamma, \xi + \epsilon) < 0$ and $\Delta V_P(m^M = 0|\gamma, \xi - \epsilon) = \Delta V_P^D(\gamma, \xi - \epsilon) > 0$, then there must exist a $\{\gamma, \xi\}$ with $\xi \in [\xi - |\epsilon|, \xi + |\epsilon|]$ such that $\Delta V_P^D(\gamma, \xi) = \Delta V_P(m^M = 0|\gamma, \xi) = 0$. This is always possible if Θ is large enough as we discussed in last section. Obviously, $\Delta V_P(m^M)$ is continuous in m^M. Since $\xi'(m) \leq 0$, it is true that for some positive δ such that $\Delta V_P(m^M = \delta > 0|\gamma, \xi + \epsilon) = \Delta V_P(m^M = 0|\gamma, \xi) = 0$. By definition, $V_P^M(\gamma, \xi + \epsilon) = \sup V_P(m^M|\gamma, \xi + \epsilon)$. Immediately we obtain the result that for $\{\gamma, \xi + \epsilon\}$, $\Delta V_P^D(\gamma, \xi + \epsilon) < 0$ while $\Delta V_P^M(\gamma, \xi + \epsilon) \geq 0$. □

This lemma indicates that the principal is more likely to transfer power when monitoring is possible. In contrast to Lemma 1, the proof of Lemma 2 relies on the continuity assumptions, which are somewhat technical but give intuitive results. With the nice properties of continuity, the valuation function ΔV_P^M is continuous in the parameter vector θ. If the parameter space Θ is indeed partitioned into two sets F and F^c, where F is the feasible set of delegation without monitoring and F^c the complement, we can pick up those parameter values of F^c close to its boundary, and disturb those values by monitoring. It is possible that those disturbed values will lie in the set F and delegation becomes feasible. The result is just as if the boundary of set F expands if monitoring is allowed. This intuitive reasoning leads to the following lemma.

LEMMA 3 *Monitoring enlarges the set of parameters under which delegation is feasible for the principal.*

PROOF We have already shown that there exists some $m^M > 0$ such that $\Delta_P^D(\gamma, \xi) \leq 0$ but $\Delta_P^M(m^M, \gamma, \xi) > 0$. In equilibrium, $\Delta_P^M(m^M, \gamma, \xi) = \Delta_P^M(\gamma, \xi(m^M))$. Let $\hat{\xi} = \xi(m^M)$, then a decision of delegation without monitoring with respect to parameters $\{\gamma, \hat{\xi}\}$ is always duplicated by a decision of delegation with monitoring with respect to parameters $\{\gamma, \xi\}$ where usually $\hat{\xi} \neq \xi$. Together with Lemma 1 that $\Delta_P^D(\gamma, \xi) \geq 0$ implies $\Delta_P^M(m^M, \gamma, \xi) \geq 0$, we have proved the result. Similar reasoning applies to the parameter γ. □

The Lemma 3 is just an extension of Lemma 2. In the three lemmas above, we have shown that monitoring (weakly) increases the value of delegation to the principal. We show in the next lemma that the individual rationality constraint of the agent does not reduce the feasible set of delegation.

LEMMA 4 *The individual rationality constraint of the agent does not reduce the feasible set of delegation when monitoring is possible.*

PROOF Under authority regime M, the agent accepts delegation if $\Delta_A^M \geq 0$. However, suppose there exists some $m^M > 0$ such that $\Delta_A^D \geq 0 > \Delta_A^M$. The agent accepts delegation when no monitoring is imposed and ignores delegation if the equilibrium level of monitoring is imposed. In this case, as long as $\Delta_P^D > 0$, the equilibrium monitoring chosen by the principal is $\bar{m}^M = 0$ since that gives her a payoff equal to V_P^D, which is greater than V_P^C, her payoff from delegation with a monitoring level m^M. This means, when monitoring is possible, a necessary condition for delegation to take place is $\max\{\Delta_A^M, \Delta_A^D\} \geq 0$, instead of $\Delta_A^M \geq 0$. Hence, the IR constraint of the agent does not reduce the feasible set of delegation. □

The result of the above four lemmas is summarized in the following proposition.

PROPOSITION 6 *Suppose there exists a pair of equilibrium value $\{\bar{e}^M, \bar{m}^M\}$, such that $V_P^M \geq V_P^C$ and V_P^M is continuous in θ. Monitoring increases the value of delegation to the principal and expands the feasible set of delegation.*

The first condition in the above proposition, $V_P^M \geq V_P^C$ for some γ and ξ, is about the feasibility of delegation, which can be guaranteed by the assumptions. The second condition, continuity of V_P^M in θ, states that from the perspective of the principal, her value of delegation is continuous in the equilibrium monitoring effort and the result is as if she could alter or at least disturb the parameter values. The main implication of the proposition is that when it is not too costly, monitoring always goes hand in hand with delegation, unless the principal is forced to commitment of no monitoring.

However the above proposition crucially depends on the assumption that the principal has the right to design the delegation contract at stage $t = 1$ and she is expected to commit her behaviour during the interaction between the two players. Under that assumption, the principal is a decision maker who can always avoid threats from the agent's misbehaviour. If monitoring can not be written down in the delegation contract or the principal can not commit her monitoring behaviour, the game becomes simultaneous, and the principal and the agent choose actions at the same time at stage $t = 2$.

Assume the existence of interior solutions $\{\hat{e}^M, \widehat{m}^M\}$. The pair is determined by solving the following two simultaneous equations:

$$\lambda \frac{\partial V^M(S,e;\gamma,\xi(m))}{\partial m} = \frac{dG(m)}{dm}$$
$$\frac{\partial B^M(S,e;\gamma,\xi(m))}{\partial e} + (1-\lambda)\frac{\partial V^M(S,e;\gamma,\xi(m))}{\partial e} = \frac{dC(e)}{de}$$

It is possible that under some parameter values the equilibrium payoffs for the principal and the agent are both worse off than the case when monitoring is not possible. This is another version of the prisoners' dilemma. The intuition can be seen from the following example. Suppose when choosing the authority regime at stage $t = 1$, the principal promises not to monitor the agent. If this is indeed the case, the agent will exert an effort level e^D and the principal and the agent will obtain V_P^D and V_A^D respectively. But if the principal's promise is not credible, the agent expects that the principal will monitor to some extent when he chooses e^D. Then it is to his benefits to deviate from e^D. Their strategic behaviour under individual rationality eventually leads to an equilibrium $\{\hat{e}^M, \widehat{m}^M\}$, which is likely to hurt both players.

To avoid this unfavorable result, it is crucial for the principal to make credible commitment of monitoring before the implementation of the task. That's why in reality monitoring is quite often an explicit item in a delegation contract. Of course, when monitoring cost is sufficiently high, the principal's behaviour always has commitment power and monitoring is not necessary to be written down explicitly.

In this section, we introduced monitoring into the model. Although the basic structure is very similar to the game without monitoring, the working mechanism is more complicated, since there is an interaction between the principal's monitoring and the agent's effort. When monitoring enters the principal's action space, the principal tends to make use of these additional actions. If monitoring is a Pareto improvement over pure delegation, there is no ambiguity. But if this is not the case, the agent is hurt by monitoring and may take actions which induce strategic actions of the principal. In equilibrium, both may be hurt. The principal should be cautious about this case when monitoring is bundled with delegation.

Leaving out the above caveat, the principal through monitoring is able to increase her real control over the usage of her assets, and hence extract more surplus, possibly at the expense of the agent's private benefits. It is not clear whether the total welfare increases or decreases in comparison to pure delegation since the principal's payoff increases because of monitoring but the agent's payoff may decrease.

4. AN EXAMPLE

In this section, we develop a highly simplified and specific model to illustrate how different regimes of authority allocation evolves as a response to distinct parameter sets.

The principal's physical assets S is normalized to unit. The critical assets owned by the principal and the actions of the agent are highly complementary. We assume that both $V(.)$ and $B(.)$ take the form of Cobb-Douglas production function. The firm value under centralisation is $V(S,e;\theta) = e$, and the agent realizes no private benefits. Under delegation, the firm value is equal to $V(S,e;\theta) = (1-\xi)(1-\gamma)e$, which will be shared between the two players, and the agent realizes private benefits $B(S,e;\theta) = \gamma\xi e$.

The agent's cost of effort is quadratic: $C(e) = \frac{1}{2}ae^2$, with $a > 0$. For simplicity, the domain of e is restricted to $[0,1]$.

The payoffs of the two players under the two authority regimes $R \in \{C, D\}$ are respectively:

$$V_P^R(e) := \begin{cases} \lambda e & \text{if} \quad R = C \\ \lambda(1-\gamma)(1-\xi)e & \text{if} \quad R = D \end{cases}$$

for the principal and

$$V_A^R(e) := \begin{cases} (1-\lambda)e - C(e) & \text{if} \quad R = C \\ \gamma\xi e + (1-\lambda)(1-\gamma)(1-\xi)e - C(e) & \text{if} \quad R = D \end{cases}$$

for the agent.

4.1. *Centralisation vs. Delegation and Feasible Set of Delegation*

Under centralisation, the agent chooses an effort level to maximize his expected payoff $V_A^C(e)$. Suppose E is sufficiently large, the equilibrium effort is given by

$$e^C := \arg\max_e V_A^C(e) = \frac{1}{a}(1-\lambda)$$

The principal and the agent's payoffs are respectively:

$$V_P^C = \frac{1}{a}\lambda(1-\lambda); \qquad V_A^C = \frac{1}{2a}(1-\lambda)^2$$

Under delegation, the agent obtains private benefits since he diverts a portion γ of his effort and steals a portion ξ of the assets for his private purpose. His equilibrium choice of effort is given by:

$$e^D := \arg\max_e V_A^D(e) = \frac{1}{a}\alpha(\gamma,\xi)$$

where $\alpha(\gamma,\xi) := \gamma\xi + (1-\lambda)(1-\gamma)(1-\xi)$. $\alpha(\gamma,\xi)$ captures the marginal return to the agent's effort: $\gamma\xi$ measuring the return from private benefits, and $(1-\lambda)(1-\gamma)(1-\xi)$ the return from his share of the firm value. The agent determines the optimal effort by setting marginal return equal to marginal cost ae. Delegation mitigates moral hazard when $e^D > e^C$.

Proposition 7 *Delegation induces higher effort from the agent if (γ, ξ) are such that*

$$\alpha(\gamma, \xi) \geq 1 - \lambda \tag{4}$$

Note that condition (4) can be rewritten as:

$$\gamma\xi - (1 - \lambda)(\gamma + \xi - \gamma\xi) > 0$$

Under delegation, the agent faces a tradeoff when he increases his effort over that under centralisation: an incremental payoff from his private benefits measured by $\gamma\xi$, and an incremental loss from his share of the firm value, measured by the second term on the left hand side of the above inequality. This loss comes from the fact that under delegation less assets $(1 - \xi < 1)$ and only a portion of his effort $(1 - \gamma)$ is used in the production of the firm value. As long as the overall incremental payoff is positive, the agent will exert higher effort under delegation than under centralisation.

The major implication of Proposition (7) is that when sharing rule can not be adjusted to give the agent the right incentive, delegation can be used as a substitute. Given a certain effort level, tunnelling of effort and theft of assets decrease the firm value. However, when the agent has the freedom to choose his actions, the opportunity of tunnelling and theft brings him private benefits. If his overall payoff is increased, he has an incentive to work harder.

As in the general model, delegation is only feasible if it improves the principal's payoff without putting the agent in a worse situation than under centralisation. The payoffs of the two players are given by

$$V_P^D = \frac{\lambda}{a}(1 - \gamma)(1 - \xi)\alpha(\gamma, \xi)$$
$$V_A^D = \frac{1}{2a}(\alpha(\gamma, \xi))^2$$

The feasible set of delegation can be found be solving the following program:

$$\Delta V_P^D = V_P^D - V_P^C \geq 0 \quad \text{subject to} \quad \Delta V_A^D = V_A^D - V_A^C \geq 0$$

The necessary and sufficient condition for $\Delta V_P^D \geq 0$ is:

$$(1 - \gamma)(1 - \xi)\alpha(\gamma, \xi) \geq 1 - \lambda$$

Since $(1-\gamma)(1-\xi) < 1$, if the above inequality holds, it implies that condition (4), the necessary and sufficient condition for $\Delta V_A^D \geq 0$, holds as well. That means if delegation improves the principal's payoff, it also improves the agent's payoff. Here we do not have a case that delegation is chosen by the principal but is ignored by the agent since it reduces his payoff.

Proposition 8 *The feasible set of delegation is given by:*

$$F = \{(\gamma, \xi) | (1 - \gamma)(1 - \xi)\alpha(\gamma, \xi) \geq 1 - \lambda\}$$

For given λ, delegation is feasible if both γ and ξ lie in an intermediate range. When γ or ξ is small, the productivity of private benefits is insignificantly low such that delegation has little incentive effect. When both γ and ξ are big, delegation is effective in providing the right incentives for the agent. In the extreme case where $\gamma = \xi = 1$, the agent exerts the efficient level of effort since he receives the entire outcome of his actions. However, this is at the expense of the principal's interest since the assets are used in a way not for her benefit. The principal would not delegate authority since her payoff decreases in comparison to centralisation.

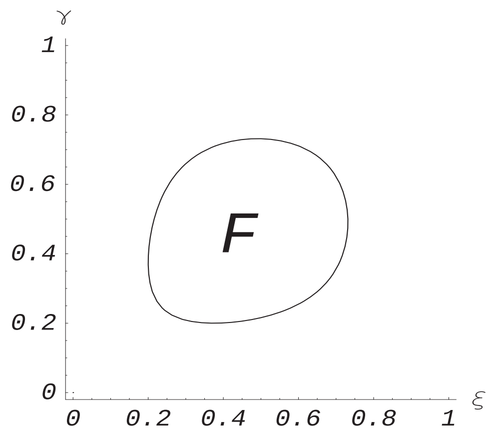

Figure 1: Feasible Set of Delegation for $\lambda = 0.95$

The feasible set F may be empty if λ is small. That is due to the assumption in this example that the assets (similarly effort) used for the private benefits and the production of the firm sum up to 1. This is true for exclusive assets whose usage for one purpose excludes the usage for another purpose, for example capital. However, there are also other assets that the usage for one purpose does not completely excludes them from being used for other purposes, for example office rooms and computers, where the feasible set may be nonempty even when λ is small.

4.2. *Delegation with monitoring*

When the possibility of monitoring is not precluded, the principal can choose between centralisation C, pure delegation D (or delegation without monitoring) and delegation with monitoring M. When delegation with monitoring is chosen, there is an interaction between the principal's monitoring and the agent's effort.

To simplify computation, we assume that the cost function of the principal's monitoring is linear: $G(m) := gm,\ m \in [0, \xi],\ g > 0$. The effect of monitoring is embodied in $\xi(m) := \xi - m$.

4.2..1 **Subgame Equilibrium under Authority Regime** M

The objective function of the agent is:

$$V_A^M(m,e) = \gamma(\xi - m)e + (1-\lambda)(1-\gamma)(1-\xi+m)e - \frac{1}{2}ae^2$$

Given a promised monitoring level m, the agent chooses his effort e that satisfies the first order condition:

$$e(m) = \frac{1}{a}\left(\alpha(\gamma, \xi) - \beta m\right) = e^D - \frac{\beta}{a} m \tag{5}$$

where $\beta := \gamma - (1-\lambda)(1-\gamma)$.

Equation (5) tells us how the agent determines his optimal effort as a response to the monitoring level chosen by the principal. β measures the impact of monitoring on the agent's payoff. One more unit of monitoring reduces the agent's private benefits by γ units and increases his payoff from the firm value by $(1-\gamma)(1-\lambda)$ units. β can be positive or negative, depending the tradeoff of the two effects. When β is positive, the agent's reaction function is downward sloping, monitoring chokes down the agent's working initiative and the negative effect on his private benefits dominates the positive effect on his share of the firm value. The agent exerts less effort when monitoring is imposed. When β is negative, monitoring and the effort of the agent are strategically complementary, and the agent's reaction function is upward sloping. The agent's return from the firm value dominates such that more strictly monitoring induces harder working[5]. $\beta = 0$ is the special case that the impact of monitoring on the agent's private benefits and returns from the firm value exactly offset each other. In our example, when we proceed to solve for the game, we will see that when $\beta \leq 0$ delegation is never feasible, since the productivity of private benefits is so low in comparison to that of the firm value that the agent's individual rationality constraint is never satisfied to accept delegation.

The principal chooses her monitoring level to maximize the following objective:

$$V_P^M(m, e(m)) = \lambda(1-\gamma)(1-\xi+m)e(m) - gm$$

Suppose the equilibria are given by $(\bar{e}^M, \bar{m}^M)$. Under delegation with monitoring, the payoffs of the two players are:

$$\begin{aligned} V_A^M &= V_A^M(\bar{m}^M, e(\bar{m}^M)) = \frac{1}{2}a\ e(\bar{m}^M)^2 = \frac{1}{2}a(\alpha(\gamma,\xi) - \beta\bar{m}^M)^2 \\ V_P^M &= V_P^M(\bar{m}^M, e(\bar{m}^M)) = V_P^C + \Delta_1(\bar{m}^M) = V_P^D + \Delta_2(\bar{m}^M) \end{aligned}$$

with $\Delta_1(\bar{m}^M)$ and $\Delta_2(\bar{m}^M)$ respectively the maximum value of the following functions:

$$\begin{aligned} \Delta_1(m) =& V_P^M(m, e(m)) - V_P^C \\ =& -\frac{\lambda}{a}(1-\gamma)\beta m^2 - (g-\hat{g})m - \frac{\lambda}{a}\left((1-\gamma) - \alpha(\gamma,\xi)(1-\gamma)(1-\xi)\right) \\ \Delta_2(m) =& V_P^M(m, e(m)) - V_P^D = -\frac{\lambda}{a}(1-\gamma)\beta m^2 - (g-\hat{g})m \end{aligned}$$

where $\hat{g} := \frac{1}{a}(1-\gamma)\lambda\left(\alpha(\gamma,\xi) - \beta + \beta\xi\right)$.

The principal's choice of equilibrium $\bar{m}^M$ depends on g. If monitoring is very costly to her, positive level of monitoring decreases her payoff in comparison to no monitoring and she would

[5] This corresponds an interesting story told by Alchian and Demsetz(Alchian and Demsetz (1972)): a group of workers may hire (maybe quite expensively) a supervisor to inspect shirking of any member. In our story, the agent pays the principal to monitor himself in order to prevent his diversion of effort to other use, which is less productive.

prefer not to monitor at all.

4.2..2 **Expansion of Feasible Set though Monitoring**

In a sequential game where monitoring level is chosen before the choice of the agent's effort, the principal can choose any monitoring level she prefers, subject to the agent's individual rationality (IR) constraint

$$V_A^M \geq V_A^C \Leftrightarrow \alpha(\gamma,\xi) - \beta\bar{m}^M \geq 1-\lambda \tag{6}$$

We first show that when β is negative, there exists no positive monitoring level that the agent's IR is satisfied.

LEMMA 5 *When $\beta \leq 0$, there exists no positive level of monitoring that satisfies the individual rationality constraint of the agent.*

PROOF Suppose $\beta \leq 0$, since $\bar{m}^M \leq \xi$, $-\beta\xi \geq -\beta\bar{m}^M$, we have:

$$\alpha(\gamma,\xi) - \beta\bar{m}^M \leq \alpha(\gamma,\xi) - \beta\xi = (1-\lambda)(1-\gamma) < 1-\lambda$$

there exists no equilibrium $\bar{m}^M$ such that (6) is satisfied. □

When $\beta \leq 0$, delegation with monitoring is not feasible to the agent, or the agent ignores delegation if it takes place. This implies that delegation is infeasible no matter monitoring is possible or not, since $F = \emptyset$ when $\beta \leq 0$. As a result, we can restrict our further discussion to $\beta > 0$.

Two cases will be distinguished. For parameters $(\gamma,\xi) \in F^c$, delegation is not feasible when monitoring is precluded. We will show that there is a nonempty subset ΔF of F^c such that delegation becomes feasible when monitoring can be used strategically by the principal. Delegation with monitoring is a Pareto improvement over pure delegation for parameters belong to ΔF.

PROPOSITION 9 *When $(\gamma,\xi) \in F^c$, delegation is infeasible without monitoring. When monitoring is possible, delegation becomes feasible* iff *(γ,ξ,g) are such that:*

$$\Delta F = \{(\gamma,\xi,g) | \beta > 0, \alpha(\gamma,\xi) + \lambda > 1, g < \bar{g}\}$$

where

$$\bar{g} = \hat{g} - \frac{1}{a}\sqrt{\beta(1-\gamma)\lambda^2(1-\lambda-\alpha(\gamma,\xi)(1-\gamma)(1-\xi))}$$

ΔF is nonempty iff (γ,ξ) are such that the following hold

$$\alpha(\gamma,\xi) + \lambda > 1, \quad \beta > 0$$
$$(1-\gamma)(\alpha(\gamma,\xi) - \beta + \beta\xi)^2 > \beta(1-\lambda-\alpha(\gamma,\xi)(1-\gamma)(1-\xi))$$

PROOF Relegated to the appendix. □

For parameters $(\gamma, \xi) \in F$, delegation is feasible when monitoring is precluded. The possibility of monitoring will not reduce the magnitude of the set F, since the principal can always choose zero monitoring when monitoring reduces her payoff. Monitoring weakly improves the principal's payoff, but decreases the agent's payoff in comparison to pure delegation. In choosing between pure delegation and delegation with monitoring, the principal is subjected to the individual rationality constraint of the agent that the agent is no worse off than his status under centralisation so that he will not ignore delegation. We will show that monitoring improves the principal's payoff for parameters values in a subset F_M. The overall social welfare effect is not clear since the agent's payoff decreases.

PROPOSITION 10 *When $(\gamma, \xi) \in F$, monitoring improves the principal's payoff for the parameters belonging to set F_M, with*

$$F_M = \{(\gamma, \xi, g) | \beta > 0, \alpha(\gamma, \xi) + \lambda > 1, g < \hat{g}\}$$

PROOF The proof is again relegated to the appendix. □

Proposition (9) and (10) tell us that delegation takes place more often when monitoring is not precluded. We also know the optimal choice of the principal in her delegation decision at stage $t = 1$ when monitoring is indeed possible:

COROLLARY 1 *When monitoring is possible, the optimal authority regime is*

1) Delegation with monitoring if $(\gamma, \xi, g) \in F_M \cup \Delta F$;

2) Delegation without monitoring if $(\gamma, \xi, g) \in F / F_M$.

3) Centralisation if $(\gamma, \xi, g) \in F^c / \Delta F$.

We close this section with a numerical example.

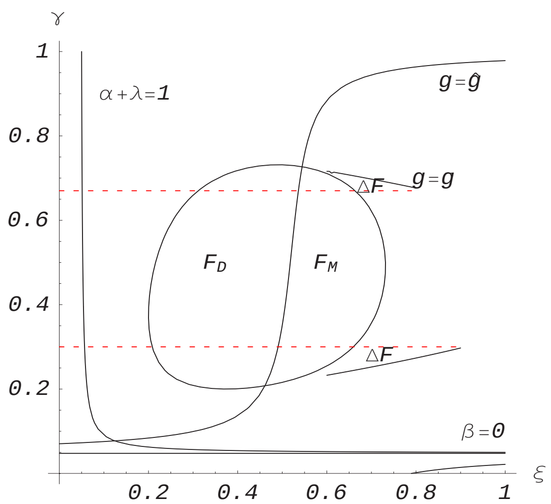

Figure 2: Optimal Authority Regime for $(\lambda, a, g) = (0.95, 0.2, 0.1)$

EXAMPLE 1 *Suppose $(\lambda, a, g) = (0.95, 0.2, 0.1)$.*

1. $(\gamma, \xi) = (0.3, 0.66)$ *is an element from set* F^c. *Without monitoring, delegation is infeasible. When the principal can monitor, a positive level of monitor* $m = 0.164$ *improves the principal's payoff by* $\Delta_P^M = 0.017$ *and increases the agent's payoff by* $\Delta_A^M = 0.054$. *Delegation with monitoring is a Pareto improvement over centralisation and pure delegation. The entire feasible set of delegation for* $(\lambda, a, g) = (0.95, 0.2, 0.1)$ *is indicated as* ΔF *in Figure (2).*

2. $(\gamma, \xi) = (0.6, 0.7)$ *is an element from set* F *(*$F_D + F_M$ *in Figure (2)). In comparison to pure delegation, delegation with monitoring improves the principal's payoff by* 0.033 *and decreases the agent's payoff by* 0.187. *The total social welfare decreases. The set that the principal's payoff is higher under delegation with monitoring is denoted by* F_M *in Figure (2).*

5. CONCLUSIONS

We developed a theory of authority, based on the common conception in sociology and business adminstration. We distinguish formal authority and real authority to answer the important questions such as how human assets are transacted and the resulting inefficiencies. It is true that the inalienable property discriminates human assets from physical assets, but the formal (nominal) right of employing human assets is still contractible within some limits and separation of formal authority and real authority prevails in economic relations. The critical problem with human assets is that formal authority is difficult to verify and enforce. An employer of human assets has to provide sufficient incentives to induce desirable actions when the contract of formal authority is incomplete or legal enforcement is hardly possible.

Delegation is an important instrument to invite incentives as it allows for free manipulation of human assets by the body of these human assets. Balancing a tradeoff between inducing incentives and losing control, the principal decides how to allocate formal authority by choosing centralisation or delegation. As we put emphasis on value of real authority over human assets, the nature of production process, which is a joint result of human assets and physical assets, is the key determinant of allocation of authority. Delegation is more likely when tasks are not too simple and assets are not too specific. We also analyzed the role monitoring plays in the decision of delegation. Monitoring expands the principal's action space and serves as an additional instrument to fine tune the tradeoff between incentive and control. Value of monitoring depends on structure of the game.

Our model is general and simple enough to incorporate repeated interactions, information asymmetry, multiple tasks and multiple agents etc. One additional advantage of the theory is that the production process is basically measurable, at least from the point of view of the involved players. As a result, it is possible to make reasonable specifications and put them to empirical test.

Despite a wide range of applications, our theory should be regarded as a start point to address the issue of transaction of human assets. Many important questions are left unanswered. One fundamental issue is why the principal accepts formal authority over an agent's human assets at the first place when she knows that it would be better for her to delegate formal authority back to the agent. Put in other words, in our model, it is assumed that the capitalist employs the worker, but it may be Pareto improvement if the worker purchases (possibly with credit) the physical assets and employs the capitalist. This is closely related to the theory of firm and deserves careful investigation.

In our model, the ex ante inefficiency of the contract comes from an exogenous sharing rule and this inefficiency can be mitigated by delegation but in general can not be eliminated ex post as we rule out renegotiation and monetary transfer by assumptions. It would be possible to improve efficiency by relaxing some of these assumptions and introducing more actions to the players. For instance, the principal may design the acceptance area to make the agent's actions more enforceable. This is of particular interests when the principal faces multiple tasks. Another possibility is to allow the principal to design payment scheme. We expect that payment scheme is a substitute to delegation but if an efficient payment scheme is not available, allocation of authority still plays a role. Interaction between task design or payment design and decision of delegation requires more structure of the players' preferences.

Appendix

Proof of Proposition 9 Suppose $\beta > 0$ and $(1-\gamma) - \alpha(\gamma,\xi)(1-\gamma)(1-\xi) > 0$ ($(\gamma,\xi) \in F^c$). Recall that $V_P^M = V_P^C + \Delta_1(\bar{m}^M)$, and $\Delta_1(\bar{m}^M)$ is the maximizer of $\Delta_1(m)$ with:

$$\Delta_1(m) = K_1 m^2 + K_2 m + K_3$$

where

$$K_1 = -\frac{\lambda}{a}(1-\gamma)\beta, \quad K_2 = -(g - \hat{g})$$
$$K_3 = -\frac{\lambda}{a}\left((1-\gamma) - \alpha(\gamma,\xi)(1-\gamma)(1-\xi)\right)$$

By assumption, $K_1 < 0$ and $K_3 < 0$. The principal will only delegate authority if $\Delta_1(\bar{m}^M) > 0$. For the existence of such $\bar{m}^M$, the necessary and sufficient conditions are

$$K_2 > 0, \quad K_2^2 - 4K_1K_3 > 0$$

$K_2 > 0$ is satisfied *iff* $g < \hat{g}$ and $K_2^2 - 4K_1K_3 > 0$ is satisfied *iff* $g < \bar{g}$. Since $\bar{g}$ is smaller than $\hat{g}$, $\bar{g}$ gives the upper bound of g that guarantees the existence of a positive monitoring level that leads to a positive value of $\Delta_1(m)$.

Suppose $g < \bar{g}$, denote the roots of $\Delta_1(m) = 0$ as m_1 and m_2, with $m_1 < m_2$. If $m_1 < \xi$, then we are assured of the existence of a positive monitoring level that leads to an improvement of the principal's payoff ($\Delta_1(\bar{m}^M) > 0$).

$$m_1 = \frac{-K_2 + \sqrt{K_2^2 - 4K_2K_3}}{2K_1} < \xi \Leftrightarrow g > -\frac{1}{a}\gamma\xi(1-\lambda)(2-\gamma)$$

which always holds since $g > 0$.

However, in choosing the optimal monitoring level, the principal is subjected to the individual rationality (IR) constraint of the agent:

$$V_A^M \geq V_A^C \Leftrightarrow \alpha(\gamma, \xi) - \beta \bar{m}^M \geq 1 - \lambda$$

This constraint gives us the maximum monitoring the agent can bear when he accepts delegation, $m_{\max} = \frac{\alpha(\gamma,\xi)-1+\lambda}{\beta}$. As long as this $m_{\max} \geq m_1 > 0$, there always exists a positive monitoring level that improves the principal's payoff without violating the agent's IR condition. $g < \bar{g}$ guarantees that $m_1 > 0$. A necessary condition for $m_{\max} \geq m_1$ is $\alpha(\gamma, \xi) + \lambda > 1$. Supposing this condition holds, we have:

$$m_{\max} \geq m_1 \Leftrightarrow g \geq -\frac{\gamma^2(1-\lambda)\lambda}{\alpha(\gamma, \xi) + \lambda - 1}$$

which is always satisfied. Therefore, the condition needed to satisfy the agent's IR is given by $\alpha(\gamma, \xi) + \lambda > 1$.

We have completed our proof that ΔF is indeed the set of parameters that the principal will delegate when monitoring is possible but not when monitoring is precluded. To ensure that ΔF is nonempty, we need $\bar{g} > 0$, which immediately gives us the last part of the claim. □

Proof of Proposition 10 We want to show that for $(\gamma, \xi) \in F^M \subset F$, $V_P^M > V_P^D$, subject to the agent's IR constraint that $V_A^M \geq V_A^C$.

Recall that $V_P^M = V_P^D + \Delta_2(\bar{m}^M)$ with $\bar{m}^M$ the maximizer of $\Delta_2(m)$.

$$\Delta_2(m) = -\frac{\lambda}{a}(1-\gamma)\beta m^2 - (g - \hat{g})m$$

Obviously one root of $\Delta_2(m) = 0$ is 0. A necessary and sufficient condition that a positive monitoring level exists such that $\Delta_2(m) > 0$ is that

$$\frac{d}{dm}(\Delta_2(m))|_{m=0} = g - \hat{g} > 0 \Leftrightarrow g < \hat{g}$$

Again due to the individual rationality constraint of the agent, the maximum monitoring level the agent can accept under delegation is given by $m_{\max}$. As long as $m_{\max} > 0$, there always exists a positive monitoring level that the agent's IR condition is satisfied. This requires $\alpha(\gamma, \xi) + \lambda > 1$. This completes our proof that for $(\gamma, \xi, g) \in F_M$, monitoring improves the principal's payoff. □

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