WORKING PAPER NO. 21

Job Design, Delegation, and Cooperation: A Principal-Agent Analysis

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EEA93

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Abstract

This paper analyzes how tasks are assigned in organizations. Tasks can be allocated vertically between a principal and an agent, or laterally among agents. The resulting organizational job design determines how many tasks are delegated to agents, and how the agents' tasks are divided among them. In the framework of the standard principal-agent relationship with moral hazard, it is shown that (i) an incentive consideration causes the principal to group a broad range of tasks into an agent's job rather than hire multiple agents and make each of them specialize in just one task; and (ii) the principal may choose to delegate all the tasks in order to mitigate a conflicting incentive problem with agents.

Job design, delegation, and cooperation

A principal-agent analysis*

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1. Introduction

One of the first things an entrepreneur must decide, upon forming a business organization as an owner-manager by hiring subordinates, is how to allocate tasks among them. There are two relevant questions. First, which of the tasks are delegated to the subordinates and which are left under the entrepreneur's control? The answer to this question determines delegation of decision making in the organization. Second, how are those tasks delegated to the subordinates to be divided among them? The answer determines the division of labor among the subordinates. The issue of job design is important in inter-firm relationships as well. A manufacturer and its parts suppliers must specify their functional roles: Do suppliers only produce parts following the drawings provided by the manufacturer, or does the manufacturer permit the suppliers themselves to design their parts? Does the manufacturer make each supplier specialize in a narrow range of components (e.g., produce only seat cover) or make a supplier responsible for various components (e.g., produce the entire seat)? It is an important step toward theories of organizational structures to understand both vertical and lateral job structuring.

This paper analyzes the job design problem of the owner-manager or the manufacturer in a simple principal-agent model with moral hazard. The party who is a residual claimant and is entitled to allocate tasks and design contractual terms is called a "principal." At the beginning, no party possesses relevant information or expertise privately. Therefore, if the

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* Paper presented for the Eighth Annual Congress of the European Economic Association in Helsinki, 27–29 August 1993, in the invited session "Contract theory and economic organization" chaired by J. Crémer. This research was supported by the Ministry of Education, Japan.

principal could perform all the tasks by herself, she would choose to do so, and the job design problem would not be an issue. I instead assume that forming an organization is inevitable: The principal must hire "agents" and allocate some of the tasks to them because, for example, her attention is limited. In contrast to the standard principal-agent relationship, however, the principal can choose to leave some of the activities under her control. This paper hence extends the analysis of job design among agents by Holmstrom and Milgrom (1991) and Itoh (1991, 1992) to include not only lateral but also vertical task assignment problems.[1]

The paper also studies implications of the use of aggregate performance measures for the job design problem. Each activity may not be measured separately, or even it can, direct observation of performance at each task is often subjective, and hence unlikely to be contractible. However, some objective aggregate performance measures are likely to be available. I hence assume that there is a verifiable and "informative" signal measuring joint performance in the organization while performance at each task cannot be measured separately. In other words, the principal and the agents engage in *team production*. In the future, the analysis in the current paper should be extended to incorporate subjective individual performance measures in a model of the three-tier hierarchy of principal-supervisor-agents. Since the focus of the paper is on the effects of objective aggregate performance measures, a model of the two-tier hierarchy is used throughout.[2]

Two results are presented in the framework described above. First, when the principal delegates all the tasks to the agents, an incentive consideration causes her to group a broad range of tasks into an agent's job rather than hire multiple agents and make each of them specialize in just one task. In the model, the activities are cost substitutes and hence when they can be perfectly observed, specialization is better. It is shown that when the activities can only be observed imperfectly through team performance measures, the principal prefers non-specialization under sufficiently small degrees of cost substitutability. The notion that labor-force specialization leads to efficiency, which has been well known in economics since Adam Smith, has been recently challenged in practice: In the best performance projects in the world automobile industry, task assignments among engineers tend to be broad both in

[1] Riordan and Sappington (1987) analyze a vertical task assignment problem in an adverse selection model.

[2] However, the qualitative results of the paper continue to hold when *contractible* performance measures at each task are available. See Itoh (1993) for details.

breadth of activities and in range of components (Clark and Fujimoto, 1991; Womack, et al., 1990); The high performance of Japanese manufacturing is often attributed to the capabilities of workers who are responsible for not only routine operations but also unusual operations such as those dealing with changes in product mix and labor mix, and with problems due to machine breakdown and defective products (Koike, 1991). The paper shows that such broad job structuring is desirable from the incentive viewpoint even without technological complementarity among tasks.

The second result is that under some conditions, the principal, when she must allocate some tasks to agents, chooses to delegate *all* the tasks in order to mitigate a conflicting incentive problem with the agents: Delegation is not a source of incentive problems but it can be an incentive device in addition to financial rewards. Such a mode of "complete delegation" is more desirable as the aggregate performance is easier to measure or the agents have more discretion about their work so as to be more responsive to incentives.

The rest of the paper is organized as follows. The model is introduced in Section 2. The results are presented in Section 3. In Section 4, the possibility of task sharing among agents is discussed. Section 5 is concluding remarks.

2. The model

The model is a simplified version of the one in Itoh (1993), which in turn utilizes the tractable linear agency model developed by Holmstrom and Milgrom (1987, 1991). A principal owns a production process that consists of two tasks $t = 1, 2$. Suppose that the benefit from production is of the specific form $x = a_1 + a_2 + \epsilon$ where $a_t \geq 0$ represents unobservable action (effort) at task t and ϵ the error term. The principal and all the agents hired by the principal have identical information. All of them believe that ϵ is Normally distributed with mean zero and variance $\sigma^2 > 0$. For simplicity, I assume that x is the only available information for contracting. This assumption can be dropped. For example, x and the actual benefit may be different. A monitoring variable for each task may be available and, though unlikely, may be contractible.[3] In this paper, I focus on the extreme case in order to highlight the effects of the use of team performance measures.

[3] These cases are analyzed in Itoh (1993).

A contract specifies payments to agents and a *task allocation mode*. The principal cannot perform both tasks by herself, and hence she must hire at least one agent to allocate tasks. The principal has four feasible task allocation modes. (i) *Partial delegation*: The principal delegates task 1 (or task 2) to an agent and performs task 2 (task 1, respectively) by herself. (ii) *Non-specialized complete delegation*: The principal delegates both tasks to an agent. (iii) *Specialized complete delegation*: The principal hires two agents called agent 1 and agent 2 and delegates task t to agent t ($t = 1, 2$). Let $w(x)$ be the payments to the agent under partial delegation or non-specialized complete delegation, and $w_t(x)$ be the payments to agent t under specialized complete delegation.

The party who is assigned a task incurs private cost. When the agent performs both tasks under non-specialized complete delegation, his cost is $\hat{C}(a_1, a_2)$. Under the other modes, the party who performs task 1 (task 2) bears cost $C_1(a_1) := \hat{C}(a_1, 0)$ (respectively $C_2(a_2) := \hat{C}(0, a_2)$).[4] To obtain explicit solutions, I assume that the cost function is quadratic and of the form

$$\hat{C}(a_1, a_2) = \tfrac{1}{2}ca_1^2 + \tfrac{1}{2}ca_2^2 + \delta ca_1a_2$$

where $c > 0$ and $\delta \in [0, 1]$. Parameter δ represents a degree of cost substitutability between two tasks. When $\delta = 0$, two tasks are independent in the sense that the choice of a_1 does not affect that of a_2 even under non-specialization. When $\delta > 0$, increasing effort at task 1 raises the marginal cost of effort at task 2. When $\delta = 1$, two activities are perfect substitutes, and the cost depends only on the total effort $a_1 + a_2$. Note that two tasks are symmetric in the cost function for all δ since $C_1(a) = C_2(a) = \frac{1}{2}ca^2$. Two modes of partial delegation are thus indifferent, and I only consider the partial delegation mode in which the agent performs task 1.[5] Let $d \in \{p, n, s\}$ represent a task allocation mode: $d = p$ implies partial delegation, $d = n$ non-specialized complete delegation, and $d = s$ specialized complete delegation.

The principal is risk neutral. There is a pool of agents who are risk averse with preferences represented by the exponential utility function: When an agent's income (payment received minus cost of action) is I, his utility is $-\exp\{-rI\}$ where $r > 0$ is the coefficient of absolute risk aversion. The principal selects agents with identical coefficient of absolute risk aversion

[4] I am assuming that task sharing is impossible, because, for example, each task requires use of a machine that cannot be operated by both agents at the same time. See Section 4 for discussion on task sharing.

[5] See Itoh (1993) for the analysis of asymmetric cases.

and identical productivity, and their reservation wages are assumed to be zero.

I assume that the payment schemes take the linear form $w(x) = \alpha x + \gamma$ under mode $d \in \{p, n\}$, and $w_t(x) = \alpha_t x + \gamma_t$ for $t = 1, 2$ under $d = s$.[6] Given a task allocation mode, the principal chooses the share parameters α or (α_1, α_2) to maximize the certainty equivalent of joint surplus subject to incentive compatibility constraints.[7] The certainty equivalent of joint surplus is given as follows:

$$\begin{aligned}
&a_1 + a_2 - C_1(a_1) - C_2(a_2) - \tfrac{1}{2}r\sigma^2\alpha^2 && \text{under } d = p; \\
&a_1 + a_2 - \hat{C}(a_1, a_2) - \tfrac{1}{2}r\sigma^2\alpha^2 && \text{under } d = n; \\
&a_1 + a_2 - C_1(a_1) - C_2(a_2) - \tfrac{1}{2}r\sigma^2\alpha_1^2 - \tfrac{1}{2}r\sigma^2\alpha_2^2 && \text{under } d = s.
\end{aligned}$$

The incentive compatibility constraints are given as follows: Under $d = p$, $\alpha - C_1'(a_1) = 0$ for the agent and $(1 - \alpha) - C_2'(a_2) = 0$ for the principal; Under $d = n$, $\alpha - \hat{C}_{a_1}(a_1, a_2) = 0$ and $\alpha - \hat{C}_{a_2}(a_1, a_2) = 0$; And under $d = s$, $\alpha_1 - C_1'(a_1) = 0$ and $\alpha_2 - C_2'(a_2) = 0$.

Let α_d^* be the optimal share parameter under mode d. Note that because of symmetry, the optimal share rates for agent 1 and for agent 2 are equal under the specialized delegation mode. The comparison among task allocation modes is based on the certainty equivalent of joint surplus under (d, α_d^*): If (d, α_d^*) yields higher joint surplus than $(d', \alpha_{d'}^*)$, then the principal prefers to choose the former than the latter. The optimal task allocation mode is d such that the joint surplus is the highest under (d, α_d^*).

3. The results

I start with the analysis of division of labor between agents. Suppose that the principal delegates both tasks. The question is whether she assigns one agent to both tasks or hires two agents each of which performs a distinct task. The optimal share rates under $d = n$ and $d = s$ are calculated as

$$\alpha_n^* = \frac{2}{2 + (1 + \delta)r\sigma^2 c} \qquad \text{and} \qquad \alpha_s^* = \frac{1}{1 + r\sigma^2 c}.$$

[6] See Itoh (1993) for a justification of this assumption. It is possible to show that the model presented here is regarded as a reduced form of a dynamic model as in Holmstrom and Milgrom (1987), in which optimal incentives are provided with linear contracts.

[7] The fixed components γ and (γ_1, γ_2) simply play a role of surplus transfer between the principal and the agents.

Fix parameters (c, r, σ^2). When $\delta = 1$ (two activities are perfect substitutes), one has $\alpha_n^* = \alpha_s^*$. This does not imply that the optimal efforts are equal under two modes, however. Under non-specialization, the total effort satisfies $\alpha_n^* = c(a_1 + a_2)$ while under specialization, for each task t, $\alpha_s^* = ca_t$. It is therefore clear that $d = s$ attains higher joint surplus than $d = n$. Next suppose $\delta = 0$. Then $\alpha_n^* > \alpha_s^*$. By the incentive compatibility constraints, the efforts chosen by the agent under contract (n, α_s^*) are equal to the optimal efforts under (s, α_s^*). However, the joint surplus is higher under the former contract because of the additional risk premium term under $d = s$. The joint surplus is hence higher under (n, α_n^*) than under (s, α_s^*) when $\delta = 0$. The optimal value of joint surplus under $d = n$ is decreasing in δ since α_n^* is decreasing in δ and the joint surplus is increasing in α. Since under $d = s$ the optimal value of joint surplus is independent of δ, I have shown the following proposition.

Proposition 1. Fix parameters (c, r, σ^2). Then there exists $\bar{\delta} \in (0, 1)$ such that for all $\delta < \bar{\delta}$, the principal prefers non-specialized complete delegation to specialized complete delegation.

The important insight from this result is that an incentive problem causes the principal to assign an agent to a broad range of tasks. If actions were publicly observable, the principal would never choose to assign an agent to both tasks for all $\delta > 0$. However, when actions are unobservable, for all values of c, r, and σ^2, non-specialization attains higher surplus for sufficiently small degrees of cost substitutability. The advantage in technology will be traded off against the incentive consideration. Note that no technological complementarity is assumed here since $\delta \geq 0$.

Next consider the optimality of delegating both tasks. The optimal share rate under partial delegation is given by

$$\alpha_p^* = \frac{1}{2 + r\sigma^2 c}.$$

It is always smaller than α_n^* and α_s^*. The underlying logic is evident from the incentive compatibility constraints. Under partial delegation, there is a conflicting interest between the principal and the agent. Once the payment scheme has been set, both the principal and the agent must be given incentives, and increasing the agent's share reduces the principal's motivation. Such a conflict disappears once both tasks are allocated to agents. However, delegating more tasks accompany more responsibility. Comparing the joint surplus under three modes leads to the following result.[8]

Proposition 2. For all $\delta \in [0,1]$, if c, r, and σ^2 are sufficiently small, a complete delegation mode, whether specialized or non-specialized, is preferred to partial delegation.

The proposition shows that there is a case where the principal prefers delegating both tasks to agents, in order to mitigate the conflicting incentive problem. Other than monetary rewards, delegation of tasks can be an additional incentive device. However, complete delegation has its own cost. Agents are given more responsibility and hence must incur more risk.

The important parameters that affect the optimal task allocation are σ^2 and c. Variance σ^2 represents the difficulty of measuring joint performance. If $\sigma^2 \to 0$, both modes of complete delegation can attain the first best since the optimal share rate approaches to one, while the conflicting interest between the principal and the agent prevents the organization with partial delegation from achieving the first best ($\alpha_p^* \to \frac{1}{2}$). On the other hand, if the team performance is hard to measure, complete delegation is costly in terms of risk sharing, and hence keeping a task under the principal's control attains higher joint surplus.

Parameter c is the slope of the marginal cost of effort when performing just one task. This parameter has an important interpretation. The inverse c^{-1} represents the *responsiveness of effort to incentives* at each task under partial delegation or specialized complete delegation: From the incentive compatibility constraints, under partial delegation (delegating task 1), $\partial a_1/\partial\alpha = \partial a_2/\partial(1-\alpha) = c^{-1}$, and under specialized delegation, $\partial a_1/\partial\alpha_1 = \partial a_2/\partial\alpha_2 = c^{-1}$. The effort responsiveness is a little different under non-specialized complete delegation, and is given by $\partial a_1/\partial\alpha = \partial a_2/\partial\alpha = [(1+\delta)c]^{-1}$. Under either mode, the share parameter is increasing in c^{-1}: Stronger incentives are provided as agents are more able to respond to them. And the effort responsiveness could be controlled. For example, as Holmstrom and Milgrom (1991) analyze, providing more freedom to agents by allowing their "private activities" can increase the agents' responsiveness and work as an incentive instrument. More generally, the principal could invest in work conditions to reduce the marginal cost of effort: the cost function could be $\hat{C}(a_1, a_2, a_3)$ with $\hat{C}_{a_3} < 0$ and $\hat{C}_{a_t a_3} < 0$ for $t = 1, 2$ where a_3 is the level of investment. Therefore, the proposition implies that when the principal can raise the agents' discretion about their work or improve their work conditions, more delegation of tasks and

[8] The derivation of the result is straightforward and not instructive, and thus omitted.

more intense incentives are likely to follow.

4. Task overlap and cooperation

In the previous analysis, it has been assumed that task overlap is not feasible: If two agents are hired, each of them specializes in a different task and does not exert effort to the other task. However, it is often observed that a group of tasks is assigned to a group of workers and they cooperate at each task within the group. Is there a merit of task overlap and cooperation?

The possibility of task sharing has been studied under the assumption that performance at each task is measured separately. Holmstrom and Milgrom (1991) show that it is never optimal for two agents to be jointly responsible for any task when there is a continuum of tasks and they are perfect substitutes. Itoh (1991) shows that there are cases in which joint responsibility is optimal. His sufficient condition is not satisfied if activities are perfect substitutes in the cost function. However, when aggregate performance measures are used for contracting, task sharing is optimal even if tasks are "almost" perfect substitutes.

To see this, suppose that δ is so high that specialized complete delegation is optimal. Let a_1^* be the optimal effort by agent 1 at task 1, that satisfies the incentive compatibility constraint $\alpha_s^* - ca_1^* = 0$. Now suppose that agent 1 can exert effort to task 2 as well. Let h_1 be agent 1's effort at task 2. Suppose that technology is of the specific linear form $x = a_1 + a_2 + h_1 + \epsilon$. Fix α_s^* and consider a pair of (a_1, h_1) that satisfies the new incentive compatibility constraints: $\alpha_s^* - \hat{C}_{a_1}(a_1, h_1) = 0$ and $\alpha_s^* - \hat{C}_{h_1}(a_1, h_1) = 0$. The solution satisfies $a_1 + h_1 = 2[(1+\delta)c]^{-1}\alpha_s^* > a_1^*$ for $\delta < 1$. Thus by allowing task sharing, higher joint surplus can be attained. This result follows because the share parameter for team performance already provides an incentive for an agent to exert effort to the other agent's task: There is no fixed cost to provide incentives for new activities in contrast to the case where the benefit from each task is measured separately as in Holmstrom and Milgrom (1991) and Itoh (1991).

The analysis of task sharing and cooperation is more interesting when the principal has an alternative incentive scheme that promotes "competition" via use of relative performance evaluation. When performance at each task can be measured separately and there is a systematic uncertainty so that individual measures are positively correlated, relative performance evaluation is valuable. However, since relative performance evaluation provides each agent with an incentive to reduce the others' performance, it is essential to preclude task sharing (Lazear, 1989). Which is better, preventing task overlap and using relative performance evaluation, or allowing task sharing and using joint responsibility? This question has been analyzed in Itoh (1992): Cooperation should be promoted if the correlation coefficient is sufficiently small.

An extension of the model in this paper also leads to a circumstance in which relative performance is used in the optimal contract. Suppose that there are three tasks $t = 1, 2, 3$ and two team performance measures x_1 and x_2, which are given by $x_1 = a_1 + a_3 + \epsilon_1$ and $x_2 = a_2 + a_3 + \epsilon_2$. The Normal noise terms ϵ_1 and ϵ_2 are assumed to be stochastically independent. Tasks 1 and 2 are "local" in the sense that each of them affects just one performance measure while task 3 is "global" in that both measures are affected by action at task 3. For example, task 1 and task 2 are sales activities at territories 1 and 2, respectively, and x_1 and x_2 are actual sales at those territories. Task 3 is advertising activities that affect the sales at both regions. Suppose that agent A is assigned task 1, agent B task 2, and the principal performs task 3. The agents' compensations are given by the linear schemes $w_A(x_1, x_2) = \alpha_1 x_1 + \alpha_2 x_2 + \alpha_0$ and $w_B(x_1, x_2) = \beta_1 x_1 + \beta_2 x_2 + \beta_0$.

This is the situation analyzed by Carmichael (1983). As he shows in his model, here the optimal share rates satisfy $\alpha_1^* > 0$, $\alpha_2^* < 0$, $\beta_1^* < 0$, $\beta_2^* > 0$, $|\alpha_1^*| > |\alpha_2^*|$, and $|\beta_2^*| > |\beta_1^*|$. To see this, note that the incentive compatibility constraints are given by $\alpha_1 - C_1'(a_1) = 0$, $\beta_2 - C_2'(a_2) = 0$, and $(1 - \alpha_1 - \beta_1) + (1 - \alpha_2 - \beta_2) - C_3'(a_3) = 0$ where $C_t(a_t)$ is the private cost of effort at task t. The first two equations are the incentive compatibility constraints for the agents, the last one for the principal who is assigned task 3. To provide incentives for the agents, $\alpha_1 > 0$ and $\beta_2 > 0$ must hold. This reduces the principal's incentive at task 3. However, since α_2 and β_1 come into the last equation only, they are utilized to raise the principal's incentive, and hence they are negative at the optimum.

Despite the stochastic independence between x_1 and x_2, the agents are rewarded based on not only the absolute performance x_t but also by "relative performance" $x_1 - x_2$. And again it is better for the principal to restrict task sharing between the agents. However, the principal may benefit by delegating task 3 to the agents and motivating task sharing via assignment of joint responsibility, that is, $\alpha_t > 0$ and $\beta_t > 0$ for $t = 1, 2$. Since the exact mode of delegation in this setting is hard to specify (e.g., How do the agents determine action at task 3? How are they going to share the cost of effort?) and the analysis is complicated, I only suggest the possibility and leave rigorous analysis for future research.

Note that delegating the global task to agents may be optimal because the principal can control the agents' choice through team performance measures. If the role of the global task is to reduce the cost of effort (e.g., improving work conditions), delegation is never optimal. To see this, modify technology to $x_1 = a_1 + \epsilon_1$ and $x_2 = a_2 + \epsilon_2$. The role of task 3 is to reduce the costs of effort at tasks 1 and 2: The cost functions are written as $C_1(a_1, a_3)$, $C_2(a_2, a_3)$, and $C_3(a_3)$, and satisfy $\partial C_t / \partial a_3 < 0$, $\partial^2 C_t / (\partial a_t \partial a_3) < 0$, and $C_3' > 0$ for $t = 1, 2$. Suppose that the agents, when assigned task 3, select a_3 to maximize the certainty equivalent of their joint surplus, that is, to minimize $C_1(a_1, a_3) + C_2(a_2, a_3) + C_3(a_3)$. It is then never optimal to delegate task 3 to the agents, since their choice of a_3 ignores the effects of a_3 on the incentive compatibility constraints. The principal has no way to control their choice of action at task 3.

5. Conclusion

Job design is an important decision for organizations. It determines division of labor and delegation pattern of decision making. This paper analyzed those two aspects of job design simultaneously, and showed that important insights are obtained from incentive considerations: there is an incentive reason for grouping a broad range of tasks into an agent's job, and delegation of all the tasks to a subordinate may be adopted as an incentive instrument.

The paper focused on the use of verifiable and informative team performance measures. Introducing subjective measures for each activity into the model by extending to a three-tier hierarchy is one direction for future research. The paper also adopted the "complete contracting" approach: Decision making authority was assumed to be a well specified notion, written into a contract through task assignment. However, delegated authority is often vague in scope and entitlement: Who has authority about what? The analysis of delegated authority in an "incomplete contracting" framework will be important, and hopefully the current paper offers a useful benchmark.

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