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Job Designs and Task Assignments: Implications for Organization Choice and Incentive Perspective

by

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Abstract

The purpose of this paper is to provide an explanation for the job rotation between production divisions and for the rationale attributes of incentive structures within Japanese firms. We compare the different characteristics of organization structures: (1) the vertical organizational mode in which workers do not rotate between divisions, and (2) the job rotation mode in which workers undergo job rotation. If rank-order tournament is used within each organizational structure, the job rotation mode is preferred for the workers in higher positions in more stable environment. If wages are based on individual performance measures within each organizational structure, then the job rotation mode is more likely to be preferred for blue-collar workers as the correlation coefficient across divisions is larger, the degree of technological complementary parameter is smaller between divisions, and changes in technology are more rapid. Our results are consistent with some empirical findings in the American and Japanese labor markets.
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1 Introduction

The representative features found in Japanese firms are:(a) the long term employment relationship is more prevalent;(b)workers tend to experience a wider range of related jobs; and (c) more responsibility is delegated to lower tiers of the hierarchy. However, the long term employment relationship in Japanese firms does not necessarily imply that workers tend to stay in the same job of the firm. Although the external labor market in Japan is not competitive, workers are frequently transferred across production divisions within the same company or related and subsidiary firms via limited arrangements: the former is called be job rotation, and the latter is *Shukko* (Transference). According to Koike's (1988) field research, the high performance of the Japanese manufacturing is often attributed to the capabilities of workers who are responsible for not only routine operations but also unusual ones such as those dealing with technological changes or problems due to machine malfunction and defective products. In practice, multiskilling is achieved and maintained by explicit patterns of job rotation within a worker group.

The purpose of this paper is to provide an explanation for the job rotation among production divisions and for the rationale attributes of incentive structures within Japanese firms. We attempt to compare the compensations of workers and the organizational advantages in each organizational structure. So, we do not analyze the promotion policy in different organizational structure. The job rotation needs more training costs and hinder from specializing a job. In fact, all workers do not experience a wider range of their related jobs by all means. For simplicity, we shall consider the following two organizational structures: *the vertical organizational mode* and *the job rotation mode*. In the vertical organizational mode, the firm fosters specialized workers and designs organizations where workers are promoted in the same division after appropriate periods. On the other hand, in the job rotation mode, workers are rotated between divisions and are promoted to different but related divisions.

The recent economic analysis of organization has illuminated links between job designs and incentives taken the organizational structure as fixed. However, the organizational structure has not been endogenously considered with job designs and incentives. How then should the organizational structures be designed? The lack of theoretical studies of organization structures appeares to be more serious problem in the theoretical point of view. Along this line, we will explain the following differences between the organizational structures of Japanese firms and American firms. American firms emphasize efficiency attained through fine specialization and sharp demarcation, where the coordinating task and operating task is separated from the task of identifying and preventing emergencies. By contrast, Japanese firms emphasize the capability of the workers' group to cope with local emergencies, where the coordinating task and operating task tend to be more integrated. (See Aoki, 1988, chapter2)

We first examine a tournament in which risk neutral workers participate in a vertical organizational or a job rotation structure. Under the tournament model, we investigate the optimality of wage spread and each organizational structure. As the correlation between the performance measures of junior and senior workers in the same division is larger, the workers' effort level in the vertical organizational mode is larger because the prize spread becomes larger than that in the job rotation mode. On the other hand, if the correlation between the outcomes of workers in different divisions increases, the workers' effort level in the job rotation mode is smaller than that in the vertical organizational mode.

We next discuss the case in which the reward of workers is to be based on their individual performance measures, that is, the piece-rate scheme. We show that the benefit of the vertical organizational mode increases with a complementary parameter of the cost function. We also indicate that the workers' effort level in the vertical organizational mode is smaller as the correlation between the performance measures of junior and senior workers in the same division is larger. On the other hand, if the correlation between the outcomes of workers in different divisions increases, the workers' effort level in the job rotation mode is larger than that in the vertical organizational mode.

Given these results, we can identify which organization mode induces higher effort level by rank-order tournament or by individual performance measures, thus determining an optimal organization mode for different environments and for different hierarchy: that is, when tournament is available for white-collar workers, the job rotation is suitable for stable business environment. On the other hand, if the individual performance measure is used for blue-collar workers, the job rotation is more available under unstable business environments.

This paper is also related to the literature on the optimal organization design with multiple agents, as has been studied by Icks and Samuelson (1987), Itoh (1987), Kato (1991), Meyer (1994), Meyer and Vickers (1997). These models depend on the assumption that the organizational structure is taken as fixed. In contrast, we discuss the endogenous determination of the organizational structures.

To understand our finding, consider first the arguments of Icks and Samuelson (1987) and Meyer and Vickers (1997). They show that resolve the ratchet effect, the firm induces workers to change regular job transfers in each period in an organization. Job transfer breaks the link between the current performance and the future incentive scheme, thus removing the incentive-stifling implications of the ratchet effect. The whole problem arises from the situation that there is some match-specific capital, so workers can not change their jobs costlessly. Inducing job rotation eliminates the advantages of that match specific capital. Kato (1991) considers job transfers across divisions as *an alternative to layoffs* in a two-period implicit contract model of the multi-product firm. However, our framwork uses job transfers as incentive schemes but not as an alternative to layoffs.

Itoh (1987) focuses on the choice of the informational structure in the hierarchical organization and shows the appropriateness of the Japanese-style management for moderately changing environments and the appropriateness of the American-style for not only drastically changing environments but also very stable environments. Thus, Japanese top managers tend to allow lower-level managers to accumulate more resources and motivate them to adjust to moderately changing environment. In contrast to Itoh (1987), we compare different organization structures by examining the design of incentive schemes. Meyer (1994) analyzes an optimal task assignment problem when a firm needs to learn the abilities of workers. The main result is that the no sharing mode (devoting all their time to a single project) is more informative overall than the junior sharing mode (devoting their half time to two projects) if the prior uncertainty about abilities is small relative to exogenous noises in team production. In her model, the incentive aspects and the explicit job rotation are ignored. Our analysis compares incentive issues between each organization mode.

This paper is organized as follows. Section 2 is the basic model. Section 3 considers the rank-order tournament of risk neutral workers. Section 4 deals with the case of individual performance measures. On the basis of the discussions in section 3 and 4, section 5 discusses the empirical implications for organization designs from an incentive perspective. Finally, section 6 is devoted to concluding remarks.

2 The Basic Model

In this section, we explain two designs of organizational structures that are beneficial to the firm and use a framework of the principal/multi-agent problem with moral hazard, due to Lazear and Rosen (1981) and Holmström and Milgrom (1987).

We consider, throughout the paper, an organization consisting of a risk neutral principal, who designs organization/contracts, and two risk neutral workers or two risk averse workers. The firm's total payoff before payment to the workers is $X_1^l + X_2^l$ under the organization mode $l = V, J$. We assume that the output market is competitive. Thus, the value of the product is P per unit.

2.1 Production Functions of Workers

The firm hires two identical agents who are risk neutral or risk averse workers denoted $k = 1, 2$. The firm's objective function is measured by the expected value of total output over wages paid to the agents. We assume that outputs are given by

$$\begin{aligned} X_k &= \text{Junior's} \quad \text{effort}(J_i) + \text{Junior's} \quad \text{random} \quad \text{variable}(\epsilon_i) \\ &\quad + \text{Senior's} \quad \text{effort}(S_i) + \text{Senior's} \quad \text{random} \quad \text{variable}(\eta_i), \quad i = \text{division} \quad A, B. \end{aligned}$$

We suppose two kinds of organizational structures: the vertical organizational mode and the job rotation mode. In the vertical organizational mode, a worker is assigned to a division as an apprentice (junior); and after a period of time, he moves to a senior in the same division as a veteran. Without loss of generality, we assume that worker 1 (2) is assigned to division A (B). In the job rotation mode, although a worker goes through an apprenticeship period as in the vertical organizational mode, he is transferred to the related division as a senior. More specifically, we assume that in the junior period, worker 1 (2) is assigned to division A (B). While in the senior period, worker 1 (2) is assigned to division B (A). We now formalize this assumption as follows:

(A1) 1. Vertical Organizational Mode

$$X_1^V = J_A + S_A + \epsilon_A + \eta_A$$

$$X_2^V = J_B + S_B + \epsilon_B + \eta_B \quad (1)$$

where X_k^V is the output of worker k under the vertical organizational mode.

2. Job Rotation Mode

$$\begin{aligned} X_1^J &= J_A + S_B + \epsilon_A + \eta_B \\ X_2^J &= J_B + S_A + \epsilon_B + \eta_A \end{aligned} \quad (2)$$

where X_k^J is the output of worker k under the job rotation mode.

We additionally impose the following assumption about outputs.

(A2) Outputs can be observed only at the end of the senior period.[1]

2.2 Organization Structures and Noises

We put the following assumption on the noises of each organizational sturcture.

(A3) The noise terms (ϵ_i, η_i) are normally distributed with zero mean. Let $\sigma_{\epsilon_i}^2 > 0$ be the variance of ϵ_i and $\sigma_{\eta_i}^2 > 0$ be the variance of η_i, where each variance is assumed to be symmetric, $\sigma_\epsilon^2 \equiv \sigma_{\epsilon_A}^2 = \sigma_{\epsilon_B}^2$, $\sigma_\eta^2 \equiv \sigma_{\eta_A}^2 = \sigma_{\eta_B}^2$. Furthermore, ϵ_i and η_i are correlated and let ρ be the individual correlation coefficient ($0 < \rho < 1$). However, the other relationships of random factors (ϵ_i ,ϵ_j), (ϵ_i, η_j) and (η_i,η_j), $i = A, B$, $i \neq j$ are not correlated, that is, Cov(ϵ_i,ϵ_j)=Cov(ϵ_i,η_j)=Cov(η_i,η_j)=0.

Under these assumptions, the *aggregate* of noise terms is also normally distributed with zero mean. Let $\sigma^2 = \sigma_\epsilon^2 + \sigma_\eta^2 + 2\rho\sigma_\eta\sigma_\epsilon$ be the variance of $\epsilon_i + \eta_i$ in equation (1) and $\theta^2 = \sigma_\epsilon^2 + \sigma_\eta^2$ be the variance of $\epsilon_i + \eta_j$ in equation (2), respectively. We denote the cumulative and marginal distribution of error terms $\epsilon_i + \eta_i$ by F and f and the cumulative and marginal distribution of error terms $\epsilon_i + \eta_j$ by G and g. To distinguish two organizational structures, note that $\epsilon_i + \eta_i$ and $\epsilon_j + \eta_j$ are independently normally distributed for workers 1 and 2 in the vertical organizational mode, and $\epsilon_i + \eta_j$ and $\epsilon_j + \eta_i$ are correlated in the job rotation mode where the divisional correlation coefficient is defined by $\hat{\rho} \equiv 2\rho\sigma_\epsilon\sigma_\eta/(\sigma_\epsilon^2 + \sigma_\eta^2)$. We also notice that if $\sigma_\epsilon^2 = \sigma_\eta^2$, then $\hat{\rho} = \rho$.

Under assumption (A3), in the vertical organizational mode, the outputs of workers X_1^V, X_2^V are not correlated. It consists of two independently specialized divisions. On the other hand, in the job rotation mode, workers have experience in other related division. Thus, outputs X_1^J, X_2^J are correlated in the job rotation mode.

We next make the assumption on the cost function of workers.

(A4) The cost function of worker k, $C_k^l(J, S)$, is evaluated in monetary terms at each organizational mode as follows:

[1]We assume that wage is large enough to ensure that workers do not move to another firm at the end of the junior period.

$$C_k^V(J_i,S_i) = \frac{1}{2}J_i^2+\frac{1}{2}S_i^2-\lambda J_i S_i, \quad (i=A,B;k=1,2) \tag{3}$$

$$C_k^J(J_i,S_j) = \frac{1}{2}J_i^2+\frac{1}{2}S_j^2, \quad (i\neq j) \tag{4}$$

where $\lambda \in (0,1)$. The parameter λ represents the degree of technological complementary between the junior and the senior in the vertical organizational mode. When $\lambda > 0$, increasing the junior's effort in a division will reduce the marginal cost of the senior's effort in the same division. We assume that the two activities are neither perfect complements ($\lambda = 1$) nor perfect substitutes ($\lambda = 0$) in the vertical organizational mode. Thus, the cost function of the vertical organizational mode is represented by equation (3). Equation (4) means that, under this assumption the job rotation mode costs more than the vertical organizational mode. When the workers are rotated between the divisions, they need to communicate with their teammates or take the time to understand machines and tasks. It seems reasonable to suppose that the time requirement to understand new machines and tasks is a job-specific human capital which has to be evaluated in monetary terms in the cost function.

2.3 Information Structure

Workers choose some efforts that determine the outputs from the junior and senior's job. The efforts (J_A,J_B,S_A,S_B) and the noise terms $(\epsilon_i,\epsilon_j,\eta_i,\eta_j)$ are unobservable to the firm. This assumption implies that the worker's compensation can be based on output because only the output X_k^l $(l=J,V;k=1,2)$ is publicly observable. The variances $(\sigma^2,\sigma_\epsilon^2,\sigma_\eta^2,\theta^2)$ of the noise terms are known to the firm and the workers. Since the cost fuction of workers C_k^l $(l=J,V;k=1,2)$ is publicly observerble, the output and cost function forms defined by (1) – (4) are the commom knowledge.

3 Rank-Order Tournaments with Risk Neutrality

In this section, we restrict our attention to the situation where the firm offers a contract based on the rank-order tournament. We consider the rule of the game that specifies ex ante a fixed prize W to the winner and a fixed prize L to the loser ($W > L$). The threats of losing to one's rival in the contest may provide a strong incentive to exert effort.

We will develop a model of rank-order tournament in which the firm pays workers on the basis of the relative order of their performance so that only ordinal information of their performance is used to design the compensation scheme. Since workers who participate in tournament are risk neutral,[2] their utility function is given by

$$U_k(A,C_k^l(J_i,S_i)) = A - C_k^l(J_i,S_i) \tag{*}$$

[2] Lazear and Rosen (1981) point out that rank-order tournament may be sufficient to ensure first-best outcomes with risk-neutral workers, if the effort levels of different workers are common knowledge. However we compare and focus on the explicit prize spreads in each organization mode so that we assume the risk-neutral workers. Modifying risk-averse workers would not change our results at all except first-best.

where $A = W$ if he wins, and $A = L$ if he loses. We also assume that the workers' alternative employment opportunity provides utility normalized such zero. Following the precedure Lazear and Rosen (1981), we find the pair (W, L) that maximizes a worker's expected utility in each organization mode, subject to the zero-profit constraint of the firm.

The timing of the game is as follows. In zero period, the decision whether to choose the vertical organizational mode or the job rotation mode has to be taken. Then the firm offers W for winning prizes and L for losing prizes to the juniors at each organization mode. In the first period, juniors choose an effort levels. In the second period, juniors move to seniors as a veteran in each organizational mode and choose an effort level as seniors workers. In the third period, the output is produced. In the final period, a worker who shown better outcome is promoted to a manager position by the firm's evaluation. Then, workers receive the prize for the winner and for the loser.

3.1 Vertical Organizational Mode

We begin with the vertical organizational mode, and determine the worker's optimal effort levels and optimal prize spread.

We first consider the restrictions of the vertical organizational mode. The first restriction is concerned with incentive compatibility condition of workers: worker k must choose his effort levels to maximize his expected utility. Given that worker 1 receives the wage W with probability denoted by $\text{Prob}(X_1^l > X_2^l)$ and the wage L with probability denoted by $\text{Prob}(X_1^l \leq X_2^l)$, and that worker 1 is assigned to division A, worker 1 chooses his effort levels J_A and S_A to maximize his expected utility:

$$(J_A, S_A) \in \arg\max_{J_A, S_A} U_1(W, C_1^V(J_A, S_A))\text{Prob}(X_1^V > X_2^V) + U_1(L, C_1^V(J_A, S_A))\text{Prob}(X_1^V \leq X_2^V),$$

that is,

$$(J_A, S_A) \in \arg\max_{J_A, S_A} W\text{Prob}(X_1^V > X_2^V) + L\text{Prob}(X_1^V \leq X_2^V) - \frac{1}{2}J_A^2 - \frac{1}{2}S_A^2 + \lambda J_A S_A, \quad (ICV1)$$

because the output of worker k is given by (1). Similary, the incentive compatibility condition of worker 2 is described by

$$J_B, S_B \in \arg\max_{J_B, S_B} (W - L)[1 - \text{Prob}(X_1^V > X_2^V)] + L - C_2^V(J_B, S_B). \qquad (ICV2)$$

The second restriction to be concerned with is the individual rationality condition of workers:

$$U_1(W, C_1^V(J_A, S_A))\text{Prob}(X_1^V > X_2^V) + U_1(L, C_1^V(J_A, S_A))\text{Prob}(X_1^V \leq X_2^V)$$
$$= (W - L)\text{Prob}(X_1^V > X_2^V) + L - C_1^V(J_A^*, S_A^*) \geq 0, \quad (IRV1)$$

Similary, for worker 2,

$$(W - L)[1 - \text{Prob}(X_1^V > X_2^V)] + L - C_2^V(J_B^*, S_B^*) \geq 0. \quad (IRV2)$$

Now, the firm's realized gross receipts are $P(J_A + S_A + J_B + S_B)$, and its cost are the total prize money offerd, $W + L$. So the firm's profit is defined by

$$P(J_A + J_B + S_A + S_B) - W - L, \qquad (FP)$$

the optimal contract for the firm under the vertical organizational mode is the solution to the following maximization problem:

$$\max_{J_i, S_i, W, L} P(J_A + J_B + S_A + S_B) - W - L, \qquad (\#)$$

$$\text{subject to} \quad (ICV1), (ICV2), (IRV1) \quad \text{and} \quad (IRV2).$$

To find a solution to the problem (#), we must solve for (ICV1) and (ICV2). We first consider $(ICV1)$. Assuming an interior solution, the first-order conditions for $(ICV1)$ are

$$\frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial J_A}(W - L) = J_A - \lambda S_A, \tag{5}$$

$$\frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial S_A}(W - L) = S_A - \lambda J_A. \tag{6}$$

Adding (5) and (6) side by side implies

$$\left(\frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial J_A} + \frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial S_A} \right)(W - L) = (J_A + S_A)(1 - \lambda). \tag{7}$$

Equation (7) indicates that worker 1 chooses $J_A^* + S_A^*$ such that the marginal disutility of extra effort, $(J_A^* + S_A^*)(1 - \lambda)$, equals the marginal gain from extra effort, which is the product of the wage gain from winning the tournament, $W - L$, and the marginal increase in the probability of winning.

To simplify (7), we calculate the term $[(\partial \text{Prob}(X_1^V > X_2^V)/\partial J_A) + (\partial \text{Prob}(X_1^V > X_2^V)/\partial S_A)]$. Using the Bayes' rule and the assumption of the independence of divisional random shock variables in the vertical organizational mode, the probability of winning can be derived as follows: $\text{Prob}(X_1^V > X_2^V) = \int_{-\infty}^{+\infty} \text{Prob}(\epsilon_A + \eta_A > \Delta_J + \Delta_S + \Delta_B \mid \epsilon_A + \eta_A) f(\Delta_B) d\Delta_B$, where $\epsilon_B + \eta_B \equiv \Delta_B$, $J_B - J_A \equiv \Delta_J$, $S_B - S_A \equiv \Delta_S$ and $f(\Delta_B)$ is the marginal distribution of $\epsilon_B + \eta_B \equiv \Delta_B$. Since F is the cumulative distribution of error terms of $\epsilon_i + \eta_i$, we obtain

$$\text{Prob}(X_1^V > X_2^V) = \int_{-\infty}^{+\infty} \{1 - F[\Delta_J + \Delta_S + \Delta_B]\} f(\Delta_B) d\Delta_B. \tag{8}$$

Partially differentiating (8) with respect to J_A or S_A and evaluating them at $J_B = J_B^*$ and $S_B = S_B^*$,

$$\frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial J_A} = \frac{\partial \text{Prob}(X_1^V > X_2^V)}{\partial S_A} = \int_{-\infty}^{+\infty} f(J_B^* + S_B^* - J_A - S_A + \Delta_B) f(\Delta_B) d\Delta_B \tag{9}$$

Substituting (9) into (7), we have

$$2(W-L)\int_{-\infty}^{+\infty} f(J_B^*+S_B^*-J_A-S_A+\Delta_B)f(\Delta_B)d\Delta_B=(J_A+S_A)(1-\lambda). \tag{10}$$

In the analysis that follows, we focus on the symmetric Nash equilibrium(i.e., $J_A^*+S_A^*=J_B^*+S_B^*=J^*+S^*$). Thus, (10) is rewriten by

$$2(W-L)[\int_{-\infty}^{+\infty} f(\Delta_B)^2 d\Delta_B]=(J^*+S^*)(1-\lambda). \tag{11}$$

Equation (11) shows that J^*+S^* is monotonically increasing in $W-L$, and a larger prize for winning (i.e., a larger value of W-L) motivates more effort. Since the aggregate of random shock is assumed to be normally distributed with variance σ^2, we have

$$\int_{-\infty}^{+\infty} f(\Delta_B)^2 d\Delta_B=\frac{1}{2\sigma\sqrt{\pi}}. \tag{12}$$

Substituting (12) into (11) leads to

$$\frac{1}{\sigma\sqrt{\pi}}(W-L)=(J^*+S^*)(1-\lambda). \tag{13}$$

Equation (13) is the incentive compatibility condition of the workers for the fixed prize W and L. This condition suggests that (J^*+S^*) decreases in σ in the vertical organizational mode. Since $\sigma^2=\sigma_\epsilon^2+\sigma_\eta^2+2\rho\sigma_\eta\sigma_\epsilon$, σ increases in ρ. Therefore, $(J_A^*+S_A^*)(1-\lambda)$ decreases in σ and ρ. If uncertainty $\sigma\sqrt{\pi}$ is high, $W-L$ is higher for the fixed the effort J^*+S^* Because of the symmetricity of the equilibrium, (ICV2) also reduces to (13)

Given the new incentive compatibility constraint (13), the firm determines the winning and losing prizes, W and L. We should notice that the workers' alternative employment opportunity provides utility normalized to be zero. If the firm intends to induce the workers to participate in the tournament, then the individual rationality constrains of workers (IRV1) and (IRV2) become

$$(W+L)/2-C_k^V(J^*,S^*)\geq 0, \tag{14}$$

where the worker's utility fuction is defined $(*)$.

In the symmetric Nash equilibruim, the firm's profit is rewritten by

$$2P(J+S)-W-L \tag{15}$$

The firm now solves the following problem: maximize (15) subject to (13) and (14),that is,

$$\max_{J^*,S^*,W,L} \quad 2P(J^*+S^*)-W-L, \tag{16}$$
$$s.t. \quad (13) \text{ and } (14).$$

Since the constraints (13) and (14) are always binding as in the standard principal-agent problem, substitute (13) and (14) with equality into (15)

Thus, we obtain the following lemma 1.

Lemma 1: *In the vertical organizational mode, the optimal winning and losing prize are*

$$W = \frac{2P^2}{(1-\lambda)} + P\sigma\sqrt{\pi},$$

$$L = \frac{2P^2}{(1-\lambda)} - P\sigma\sqrt{\pi},$$

and the optimal prize spread in the vertical organizational mode is $\Delta_V \equiv W - L = 2P\sigma\sqrt{\pi}$.

This lemma 1 shows that if the value of the complementary parameter λ increases, then the wages also increase. From the assumption of error terms, σ increases in the individual error term ρ.Thus,W increases in ρ, which L decreases in ρ. Therefore, the wage spread Δ_V increases with ρ.

3.2 Job Rotation Mode

We now analysis the worker's optimal effort, and winning and losing prizes in the job rotation mode. We use a model similar to the vertical organizational mode. Note that the cost function and the noise terms of the job rotation mode are different those of the vertical organizational mode.

We first consider the case in which the workers determine the optimal effort levels J_i and S_j of workers for fixed wage W and L. The optimal contract for the firm is the solution to the following problem in the job rotation mode.

$$\max_{W,L,J_i,S_j,i\neq j} P(J_A + J_B + S_A + S_B) - W - L,$$

$$s.t. \quad (J_A, S_B) \in \arg\max_{J_A^{**},S_B^{**}} (W-L)\text{Prob}(X_1^J > X_2^J) + L - C_1^J(J_A^{**}, S_B^{**}), \quad (ICJ1)$$

$$(J_B, S_A) \in \arg\max_{J_B^{**},S_A^{**}} (W-L)[1-\text{Prob}(X_1^J > X_2^J)] + L - C_2^J(J_B^{**}, S_A^{**}), \quad (ICJ2)$$

$$(W-L)\text{Prob}(X_1^J > X_2^J) + L - C_1^J(J_A^{**}, S_B^{**}) \geq 0, \quad (IRJ1)$$

$$(W-L)[1-\text{Prob}(X_1^J > X_2^J)] + L - C_2^V(J_B^{**}, S_A^{**}) \geq 0, \quad (IRJ2)$$

where (ICJ) and (IRJ) imply the incentive compatibility and individual rationality of workers, respectively.

As in previous subsection, we consider $(ICJ1)$ for worker 1. Assuming an interior solution, the first-order conditions of worker 1 for $(ICJ1)$ in the job rotation mode are

$$\frac{\partial\text{Prob}(X_1^J > X_2^J)}{\partial J_A}(W-L) = J_A, \qquad \frac{\partial\text{Prob}(X_1^J > X_2^J)}{\partial S_B}(W-L) = S_B, \tag{17}$$

where X_1^J and X_2^J are defined by (2).

Repeating the same process as (7) of the preceding subsection yields

$$\left(\frac{\partial \text{Prob}(X_1^J > X_2^J)}{\partial J_A} + \frac{\partial \text{Prob}(X_1^J > X_2^J)}{\partial S_B}\right)(W - L) = J_A + S_B. \tag{18}$$

By the Bayes' rule, the probability of winning in the job rotation mode is

$$\text{Prob}(X_1^J > X_2^J) = \text{Prob}(\epsilon_A + \eta_B > J_B + S_A - J_A - S_B + \epsilon_B + \eta_A)$$

$$= \int_{-\infty}^{+\infty} \text{Prob}[\epsilon_A + \eta_B > J_A + S_B - J_A - S_B + \epsilon_B + \eta_A \mid \epsilon_B + \eta_A] g(\epsilon_B + \eta_A) d(\epsilon_B + \eta_A)$$

$$= \int_{-\infty}^{+\infty} \text{Prob}\{1 - G[J_B + S_A - J_A - S_B + \epsilon_B + \eta_A \mid \epsilon_B + \eta_A]\} g(\epsilon_B + \eta_A) d(\epsilon_B + \eta_A), \tag{19}$$

where the marginal and cumulative distributions of the error term $\epsilon_B + \eta_A$ are given by g and G. Final equality is derived from the assumption (A3). Rearrangement of (18) with (19)

$$(W - L)[2 \int_{-\infty}^{+\infty} g(J_B^{**} + S_A^{**} - J_A - S_B + \epsilon_B + \eta_A \mid \epsilon_B + \eta_A) \times g(\epsilon_B + \eta_A) d(\epsilon_B + \eta_A)] = (J_A + S_B). \tag{20}$$

In the analysis that follows, we again focus on the symmetric Nash equilibrium, then $J_A^{**} + S_B^{**} = J_B^{**} + S_A^{**} = J^{**} + S^{**}$. Thus, we have

$$(W - L)[2 \int_{-\infty}^{+\infty} g(\epsilon_B + \eta_A, \epsilon_B + \eta_A) d(\epsilon_B + \eta_A)] = (J^{**} + S^{**}) \tag{21}$$

This equation implies that the larger prize for the winning generate more efforts in the job rotation mode. Since the aggregate random shock is assumed to be normally distributed with the variance θ and correlation $\hat{\rho}$, then

$$\int_{-\infty}^{+\infty} g(\epsilon_B + \eta_A, \epsilon_B + \eta_A) d(\epsilon_B + \eta_A) = \frac{1}{2\theta\sqrt{(1 - \hat{\rho})\pi}}. \tag{22}$$

Substituting (22) to (21) leads to the incentive constraint condition of workers in the job rotation mode:

$$\frac{1}{\theta\sqrt{(1 - \hat{\rho})\pi}}(W - L) = (J^{**} + S^{**}) \tag{23}$$

Equation (23) indicates that $J_A + S_B$ decreases in θ, but increase in $\hat{\rho}$.

Given (23), we find the firm chooses the winning and losing prizes, W and L in the job rotation mode. The individual rationality of workers is again

$$(W + L)/2 - C_k^J(J^{**}, S^{**}) \geq 0. \tag{24}$$

In the symmetric Nash equlibruim, the firm's profit is rewrriten by equation (16) such $2P(J^{**} + S^{**}) - W - L$, the firm now solves the following problem: maximize (16) subject to (23), (24). Repeating same procedure as lemma 1, we obtain the following lemma 2.

Lemma 2: *In the job rotation mode, the optimal winning and losing prizes are*

$$W = 2P^2 + P\theta\sqrt{(1-\hat{\rho})\pi},$$
$$L = 2P^2 - P\theta\sqrt{(1-\hat{\rho})\pi},$$

and the optimal prize spread in the job rotation mode is $\Delta_R \equiv W - L = 2P\theta\sqrt{(1-\hat{\rho})\pi}$.

The optimal wage spread Δ_R decreases with $\hat{\rho}$.

3.3 Comparison of Organizations in the Tournament

This tournament theory provides some implications for the compensation method appropriate for each level of the hierarchy. Comparing lemma 1 with lemma 2, we have:

Proposition1: *If* $\lambda \leq 1 - \sqrt{(1-\hat{\rho})}$ $(\lambda \geq 1 - \sqrt{(1-\hat{\rho})})$, *then the firm's expected profit is higher in the vertical organizational mode (job rotation mode) than in the job rotation mode (vertical organizational mode). The prize spread is larger in the vertical organizational mode (job rotation mode) than in the job rotation mode (vertical organizational mode).*

proof: Compare the equilibrium wage spread prizes of the firm between the each organizational modes: Δ_V in lemma 1 and Δ_R in lemma 2. If $\lambda \leq 1 - \sqrt{(1-\hat{\rho})}$, then the prize spread is larger in the vertical organizational mode than in the job rotation mode. Thus the firm's expected profit is higher in the vertical organizational mode than in the job rotation mode. A similar condition holds for the job rotation mode if $\lambda \geq 1 - \sqrt{(1-\hat{\rho})}$. Q.E.D.

If $\lambda \leq 1 - \sqrt{(1-\hat{\rho})}$, larger prize spread induces workers make higher effort levels in the vertical organizational mode.

The size of the prize spread in the rank-order tournament depends on the noise associated with the production environment. From (13), (23), if the uncertainties of production ($\sigma\sqrt{\pi}$ and $\theta\sqrt{(1-\hat{\rho})\pi}$) become larger in each organization mode, then the prize spread in the job rotation mode is smaller than that in the vertical organizational mode if and only if $\lambda \leq 1 - \sqrt{(1-\hat{\rho})}$. This means that a stable economic environment should have a smaller prize spread than an unstable economic environment. A stable environment prefers the job rotation mode because the prize spread is smaller in the job rotation mode than in the vertical organizational mode, compare equations lemma 1 and lemma 2.

Consider the special case $\lambda = 0$.[3] This case means that the costs of the vertical organizational mode is equal to those in the job rotation mode i.e., $C^J = C^V = \frac{1}{2}J^2 + \frac{1}{2}S^2$. Then we have corollary

[3] As will be explained in following footnote 9 and section 5

Corollary: *Suppose that the cost function is same. Then, the firm's expected profit is always higher in the vertical organizational mode than in the job rotation mode. The prize spread is larger in the vertical organizational mode than in the job rotation mode.*

If the cost function is same, the optimal prize spread is not change and only optimal winning and losing prize in vertical organizational mode change $W = 2P^2 + P\sigma\sqrt{\pi}, L = 2P^2 - P\sigma\sqrt{\pi}$. Corollary implies that the vertical organizational mode is preferred because of $0 < \hat{\rho} < 1$ from the assumptions (A3) of the noise terms, $\theta\sqrt{(1-\hat{\rho})\pi} < \sigma\sqrt{\pi}$. By same cost function, we have some inplications. First, the increase in $W - L$ implies a higher equilibrium level of effort, since $C'(\cdot)$ is monotonically increasing in J and S. A bigger prize spread induces workers to compete harder for the promotion. A second implication is that the lower density function is $\frac{1}{\theta\sqrt{(1-\hat{\rho})\pi}}$, the lower is the level of effort exerted in equilibrium, since density functions $\frac{1}{\theta\sqrt{(1-\hat{\rho})\pi}}, \frac{1}{\sigma\sqrt{\pi}}$, are the measure of the importance of luck in production environment. When luck is completely unimportant, $\frac{1}{\theta\sqrt{(1-\hat{\rho})\pi}}, \frac{1}{\sigma\sqrt{\pi}}$ go to infinity. When luck is very important, $\frac{1}{\theta\sqrt{(1-\hat{\rho})\pi}}, \frac{1}{\sigma\sqrt{\pi}}$ become very small. Thus, as the importance of luck increases, the amount of effort exerted for any given prize spread declines.

The above discussions stated above have ignored the possibility of the collusion among workers. For example, the workers may interact in course of production. The tournament may fail to motivate suitable effort levels under the collusion.[4]

4 Individual Performance Measures with Risk Aversion

The prizes in the tournament are based on the relatively simple forms of performance appraisal so that the firm does not concern about the individual effort levels and noise terms. If workers' the attitude of risk preference is not same among workers, then the tournament that workers to whom do not prefer are compelled to share more risk.

In this section, we consider an alternative compensation scheme: piece-rate. A piece rate that is contingent on the outputs of workers. To capture the various aspects of the setting, we use a linear piece-rate scheme that is a special case of Holmström and Milgrom (1987, 1991).

We preserve all the assumptions of the preceding section except that workers are risk-averse. To simplify the analysis, the value of the product per unit in the competitive output market is one. Workers' preferences are represented by the exponential utility function with the coefficient of constant absolute risk aversion denoted by $r_k > 0, k = 1, 2$. Thus his utility function is given by $U(W_k) = -\exp(-r_k(W_k - C_k^l))$. The firm is risk neutral, and she designs the incentive contract $(J + S; W)$ which specifies the workers efforts' and performance contingent payment. The model presented here can be regarded as a reduced form of their dynamic model. We assume

[4] A less than $J^* + S^*$, each workers would still win with probability 1/2, and obtain same expected prizes. However, this problem does not arise if the marginal disutility of effort is strictly increasing, then there is unique symmetric equilibrium. This problem was discussed by Mookherjee (1984) and Demski and Sappington (1984) in related context. On the other hand, Tirole (1986) notes job rotation that breaks the long term relationship of a worker with particular supervisor restricts collusion.

that payment schemes of each organization mode are linear in the performance measure;

$$\begin{aligned} W_1(X_1^l, X_2^l) &= \alpha_1^l X_1^l + \alpha_2^l X_2^l + \alpha_0, \\ W_2(X_1^l, X_2^l) &= \beta_1^l X_1^l + \beta_2^l X_2^l + \beta_0, \end{aligned} \tag{25}$$

where the compensation schemes consist of a base amount α_0 and β_0, and the incentive shares of profit (α_k^l, β_k^l) that vary with the observed output under organization mode $l = V, J$.

The optimal contract maximizes the certainty equivalent of the joint surplus of the three parties subjected to the individual rationality which guarantee some minimum levels of utility for the workers, and the incentive compatibility constraints which ensure that the workers, behaving independently, follow the instructions by the firm, and their choice forms a Nash equilibrium.

The timing of games we consider is similar so that described in section 3. There is neverthless one difference. It is the wage system. The decision is as follows. In zero period, the decision whether to choose vertical organizational mode or the job rotation mode has to be taken. Then the firm offers wage schemes as equation (25) to juniors. In the first period, juniors choose an effort levels. In the second period, juniors move to seniors as veterans in each organizational mode and choose an effort level as seniors workers. In the third period, the output is produced. In the final period, a worker who shown better outcome are be promoted to a manager position by the firm's evaluation. Then, workers receive their wages.

4.1 Vertical Organizational Mode

We begin with vertical organizational mode and find optimal effort level which the workers are risk averse.

Each worker will choose an effort $J_i + S_i$ independently in order to maximize his expected utility, given the optimal sharing rule $W_k(X_1^V, X_2^V)$ is a linear function of each worker's output, X_k^V where $\epsilon_i + \eta_i$ is normally distributed with zero mean and variance σ^2.

We find that worker k's certainty equivalent wage (CE_1^V) consists of expected wage minus the personal cost of supplying effort and minus a risk premium for the wage risk averse worker bears:

$$\begin{aligned} CE_1^V &= \alpha_1^V X_1^V + \alpha_2^V X_2^V + \alpha_0 - C_1^V - \frac{1}{2} r_1[(\alpha_1^V)^2\sigma^2 + (\alpha_2^V)^2\sigma^2] \\ CE_2^V &= \beta_1^V X_1^V + \beta_2^V X_2^V + \beta_0 - C_2^V - \frac{1}{2} r_2[(\beta_1^V)^2\sigma^2 + (\beta_2^V)^2\sigma^2] \end{aligned} \tag{26}$$

where the risk premiums are $(1/2)r_1[(\alpha_1^V)^2\sigma^2 + (\alpha_2^V)^2\sigma^2], (1/2)r_2[(\beta_1^V)^2\sigma^2 + (\beta_2^V)^2\sigma^2]$. Worker's certainty equivalent is the incentive compatibility constrains stating that $J + S$ in Nash equilibrium. Since the firm is risk neutral, her certainty equivalent (CE_F^V) consists of expected gross profit minus the expected compensation paid;

$$CE_F^V = X_1^V + X_2^V - (\alpha_1^V X_1^V + \alpha_2^V X_2^V + \alpha_0) - (\beta_1^V X_1^V + \beta_2^V X_2^V + \beta_0) \tag{27}$$

It follows that any efficient contract must specify the parameter so that they maximize the sum of the certainty equivalent wage of three parties. Combining the certainty equivalent yields the total certainty equivalent (TCE^V) and the firm's problem can be expressed as maximizing TCE^V subject to an incentive constraint (IC) for a worker k,

$$\begin{aligned} TCE^V \max_{J_A,S_A,\alpha_1^V,\alpha_2^V,J_B,S_B,\beta_1^V,\beta_2^V} & X_1^V + X_2^V - C_1^V - C_2^V - \frac{1}{2}r_1((\alpha_1^V)^2\sigma^2 + (\alpha_2^V)^2\sigma^2) \\ & - \frac{1}{2}r_2((\beta_1^V)^2\sigma^2 + (\beta_2^V)^2\sigma^2) \\ & s.t. \alpha_1^V = (1-\lambda)J_A = (1-\lambda)S_A(IC1^V) \\ & \beta_2^V = (1-\lambda)J_B = (1-\lambda)S_B(IC2^V) \end{aligned} \tag{28}$$

where $\sigma^2 = \sigma_\epsilon^2 + \sigma_\eta^2 + 2\rho\sigma_\epsilon\sigma_\eta$ is defined by assumption (A2). (IC^V) is the level that makes the derivatives of that expression equal to zero. It says that workers will select their more effort levels in such a way that their marginal gains from more effort equal their marginal personal costs. The analysis of incentive contracts is to determine how intense the incentives should be. Equation specified what is to be maximized in vertical organizational mode. The maximization results of (28) are as follows:

$$\begin{aligned} J_A^{*V} + S_A^{*V} &= \frac{2}{(1-\lambda)(1+r_1\sigma^2(1-\lambda))} \\ \alpha_1^{*V} &= \frac{1}{1+r_1\sigma^2(1-\lambda)}, \alpha_2^{*V} = 0 \end{aligned} \tag{29}$$

where α_1^{*V} is nonnegative. Since the risk that workers bear in a vertical organization mode is independently distributed, the value of α_2^{*V} is zero. Notice in our assumption we have excluded the possibility of λ being one or zero. If workers were risk neutral ($r_k = 0$), then the optimal effort is given by $J_A + S_A = 2/(1-\lambda)$ in this mode because the value of the firm, P, is normalized. According to (29), there are some factors that interact to determine the appropriate intensity of incentives. The first is its variance σ^2 with which performance is measured. Low variance corresponds to high social welfare because variance σ^2 is related to ρ. The second factor is the complementary parameter, λ of cost, which social welfare increase in λ. These parameters (λ, σ^2) illustrate the trade-off that determine the optimal effort level in the vertical organizational mode.

4.2 Job Rotation Mode

In the result presented previous subsection, the divisional correlation in error terms is assumed to be independent but in this subsection is assumed to have the divisional correlation in a job rotation mode.

Noting that cost function and risk premium is different with zero mean and variance θ^2 and $\hat{\rho}$ be divisional correlation coefficient $0 < \hat{\rho} < 1$, each worker will choose an effort $J_i + S_j$ independently in order to maximize his expected utility, given the optimal sharing rule $W_k(X_1^J, X_2^J)$

is a linear function of each worker's output, X_k^J where $\epsilon_i + \eta_j$ is normally distributed with zero mean and variance θ^2. The worker 1's certainty equivalent (CE_1^J) in the job rotation mode is:

$$\begin{aligned} CE_1^J &= \alpha_1^J X_1^J + \alpha_2^J X_2^J + \alpha_0 - C_1^J - \frac{1}{2} r_1 [(\alpha_1^J)^2\theta^2 + (\alpha_2^J)^2\theta^2 + 2\hat{\rho}\alpha_1^J \alpha_2^J \theta^2] \\ CE_2^J &= \beta_1^J X_1^J + \beta_2^J X_2^J + \beta_0 - C_2^J - \frac{1}{2} r_2 [(\beta_1^J)^2\theta^2 + (\beta_2^J)^2\theta^2 + 2\hat{\rho}\beta_1^J \beta_2^J \theta^2] \end{aligned} \tag{30}$$

where the risk premiums are $(1/2)r_1[(\alpha_1^J)^2\theta^2 + (\alpha_2^J)^2\theta^2 + 2\hat{\rho}\alpha_1^J\alpha_2^J\theta^2]$ and $(1/2)r_2[(\beta_1^J)^2\theta^2 + (\beta_2^J)^2\theta^2 + 2\hat{\rho}\beta_1^J\beta_2^J\theta^2]$. On the other hand, the firm's certainty equivalent (CE_F^J) is:

$$CE_F^J = X_1^J + X_2^J - (\alpha_1^J X_1^J + \alpha_2^J X_2^J + \alpha_0) - (\beta_1^J X_1^J + \beta_2^J X_2^J + \beta_0) \tag{31}$$

As analysis in the vertical organizational mode, it follows that they maximize the TCE^J of the parties. That TCE^J what is to be maximized

$$\begin{aligned} TCE^J \quad \max_{J_A, S_B, J_B, S_A, \alpha_1^J, \alpha_2^J, \beta_1^J, \beta_2^J,} \quad & X_1^J + X_2^J - C_1^J - C_2^J - \frac{1}{2} r_1 [(\alpha_1^J)^2\theta^2 + (\alpha_2^J)^2\theta^2 + 2\hat{\rho}\alpha_1^J\alpha_2^J\theta^2] \\ & - \frac{1}{2} r_2 [(\beta_1^J)^2\theta^2 + (\beta_2^J)^2\theta^2 + 2\hat{\rho}\beta_1^J\beta_2^J\theta^2] \\ & s.t. \ \alpha_1^J = J_A = S_B, \quad (IC^J) \\ & \beta_2^J = J_B = S_A, \quad (IC^J) \end{aligned} \tag{32}$$

where $\theta^2 = \sigma_\epsilon^2 + \sigma_\eta^2$. The maximization results of (32) are

$$\begin{aligned} J_A^{*J} + S_B^{*J} &= \frac{2}{1 + r_1\theta^2(1 - \hat{\rho}^2)} \\ \alpha_1^{*J} &= \frac{1}{1 + r_1\theta^2(1 - \hat{\rho}^2)}, \alpha_2^{*J} = -\hat{\rho}\alpha_1^{*J} \end{aligned} \tag{33}$$

where α_1^{*J} is nonnegative. In particular, when there exist symmetric risks so that divisional error terms are positively correlated, the firm can filter out systematic risks by comparing workers with each other. It is supposed to filter out the common uncertainty in working environments, and to provide correct incentives for workers while not imposing uncertainty risks on them. When junior becomes senior by rotating his position, the value of variance falls down below $\theta^2(1 - \hat{\rho}^2)$ from θ^2. It is always to obtain first best that $\hat{\rho}^2$ equals one because high value of $\hat{\rho}$ raises the social welfare and benefit of the job rotation mode. When $\hat{\rho}$ is zero, it cannot use relative performance evaluation in the job rotation mode.

4.3 Comparison of Organizations with Risk Aversion

We summarize the discussions of the preceding subsection 4.1 and 4.2, as the following proposition.

Proposition 2: *If the degree of technological cost complementary, λ is sufficiently small and the divisional correlation coefficient, $\hat{\rho}$ is sufficiently large, then the job rotation mode is preferable to the vertical organizational mode. On the other hand, if the degree of technological cost complementary, λ is sufficiently large and the individual correlation coefficient, ρ is sufficiently small, then the vertical organizational mode is preferable to the job rotation mode.*

Proposition 2 implies both incentive-based rationale of the job rotation and the specialization of job from the endogenous factors. We think of λ as describing the job related-speficity. Since the cost function is common knowedge, increasing of the value λ is associated with reflecting the economic of scale. If the perspective of future demand can be relatively predictable, then the firm may be beneficial to use the vertical organizational mode. If technological cost parameter λ is, however, sufficiently small and the divisional correlation coefficient $\hat{\rho}$ is sufficiently large, then the job rotation mode may be more responsive to changes in local operating task or technology. For instance, when the workers incur large costs to learn a new operating technology, the firm prefers the job rotation mode for which the individual error term, $\hat{\rho}$ is sufficiently large. In a competitive production market, firm may be beneficial to adopt the job rotation mode which is available for a flexible manufacturing system. Note that we concentrate on incentive structure in an organization rather than the information problem. In the general choice of production technology that is relevant to "strategic task or technology" by the firm, the benefit of vertical organizational mode (specialization of job) is larger by sacrificing the job rotation, such as the high-tech manufacturing faces a drastically changing environment which λ is very high. We next turn to the case in which the firm can design organizational mode for the variance value of the error terms.

Suppose that the value of variance, σ_ϵ^2 of junior's error term or the value of variance, σ_η^2 of senior's error term becomes larger. Then, risks faced by junior and senior workers in the production of the vertical organizational mode, σ^2 are larger because $\sigma^2 = \sigma_\epsilon^2 + \sigma_\eta^2 + 2\rho\sigma_\eta\sigma_\epsilon$ and $\theta^2 = \sigma_\epsilon^2 + \sigma_\eta^2$. Increasing σ_ϵ^2 or σ_η^2 implies that it is larger $2\rho\sigma_\eta\sigma_\epsilon$ in the vertical organizational mode. Thus, workers bear more risks in the vertical organizational mode than in the job rotation mode. As increasing ρ, its effect exists for larger value of $\hat{\rho} \equiv 2\rho\sigma_\epsilon\sigma_\eta/(\sigma_\epsilon^2 + \sigma_\eta^2)$. As a result, the intensity of the incentives in (29), α_1^{*V} is lower than that in (33), α_1^{*J}. This implies that the wage payment is lower in the vertical organizational mode than in the job rotation mode.Thus, optimal organization mode is determined by the relative importance of the worker's incentives and risk sharing as the following proposition[5].

Proposition 3: *If the uncertainties of the junior and senior are larger, such as unstable environments, then workers prefer the job rotation mode to the vertical organizational mode because it enable workers to share less risk in evaluating performance. But if the uncertainties of the junior and senior are smaller, such as stable environments, then workers prefer the vertical organizational mode to the job rotation mode.*

[5]From the pointveiw of firm, we cannot calculate the case which has the higher optimal value of TCE.

Proposition 3 is different from the results of Itoh (1992). In his analysis, since the systematic risk is not important (the correlation coefficient between outcomes of workers in different divisions is sufficiently small), the firm prefers "induced cooperation" to relative performance evaluation, she would also like to encourage the workers to monitor each other's efforts and to coordinating them, attaining "delegated cooperation". This is the result of trade-off between relative performance evaluation and risk pooling[6,7]. In contrast, if the divisional correlation coefficient is large, relative performance evaluation is still available for the job rotation mode. Itoh (1992) analyzes comparative contract structures rather than an optimal organization mode for different business environment.

5 Implications for Organization Designs

5.1 Comparison of Incentive Contracts

This subsection compares our theoretical predictions with empirical evidence available in the recent literature. Our theoretical implications that are potentially testable are summarized as follows:

(1) The vertical organizational mode yields higher firm's expected profits than the job rotation mode because the wage spread induces higher effort level the in vertical organization mode than in the job rotation mode.

(2) If wages are based on the individual performance measures within each organizational structure, then the job rotation mode is more likely to be preferred as the correlation coefficient across divisions is sufficiently larger and the degree of technological complementary parameter is sufficiently smaller between divisions; and the vertical organizational mode is preferred as the individual correlation coefficient is sufficiently small and the degree of complementary parameter is sufficiently large.

Though tournaments and individual performance measures are different devices for creating incentives, we can have some implications and interpretations in organizational design problems. Lazear and Rosen (1981) pointed out that "Salesmen, whose output level is easily observed, typically are paid by piece rate, whereas corporate executives, whose output is more difficult to observe, engage in contests" (p.848). From their interpretation, the tournament is equvalent to using promotion as an incentive device for the the top person or white-collar workers in the firm,[8] and individual performance measures may be explained by blue-collar workers because of the cost of measurements.

If rank-order tournament is adopted by Japanese firms, the job rotation mode is suitable for the stable environments by higher positions in organizational hierarchy from our incentive

[6] Meyer (1995) shows that joint responsibility in a static model is not robust in a dynamic setting with limited intertemporal commitment. The reason why the principal for job can change so as it introduce dynamics is that the ratchet problem.

[7] Ishiguro and Itoh (1996) show that the principal can improve her welfare by collusion that occur after action choice for any correlation coefficient between noise terms of workers outputs.

[8] Main *et al* (1993), Lambert *et al* (1993) test the prize compressions are an increasing as one moves up the organizational hierarchy. In particular, Itoh and Teruyama (1997)'s empirical study also find wage spread among white-collar workers that induce more higher effort level in Japanese firm.

perspective. The empirical findings seem to show that this feature is supported. Xu (1997) argued that the probability of the promotion in American firm is lower than that of promotion in the Japanese firm because the size of Japanese firms is relatively small. The wage spreads of the tournament between American firms and Japanese firms may reflect the difference of the probability of promotion. This result indicates that larger firms are matched with more able executives, which suggests a positive correlation between executive compensation and the size of the firm. Furthermore, Kato and Rokel (1992) finds stronger associations between executive compensation and firm performance for the United States than for Japan. These empirical studies reflect that the tournament theory appears to find more support in the structure of United States executive compensation than in the structure of Japanese executive compensation[9].

On the other hand, when the individual performance measure is available by lower positions, proposition 3 suggests that the job rotation mode is suitable for unstable environments. There is not much systematic evidence, however. Asanuma (1994) and Koike (1988, 1994) offer some evidence of job rotation in Japanese firms. According to their study, the job rotation implies that the mobility of workers extend over a wide range of job and that blue-collar workers in large Japanese firms have broader careers than their Western counterparts. Thus, output can be made more responsive to fluctuations demand. The job rotations are associated with the acquisition of firm specific skills from sources internal to the plant. Since external vocational education is rarely publicly sponsored in Japan, the responsibility for job training has fallen on company: hence, internal training may make a greater contribution to job skills among the Japanese firms (Kalleberg and Lincolin, 1988). This implies that λ is sufficiently small and $\hat{\rho}$ is sufficeintly large. Thus, proposition 2 shows that the job rotation mode is preferred to vertical organizational mode. In contrast, workers in American firm may be either in place where most of the one workshop's main assignment are experienced, or else where only some of the jobs are passed around. The higher degree of specialization in the American firm than in the Japanese firm has been reported in various case studies, for example, by Koike (1988,1994) and by Lincolin *et al* (1986). This implies that λ is sufficiently large and ρ is sufficiently small, hence proposition 2 is explained. Commonly, Japanese firms set up in advance the *basic* skills of minimum level and inexperienced workers who have just entered the firm are normally assigned to relatively easier skill so that they can be almostly promoted in any given critical rank at the same time. At this stage, firms do not put the workers into competition with each other for a promotion. All workers are then motivated to collect the *basic* skills. This observation also suggests another disadvantage of rank-order tournament in Japanese firms from the standpoint of lower hierarchy. Thus, our theoretical results suggest that individual performance measures

[9]Suppose that workers in the vertical organizational mode and workers in the job rotation mode compete for a promotion and that the output of each mode is independent. Unfair contests will yield inefficient effort level because of the complementarities in the vertical organizational mode. The worker in the job rotation mode who is disadvantaged by the tournament will have greater incentives to shirk. Thus, the tournament must be designed so that the worker does not choose to set his effort level at zero. That is global no-shirking condition: $C_k^J(J_i, S_j) < [(\partial P^J/\partial J_i) + (\partial P^J/\partial S_j)](W - L)$ where P^J is the probability of winning in the job rotation mode. See O'Keeffe *et al* (1984) for this argument. In fact, the job rotation needs more training cost. Workers in vertical organzational mode may have lower marginal costs than workers in the job rotation mode. In practice, the firm awards more appraisal evaluation scores to make fair contest to the workers in which undergo job rotation and can use a handcapping system that simply adjusted the prizes for each worker. See Asanuma (1994) for the Japan case.

with job rotation mode are suitable for Japanese firms such as that blue-collar workers. Thus our theoretic results are consistent with the emperical studies that Japanese firms emphasize the capability of the workers' group to cope with not only routine operations but also unusual operations.

Remark: Pfeffer (1995) pointed out that three dimensions of wage spread can be existed in the hierarchical organization. First, since wages attach to the job rather than to individuals, there is the wage spread among hierarchical organization. What any particular employee is paid is determined primarily by his job assignment rather than actual individual productivity. Second, there is a different wage spread between divisions and job assignments. Third, the pay awarded to each individual employee is determined on the basis of the supervisor's evaluation of employee's merit. Since the pay is determined by job rotation or existing same division, our analyses section 3 and 4 adopted the approach of the second and the third. Pfeffer (1995) and Morishima (1997) argue that the structure of job assignment may lead to a different wage spread. Thus, if the cost of complementary among the job assignments is insufficient, then the wage spread may larger such that the cost function will reduce the marginal cost in the vertical organizational mode. Therefore, if we have lower cost complementary in the job rotation mode, it can be reduced wage spread. Our theoretic results are consistent with Morishima (1997), which argue that long-term employment relationship in the internal labor markets are the increased opportunities to invest profitably in firm-specific human captal with the smaller wage spread.

5.2 Performance Evaluations of Supervisors in Organizations

It is worth considering performance evaluation by supervisors. Suppose that there is one supervisor in each organization mode. Performance in various jobs cannot be measured objectively by the supervisor even if he/she has a good understanding of the various job's difficulties. Thus, introducing subjective measures of supervisor for each job cannot be avoided. In the vertical organizational mode, the supervisor imperfectly observe the effort of his own subordinates at each division. This cannot be done by other supervisors from different divisions. However, the job rotation mode has some merits because rotation provides additional observations of a worker's ability.[10] Thus, the job rotation mode reduce a need for subjective performance evaluation. In fact, many worker perceives that their performance evaluations are neither appropriate nor useful, and they do not trust their supervisors to evaluate them fairly and accurately. In some related work Prendergast (1993) analysis at the incentives for workers to provide correct evaluation in an organization. He argued that yes man may result when supervisors calculate the effect their statement may have their own positions. However, supervisors strongly resist their workers' job rotation if they are core-skilled workers in division. Thus, if supervisors rotate

[10]Koike (1994) points out that skill development includes the capability of handling problems, which is difficult to identify accurately without the keen observation of those who know the worker well. This implies a danger of favoritsm, which might cause demoralization on the shopfloor. The major constraint adopted is to make a job matrix and to post it on the bulletin board at the shopfloor. This means that subforeman's assessment is exmined by the workers, who work together everyday in the workshop and have keen critical eyes. So not much room remains for subjective judgement in the Japanese firm. See also Aoki (1988: chap.2) and Asanuma (1994: section 2) for this argument.

workers, then they would always rotate lower ability workers. As a result, it is important for the firm to coordinate the incentives among supervisors, workers and personnel department.

6 Concluding Remarks

Firms typically need to design the organization structure in order to make efficient promotion and task assignment decision. In this paper, we have examined the moral hazard problems associated with efforts by using the linear principal/multi-agent model developed by Holmström and Milgrom (1987) and the rank-order tournament modeled by Lazear and Rosen (1981). This paper has developed simple model to study the determinants of the optimal use of alternative organization forms: (1) the vertical organizational mode in which workers do not rotate between divisions, and (2) the job rotation mode in which workers undergo job rotation. If rank-order tournament is used within each organizational structure, the job rotation mode is preferred for the workers in white-collar positions in more stable environment. If wages are based on individual performance measures within each orgnaizational structure, then the job rotation mode is more likely to be preferred for blue-collar workers as the correlation coefficient across divisions is larger, the degree of technological complementary parameter is smaller between divisions, and changes in technology are more rapid. Our results are consistent with some empirical findings in the American and Japanese labor markets.

We conclude by mentioning directions for future researches. First, if we extend to team production the principal-supervisor-agent hierarchy in each organization structure, there are many other factors potentially relevant to monitoring of team production and collusion between a supervisor and an agent. However, there are few researches that explain the difference in organization structures under collusion.[11] The conventional research such as Tirole (1986), Kofman and Lawarrée (1993), Felli (1993) , Laffont and Martimort (1997) consider the organization structure to be fixed. It is considerably interesting to extend our analysis to the collusion cases among organization modes. Second, we have focused only on the static incentive aspects of comparative organizational structures. It is more promising to incorporate all dynamic aspects of organizational design problems.

[11] Except for Bac (1996) and Laffont and Martimort (1995). Laffont and Martimort (1995) performs the comparison between both organizational forms of centralization and decentralization when collusion is concerned. Bac (1996) analysis that in relatively principal one supervisor-two agents hierarchy economics of scale in monitoring reduce implementation costs but may increase the risk of collusion. This result is due to monitoring externality in the supervision chain.

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