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Market Characteristics, Intra-Firm Coordination, and the Choice of Human Resource Management Systems: Evidence from New Japanese Data

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Abstract

This paper explores theoretically and empirically potentially important yet often-neglected linkage between task coordination within the organization and the structure of organization and bundling of HRMPs (Human Resource Management Practices). In so doing, we also provide fresh insights on the interplay between the firm's technological and output market characteristics and its choice of HRMP system. We begin with constructing a team-theoretic model and derive three task coordination modes: vertical control, horizontal coordination, and hybrid coordination. The model provides rich implications about complementarity involving task coordination modes, HRMPs, training and hiring, and management strategies, and illustrates how such complementarity is affected by the firm's technological and output market conditions. Guided by the theoretical exploration, we analyze unique data from a new survey of Japanese firms which provide for the first time data on newer forms of HRMPs adopted by Japanese firms (such as cross-functional offline teams and self-managed online teams). One novel finding (which is consistent with the theory) is that the adoption of both self-managed online teams and cross-functional offline teams usually arises in firms with shop-floor committees while the introduction of cross-functional offline teams alone often takes place in firms with joint labor-management committees. We also confirm implications from our theory that firms in more competitive markets are more likely to adopt both types of teams while firms facing more erratic price movement tend not to adopt self-managed online teams (JEL: M5, L2, J53, D2)

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I. Introduction

Much of the literature on innovative HRMPs (Human Resource Management Practices) focus on their effects on enterprise performance. They generally find that HRM systems with complementary practices such as teams, joint labor-management committees, and incentive pay raise productivity or other firm performance measures.[1]

However, a relatively fewer attempts have been made to identify under what circumstances firms adopt these new practices and how they select a particular combination of HRMPs. Earlier works such as Osterman (1994) use nationally representative samples of U.S. establishments encompassing diverse industries and study general patterns of the adoption and diffusion of innovative work practices. More recent works tend to focus on specific industries in the U.S. and examine the adoption of various complementary work practices in more detail (see for example Pil and MacDuffie, 1996 on automobile plants and Boning, Ichniowski and Shaw, 2005 on mini-mills).[2]

Evidence on the incidence of new innovative work practices is even more limited outside of the U.S. Thus, Jones and Kato (1993) find for publicly traded firms in Japan that firms were more likely to adopt employee stock ownership plans when recent business performance was below average, the capital/labor ratio was relatively low, and employment growth was relatively fast. The results are consistent with the following explanations: (1) employees'

[1] See, for example, Ichniowski, Shaw and Prennushi (1997), Freeman, Kleiner, and Ostroff (2000), Cappelli and Neumark (2001), Hamilton, Nickerson and Owan (2003), Boning, Ichniowski , and Shaw (2005), Black and Lynch (2001, 2004), Bartel (2004), for the U.S.; Jones and Kato (1995) and Kato and Morishima (2002) for Japan; Leoni, et. al. (2001) for Italy; Addison and Belfield (2000); Conyon and Freeman (2001); and DeVaro (2006) for the U.K.; Eriksson (2003) for Denmark; Bayo-Moriones, et. al. (2003) for Spain; and Zwick (2004) for Germany.

[2] One notable exception is a new NBER working paper which uses a representative sample of U.S. establishments including both manufacturing and non-manufacturing (Lynch, 2007).

incentives to monitor and impose peer pressure on each other should be stronger when they face risks of bankruptcy, wage reduction or layoffs in poor business environment; (2) group incentives are less likely to be effective in highly automated production systems; and (3) the interests of employees in growing organizations are more aligned with those of shareholders and management and thus more of them are likely to participate in the ESOP. For Europe, Poutsma, Hendrickx, and Huijgen (2003) use a survey of firms in ten EU members and stress the importance of country specific factors as a determinant of the adoption and diffusion of participatory employment systems. However, the focus of previous works tends to be narrow with insufficient attention to the relationship between business or market environments and the design of HR system as a whole.

By reviewing the literature on the adoption of HRMPs, we are struck by the relative absence of coherent theory on the firm's choice of HRMPs. In particular the literature is often silent on potentially important interplay between modes of task coordination within the organization and the structure of organization and bundling of HRMPs. Moreover, as the contingency theory in organizational behavior developed in the 1960s stress, the firm's technological and output market conditions may play a crucial role in determining the firm's choice of a specific mode of task coordination within the organization and hence its selection of a specific HRM system (provided there is a important link between task coordination modes and HRM systems).[3]

[3] The literature of contingency theory in organizational behavior published in the 1960s attempted to make a connection between the varying technical and economic conditions outside the organizations and the pattern of organization and administrative architecture that exhibit successful performance. Early works generally found that when the environment and task of the organization were certain and predictable then centralization and formalization were appropriate, but when they were uncertain and unpredictable then decentralization and lack of formalization were required. For example, Burns and Stalker (1961) concluded from their research with 20 English manufacturers that the more rapidly the firms' technological and market environments were changing, the more flexible or "organic" their structures tended to be. Essentially similar conclusions were reached by Lawrence and Lorsch (1967) in their study of 12 large American firms.

This paper begins with constructing a coherent team-theoretic model by building on the works by Dessein and Santos (2006) and Aoki (1986), and derives three distinct modes of task coordination within the organization: vertical control, horizontal coordination, and hybrid coordination.[4] The model is then used to generate rich implications about complementarity involving task coordination modes, HRMPs, training and hiring, and management strategies, and illustrate how such complementarity is affected by the firm's technological and output market conditions. Guided by the theoretical exploration, we analyze unique data from a new survey of Japanese firms which provide for the first time data on newer forms of HRMPs adopted by Japanese firms (such as cross-functional offline teams and self-managed online teams). One

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Subsequent studies in the contingency theory, however, seem to have lost their interests in the role of purely economic and market conditions in shaping the structure and management system of the organization. They primarily focused on the relationships between the process technology adopted within the organization and its structure (Woodward 1965, Hickson et al. 1969, Gerwin 1979, Reimann 1980, Drazin and Van de Ven 1985). They all reported that as the production process of work group become less routine, more uncertain, and/or more complex, its structure becomes more organic organization, with increased participation, autonomy, and informality for group members (The same cannot be said for most of the research studies examining structure and production process technology at the system (managerial) level. See Hickson et al. 1969). Since the choice of process technology is the decision variable for the firm, it may be argued that a particular process technology may tend to develop in response to certain market, technological, or industry characteristics. The possibility that such environmental factors are affecting both the adoption of particular process technologies and organizational structures has for long been ignored. It is surprising that few works in contingency theory literature attempts to answer the above question raised by Lawrence and Lorsch (1967) from a different perspective or using a large-scale dataset.

[4] Aoki (1986, 1988) compares localized horizontal coordination with centralized hierarchical coordination and concludes that the latter is more efficient if information regarding emergent events is relatively more precisely monitored at the top level and concomitant centralized solutions are more swiftly implemented at the shop-floor level without distortion. In such situations where gradual and speedy reaction to on-site local information is more efficient, however, self-managed on-line teams will likely be chosen as effective coordination and decision making device.

Dessein and Santos (2006) also analyzes how organizations choose the level of adaptation to a chancing environment when coordination among specialized tasks is a concern. One of their important findings is that the relationship between the need for task bundling (e.g. job enlargement or multi-tasking) and the quality of communication channels is not monotone. On the one hand, an improvement in the quality of communication makes it easier to coordinate specialized activities, reducing the need for task bundling. On the other hand, as coordination through communication improves, the organization will find it optimal to increase employee flexibility and become more adaptive, favoring more task bundling in order to reduce coordination failures. The latter effect tends to dominate the former when communication channels are poor and/or the interdependence among specialized activities is high. Dessein and Santos (2006) also shows that broad job assignment and investment in the quality of communication co-vary at the optimum under a reasonable assumption.

novel finding (which is consistent with the theory) is that the adoption of both self-managed online teams and cross-functional offline teams usually arises in firms with shop-floor committees while the introduction of cross-functional offline teams alone often takes place in firms with labor-management committees. We also confirm implications from our theory that firms in more competitive markets are more likely to adopt both types of teams while firms facing more erratic price movement tend not to adopt self-managed online teams.

In the next section, we present our theoretical exploration, followed by the empirical analysis of the new Japanese data with a brief introduction to the new survey in Section III. Concluding remarks are offered in Section IV.

II. Theoretical exploration

In this section, we present a team-theoretic model that will be used to explain the firm's decision to introduce innovative HRMPs. As in Dessein and Santos (2006), we assume that production requires the combination of n tasks and the firm's profit depends on how well it adapts to the organizational environment and how well tasks are coordinated with each other. We assume that the firm can do two things to enhance its coordination capabilities: (1) decision rights are retained in the hands of the management to coordinate perfectly among tasks at the expense of adaptation; or (2) tasks are bundled and delegated to teams so that coordination within teams will be perfect. Unlike Dessein and Santos (2006), we interpret task bundling as team formation instead of job enlargement. Namely, when employees work in teams, the quality of communication within teams improves significantly and the members obtain "perfect" coordination among the tasks.

Task i requires taking primary action a^{ii} to adapt to a changing environment and complementary actions a^{ij} (for all j such that $j \neq i$) to coordinate with other activities in the firm.

There are two types of information that are relevant to the choice of optimal actions: η, set of systematic environmental information, and θ^i (i = 1,…,n), local environmental information that is only observed by those working on task i. The former is the set of information that affects the optimal action in each task systematically including macro-economic conditions, emergence of new technology, and changes in customer taste while the latter is the one that is relevant only to the task where the information is observed. θ^i is a random variable whose prior distribution is assumed to be known to all members of the firm. The set of systematic information η can be used to update the prior distribution of θ^i to obtain more accurate prescription for desirable actions. Let $\hat{\theta}^i(\eta) = E(\theta^i \mid \eta)$ and $\sigma^2(\eta) = Var(\theta^i \mid \eta)$ where the variance is common across i. Assume $0 < \underline{\sigma}^2 \le \sigma^2(\eta) \le \sigma^2(\phi)$ where ϕ indicates the null set meaning that the decision maker has no systematic information. When $\eta \subset \eta'$, $\sigma^2(\eta) \ge \sigma^2(\eta')$. The adaptation calls for the use of local information and the primary action a^{ii} should be set equal to θ^i. On the other hand, to achieve perfect coordination between i and j, action a^{ij} should be set equal to the primary action a^{jj}. Let C^i be the adaptation and coordination losses for task i. Then,

$$C^i(a^{1i}, a^{2i}, \ldots, a^{ni}) = \alpha(a^{ii} - \theta^i)^2 + \sum_{j \neq i} \beta(a^{ji} - a^{ii})^2 \qquad (1.1)$$

where the parameters α and β determine the importance of adaptation and coordination respectively.

Each task can be assigned either to one employee or a group of employees. t tasks can be assigned to a group of t employees where $1 \le t \le n$. Hence, t = 1 is simply a special case of team assignment where each task is assigned to an individual. We denote by $T(i)$ the group of employees to which task i is assigned. To simplify our analysis, we restrict the team structure to be "almost" symmetric meaning that all teams have either l members or l +1 members where $l \ge$

1 is an integer. By abusing notation, we let t stand for the average size of teams in the firm. Namely, $t \in T = \{\frac{1}{n}\sum_i |T(i)| \,|\, T(i)$ is "almost" symmetric$\}$ where $|T(i)|$ stands for the number of members in $T(i)$. θ^i is Hayekian in the sense that employees can share the realization of the local information θ^i only by working closely together but cannot transmit the information to the management ex post within the time period in which planned decisions may be revised. We assume that employees in $T(i)$ can jointly observe θ^i prior to the actual implementation of the actions, hence $a^{ji} = a^{ii}$ for $j \in T(i)$. Therefore, t should not be interpreted just as the size of teams, rather it is the degree of task bundling and multitasking as is modeled by Dessein and Santos (2006) as team members need to work together, share information, and constantly coordinate their activities within teams. The local information can also be communicated to other colleagues outside teams when the outsiders happen to have close interaction with the team members that facilitate the transfer of the tacit information. Following Dessein and Santos (2006), we model such communication in the following way: each team $T(i)$ sends a message concerning θ^i to all employees outside the team. With a probability p, an employee in charge of task $j \notin T(i)$ perfectly understands the message and takes the complementary action a^{ji} that is set precise equal to the primary action a^{ji}. With the probability of $1 - p$, the message concerning θ^i will be pure noise for the employee, and thus the choice of the relevant complementary action a^{ji} cannot be made contingent on it.

There are costs associated with team formation such as training cost, communication cost, and the cost of practices supporting team activities. Furthermore, the firm develops communication channels such as cross-functional off-line teams, and invests in information and communication tools to raise p. Let $h(t, p, \tau)$ be the total cost of such expenditures for team

formation and intra-firm horizontal communication per employee where the parameter τ denotes the firm's capability of training its employees for better workplace communication and team activities. Such capability depends on the firm's pre-existing conditions including labor-management relationship, corporate culture, adoption of multi-skilling practices such as job rotation, quality of workforce, and accumulation of human capital. $h(t, p, \tau)$ is increasing in (t, p) but non-increasing in τ with $h(1, 0, \tau) = 0$. The firm develops communication channels to raise p and the level of such investment in communication quality is optimally chosen.

We assume that management obtains some systematic information from various activities including the use of consultants, market and technology research, and thorough the analyses of its operations but observes no local information directly. On the other hand, employees observe their local information relevant to their own tasks but have no direct access to systematic information. With the spirit of Aoki (1986, 2001), we first consider two distinct modes of information processing systems: vertical control and horizontal coordination and assume that the firm chooses the information processing system that minimizes the sum of adaptation and coordination losses and the cost of team formation. Later, we will consider a hybrid mode of information processing: participatory control system.

A. Vertical Control System

When the systematic information possessed at the top is sufficient to infer the local information collected at the lower levels of organization relatively precisely, the management will try to pre-specify both primary and complementary actions to minimize coordination losses. The management's instructions, however, are not necessarily understood correctly by their employees. There could be communication errors, distortion, or delay in implementation during which the environment may change. We assume that a noise v^{ij} is added to the management's

instruction for the action a^{ij} where v^{ij}'s are independent of each other and θ^{i}'s and have a common variance σ_v^2. Since forming teams or investment in communication quality creates no economic value in this system but imposes the cost $h(t, p, \pi)$ to the firm, each task is assigned to an individual who is not required to work in team or communicate local information to other employees. *i.e.* $h(1,0,\tau) = 0$. The employee assigned task i takes $a^{ii} = \hat{\theta}^{i}(\eta) + v^{ii}$ and $a^{ij} = \hat{\theta}^{j}(\eta) + v^{ij}$ (for $j \neq i$).

With this vertical control system, the organization's total cost is given by

$$\begin{aligned}\sum_{i=1}^{n} \underset{\theta}{E}[C^{i}(a^{1i}, a^{2i}, \ldots, a^{ni}) \mid \eta] &= \alpha \sum_{i=1}^{n} \underset{\theta}{E}[(a^{ii} - \theta^{i})^2 \mid \eta] + \beta \sum_{j \neq i} \underset{\theta}{E}[(a^{ji} - a^{ii})^2 \mid \eta] \\ &= n\alpha(\sigma^2(\eta) + \sigma_v^2) + 2n(n-1)\beta\sigma_v^2\end{aligned} \tag{1.2}$$

Note that the firm may perform better by building a bureaucratic organization where all activities are governed by routines and the management does not respond to new environment. Namely, when the firm sets $a^{ii} = a^{ji} = \hat{\theta}^{i}(\phi)$ for all i and j,

$$\sum_{i=1}^{n} \underset{\theta}{E}[C^{i}(a^{1i}, a^{2i}, \ldots, a^{ni})] = n\alpha\sigma^2(\phi)$$

To simplify our discussion, we assume that such bureaucratic organizations are never the optimal in modern business world. Formally stated:

Assumption 1 $\alpha(\sigma^2(\eta) + \sigma_v^2) + 2(n-1)\beta\sigma_v^2 < \alpha\sigma^2(\phi)$

Assumption 1 implies that $\alpha > \underline{\alpha}(\beta) \equiv \dfrac{2(n-1)\beta\sigma_v^2}{\sigma^2(\phi) - \sigma^2(\eta) - \sigma_v^2}$ or

$\beta < \bar{\beta}(\alpha) \equiv \dfrac{\alpha(\sigma^2(\phi) - \sigma^2(\eta) - \sigma_v^2)}{2(n-1)\sigma_v^2}$. Namely, it requires that the adaptation to changing business environment is sufficiently important and the interdependency among tasks that necessitates coordinated activities is not so high.

B. Horizontal Coordination System

When the management believes that adaptation at the lower levels of organization creates substantial economic value, they will let the employees choose their own actions. As is conventional with team-theoretical models, we assume that there is no conflict of interests between the management and the employees and the latter choose their actions to minimize the firm's cost. We believe, however, that choosing the optimal actions taking into account the possibility of coordination failure requires more highly trained employees than obeying the bosses' instructions does in the vertical control system. Hence, we assume that the firm has to pay additional wage cost to hire more educated workers or provide additional training to help empowered workers to make decisions. Let *d* be such a cost. The total adaptation and coordination cost (including that for team formation and human capital) is

$$\sum_i C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) = \sum_i \alpha(a^{ii} - \theta^i)^2 + \sum_{i, j \notin T(i)} \beta(a^{ji} - a^{ii})^2 + nh(t, p, \tau) + nd \quad (1.3)$$

Note that the coordination losses within the same team $T(i)$ do not appear in the expression because we expect the members of $T(i)$ to perfectly coordinate among themselves. The average size of teams *t* and the precision of horizontal communication *p* are chosen by the management but the actual actions are taken by the employees themselves.

The timing of the decision-making is as follows:

1. Once the management chooses the horizontal coordination system, they determine the size of teams *t* and the investment in communication quality *p*.
2. The local information θ^i, $i = 1, 2, ..., n$, are realized and observed by the employees of the group in charge of task *i*.
3. Workers communicate the realizations of local information, and with an independent

probability *p*, these communications are successful. Whether or not communications are successful is known by the receivers of the information only and the sender does not find the outcome of the communication.

4. For all $i = 1, 2, ..., n$, the employees of the group in charge of task *i* choose actions a^{ij}, $j = 1, 2, ..., n$, that would minimize the expected cost function (1.3), subject to their information constraints.

First, it is important to realize that the employees in charge of task *i* do not necessarily choose $a^{ii} = \theta^i$, the action that adapt to the environment perfectly, because it raises the cost of coordination failure that takes place when the communications with other employees failed. Note that the decision-makers for task *i* minimize $\alpha(a^{ii} - \theta^i)^2 + \sum_{j \notin T(i)} \beta(a^{ji} - a^{ii})^2$. Let $\hat{a}^{ji}$ be the complementary action taken by the employees outside of $T(i)$ who fail to receive the right information from the decision-maker for task *i*. The optimal primary action a^{ii*} and $\hat{a}^{ji}$ satisfy

$$a^{ii*} = \frac{\alpha\theta^i + \beta(n-t)(1-p)\hat{a}^{ji}}{\alpha + \beta(n-t)(1-p)} \quad \text{and} \quad \hat{a}^{ji} = \underset{\theta^i}{E}\, a^{ii*}. \qquad (1.4)$$

By solving (1.4), we get

$$a^{ii*} = \hat{\theta}(\phi) + [\frac{\alpha}{\alpha + \beta(n-t)(1-p)}](\theta^i - \hat{\theta}(\phi)) \qquad (1.5)$$

and

$$a^{ji} = \begin{cases} a^{ii*} \text{ when task } j \text{ learns } \theta^i \\ \hat{\theta}^i(\phi) \quad \text{when task } j \text{ does not learn } \theta^i \end{cases} \qquad (1.6)$$

Hence, with the horizontal coordination system, the total cost is given by

$$\sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) \mid \phi] = n\frac{\alpha\beta(n-t)(1-p)}{\alpha + \beta(n-t)(1-p)}\sigma^2(\phi) + nh(t, p, \tau) + nd \quad (1.7)$$

The management will choose (*t*, *p*) to minimize this cost function. Let *t** and *p** be the

optimal size of team and the optimal investment in communication quality. In order to insure the uniqueness of the optimal organizational design, we make the following assumptions:

Assumption 2 The function $\sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) \mid \phi]$ is strictly quasi-convex in (t, p).

Assumption 3 $\frac{h(t, p, \tau)}{n-t}$ is submodular (or $-\frac{h(t, p, \tau)}{n-t}$ is supermodular), namely the function has non-increasing differences for any pair of (t, p, τ).[5]

Since each employee has to send a signal to $(n - t)$ employees outside his team and evaluate the signals concerning $(n - t)$ tasks, $\frac{h(t, p, \tau)}{n-t}$ can be interpreted as the opportunity cost for communicating with other employees to determine the optimal complementary actions per task. This submodularity assumption is reasonable because: (1) the greater is the average team size, the higher is the chance that an arbitrary outsider happens to have close interaction with someone in $T(i)$ leading to a better communication quality; and (2) the higher is the firm's capability of training its employees for teamwork, the easier will be to increase team size and communication quality.

Next, we state the proposition due to Dessein and Santos (2006):

Proposition 1 Suppose the horizontal coordination is more efficient than the vertical control system. Team size, t^*, and the quality of communication channels, p^*, are increasing in the parameters $\alpha, \sigma^2(\phi)$ and τ. **(Proof in the Appendix).**

The use of teamwork and communication channels will be more extensive as the importance of adaptation, the uncertainty of business environment, and the firm's capability of team building and supporting horizontal communication are greater. Note that assumption 3 is

[5] Function $f(x,y)$ is said to have non-increasing differences when $f(\bar{x}, y) - h(\underline{x}, y)$ is non-increasing in y for any $\bar{x} > \underline{x}$.

critical in generating this monotonicity result.

As Dessein and Santos (2006) discuss, t^* and p^* are not necessarily monotonically increasing in β, the degree of task interdependence or the cost of coordination failure, contrary to the conventional wisdom. While an increase in β encourages the firm to raise t^* and p^* to hold down the coordination cost, it also induces the firm to take less adaptive primary actions (*i.e.* farther apart from θ^i), which in turn reduces the need to coordinate among employees. Therefore, t^* and p^* are monotonically increasing in β only when α, the importance of adaptation, is sufficiently high.

C. Choice of Management System

The firm will choose the vertical control system (horizontal coordination system), if

$$\sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}) \mid \eta] \underset{(>)}{<} \sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) \mid \phi]$$

Or equivalently,

$$\alpha(\sigma^2(\eta) + \sigma_v^2) + 2\beta(n-1)\sigma_v^2 \underset{(>)}{<} \frac{\alpha(n-t^*)(1-p^*)}{\alpha/\beta + (n-t^*)(1-p^*)}\sigma^2(\phi) + h(t^*, p^*, \tau) + d \qquad (1.8)$$

Note that the left-hand side, the adaptation and coordination losses in the vertical control system, is a linear function of α and β while the right-hand side, those in the horizontal coordination system, is a concave function of α and β. Figure 1 and 2 illustrates the cost structures of the two systems. As α increases or β decreases, the optimal primary actions chosen in the horizontal coordination system approach to $\{\theta^1, ..., \theta^n\}$, the true state of the environment, to reduce adaptation losses, and the management readjust *t* and *p*, the extent of teamwork and the

investment in communication quality to reduce the coordination cost. Therefore, the adaptation and coordination losses do not rise in proportion with the increase in α and β in the horizontal coordination system. As Figure 1 shows, the horizontal coordination system should perform well for a sufficiently large α. We state this result in the form of proposition:

Proposition 2 Holding the other parameters fixed, there exists $\hat{\alpha}$ such that the horizontal coordination system functions better for all $\alpha > \hat{\alpha}$. (**Proof in the Appendix).**

In theory, it is imaginable that, for a very small α, the horizontal coordination system becomes more efficient if the additional employment cost *d* is sufficiently small relative to the cost of errors in vertical communication $2\beta(n-1)\sigma_v^2$. The dotted line in Figure 1 illustrates the possibility. In such a case, the choice of management system could become non-monotonic. Namely, the horizontal coordination system is adopted for very small α and a sufficiently large α.

In reality, however, delegating strategically or operationally critical decision problems to lower-level employees is a risky managerial policy. Hence, the policy requires substantial investment in employee training which raises *d*. Then, unless more adaptation generates substantial returns to the firm, it is unlikely to adopt the horizontal coordination system. Therefore, we conjecture that as α increases, the horizontal coordination system is more likely to be adopted. With this conjecture and Proposition 1 combined together, we get the following implication: team organization is more likely to be adopted, investment in horizontal communication channels to raise *p* is likely to be greater, as adaptation to a new environment becomes more important. So the next question is when adaptation is more likely to be relevant for the firm's success. We argue that speedy adaptation creates more value when the competition is more intense (i.e. slow response to environmental changes could result in bankruptcy), and

when the product development cycle is shorter (i.e. technological changes and/or changes in customer taste or needs are rapid).

Before presenting a similar result for coordination parameter β, we add one more assumption to ensure that the horizontal coordination system could be optimal for a certain range of β.

Assumption 4 $d < \alpha(\sigma^2(\eta) + \sigma_v^2)$

Proposition 3 Holding the other parameters fixed, there exists $\hat{\beta}$ such that the horizontal coordination system functions better for $\beta < \hat{\beta}$. (**Proof in the Appendix).**

When *d* is sufficiently large relative to the cost of errors in vertical communication $2\beta(n-1)\sigma_v^2$, the horizontal coordination system could be optimal for a sufficiently high β. This case is illustrated by the dotted curve in Figure 2. Together with our earlier discussion that the relationships between (*t*, *p*) and β are not monotone in general in the range where the horizontal coordination system is efficient, the result reinforced our view that there is little clear-cut implication about how the adoption of self-managed teams and horizontal communication channels are related to the needs of coordinated actions. Nevertheless, we will attempt to explore the issue empirically.

What factors would raise the value of coordination? One possible argument is that the need to coordinate activities across units depends on the product or business architecture (Ulrich 1995, Baldwin and Clark 2000, Fujimoto et al. 2001). Researchers in design theory argue that there are two distinct types of product architecture: modular and integral. Modular architecture has the design rule that requires one-to-one mapping between functions and components and thus each component is self-contained. Products designed under this rule often has standardized interface and therefore is compatible. Very naturally, modular architecture could lead to open

procurement systems where the assemblers could buy most necessary components in spot markets. Integral architecture assumes complex multi-dimensional linkage between functions and components. This means that in order to improve on one function, the designer has to re-work on and coordinate across multiple components. The procurement system will be closed if the architecture is integral or the interface is not standardized in modular architecture. According to Fujimoto et al. (2001), the type of architecture is not necessarily determined by the industries where the firms operate but rather it is the product of technology adopted and business process strategically chosen by each firm. Therefore, it is possible that we observe variation in product architecture even in the same product market. As Baldwin and Clark (2000) and Fujimoto et al. (2001) have implied, modularization of product architecture induces disintegration of production process and reduces transaction costs in spot markets and encourages competition among suppliers.

Presumably β is greater when the firm adopts integral architecture. Furthermore, when the customer adopts the integral product architecture, the buyer-supplier relationship will likely become more long-term and exposes suppliers to less spot market competition:

Proposition 4 As the systematic information becomes more important (*i.e.* $\sigma^2(\eta)$ gets smaller) and the labor-management communication involves less noise (*i.e.* σ_v^2 becomes smaller), the vertical control system becomes more desirable. On the other hand, as the pre-conditions that facilitate team formation and inter-team communication prevail (*i.e.* τ rises), the horizontal coordination system is likely to be superior. **(Proof is straightforward from (1.8) and thus omitted).**

Proposition 4 may imply that as the technological and market changes become more disruptive, primary actions and coordination responsibilities are less likely to be delegated to

lower-level employees because local information is less likely to be sufficient for the employees to engage in complex coordination activities in such occasions. This result together with other implications from (1.8) is consistent with the findings in Itoh (1987). Namely, a higher level of global changes leads to more knowledge resources as the variance of the macroenvironment is relatively small, but reduces the total amount of resources as the variance exceeds a certain value. In our model, teams and communication quality are knowledge resources. When $\sigma^2(\eta)$ is large so the information about the macroenvironment has relatively small value, the horizontal coordination system is adopted and an increase in $\sigma^2(\phi)$ leads to increases in *t* and *p* (Proposition 1). But, when $\sigma^2(\eta)$ is small enough, an increase in $\sigma^2(\phi)$ makes it more likely that the vertical control system is adopted (see (1.8)).

A mechanism for better labor-management communication such as joint labor-management committees (JLMCs) may be complementary with vertical control system because it will reduce the communication errors or misunderstanding that might induce wrong actions to be taken by employees (*i.e.* smaller σ_v^2). The relative efficiency of hierarchical structures depends on whether they can implement centralized solutions swiftly without distortion. Knowing management decisions well, employees or teams will more likely take actions without delay or misunderstanding.[6]

τ, the parameter of the firm's capability to train its employees for team and communication activities could potentially include many attributes of the firm. For example, the

[6] According to the Survey of Labor-Management Communication by the Ministry of Health, Labour, and Welfare conducted in 2004, more than 60 percent of the firms use JLMCs for information sharing for basic management decisions such as business strategies and production and sales plans. According to field research conducted at a variety of Japanese firms by Kato (2003), labor representatives to JLMCs believe that some of the information they receive from top management can be considered "insider information." With such information on management decisions and their background, employees are more likely to internalize organizational goals (although it is still not a trivial task to motivate them) and implement the firm strategy in a coordinated fashion.

highly-skilled workforce with broad tasks will encourage the firm to adopt more decentralized decision-making structure. We will investigate the effect of human capital on the incidence of HRMPs in our empirical analyses.

D. Hybrid coordination system

Although hierarchical structure are often perceived to be incompatible with delegation or team organizations, increasing number of firms seem to try to combine the empowerment approach with the traditional hierarchical structure. For example, Nonaka and Takeuchi (1995) argue that "hypertext" organization which has two layers, the hierarchical business layer and the project team layer, is an effective way to acquire, create, exploit, and accumulate new knowledge. According to them, this type of organization has been adopted by a number of large Japanese firms including Sharp and Kao Corporation.

We can now consider a hybrid organization where employees adjust their actions according to their local information after receiving instructions from the management. Let us call this information processing system "hybrid coordination" or "participatory control" interchangeably. The total adaptation and coordination losses for such organizations can be obtained simply by replacing $\sigma^2(\phi)$ with $\sigma^2(\eta)$ in the cost function for horizontal coordination and adding the cost of vertical communication errors σ_v^2. We further assume that the training cost in this system *d'* is smaller than that in the horizontal coordination system, *d*. The total cost function for the type is

$$\begin{aligned}&\sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) \mid \eta] \\ &= \frac{\alpha(n-t^{**})(1-p^{**})}{\alpha/\beta + (n-t^{**})(1-p^{**})}\sigma^2(\eta) + \alpha\sigma_v^2 + 2\beta(n-1)\sigma_v^2 + h(t^{**}, p^{**}, \tau) + d'\end{aligned} \tag{1.9}$$

where t^{**} and p^{**} are chosen optimally to minimize the expression (1.9).

The following two propositions are immediate:

Proposition 5 Hybrid coordination system dominates traditional vertical control system if *d'*= 0. (**Proof in the Appendix).**

Note that the rationality required for employees in this hybrid coordination system is higher than that required for those in the vertical control system. In the latter, the employees only need to execute what is prescribed by the management. In the former, in contrast, the employees have to predict what complementary actions their colleagues might choose and solve the cost minimization problem as is discussed in equations (1.4)-(1.6). Therefore, only firms with capable employees and complementary practices can implement the hybrid coordination system. In other words, *d'* is likely to be substantial and thus the vertical control system could still be the optimal.

Note that hybrid coordination system does not always dominate the horizontal coordination system. When σ_v^2 sufficiently high, horizontal coordination is will be more efficient than hybrid coordination. Specifically, we can show that the adaptation and coordination cost in the horizontal coordination system is lower than in the hybrid coordination system for sufficiently small β and around $\beta = \overline{\beta}$ when the difference between *d* and *d'* is sufficiently small. Furthermore, we can show that workers are less adaptive in the firm with participatory control than in the one with horizontal coordination as follows:

Proposition 6 $t^{**} \le t^{*}$ and $p^{**} \le p^{*}$. (**Proof in the Appendix).**

Proposition 6 implies that this participatory control system will not adopt all practices that horizontal coordination systems employ because marginal benefit of team organization or that of investment in communication quality is smaller. Especially, self-managed on-line teams often require substantial training and other complementary practices such as cross-training that are

costly. Cross-functional project teams may be less costly especially if they are monitored and controlled closely by the management.

E. Compensation system

Compensation contingent on performance at the individual or group level is usually perceived as complementary with work organization where employees are given a high level of discretion. Group incentives are especially likely to be desirable in organizations with highly autonomous teams and broad task bundling. Group incentives are subject to free-riding but multi-skilled workers in self-managed teams are more likely to engage in mutual monitoring and/or develop social ties within the group creating peer pressure that would effectively prevent free-riding. On the other hand, individual incentives will be at odds with team activities from the following three reasons: (1) individual performance is more difficult or costly to measure in a team setting; (2) individual incentives will discourage cooperation and coordination that are key to successful team activities; and (3) job rotation that is often necessary to enhance employees' team skills will make it even more difficult to observe individual performance.

One caveat in applying the above idea to the Japanese data is that pay for performance introduced in Japanese firms is often coupled with management by objectives (MBO). Namely, employees are evaluated based on how much of their objectives are achieved and paid accordingly. Therefore, they are paid based on some subjective evaluation measures and the above issues of measurement and lack of cooperation may not be a serious problem. If a moderately-powered individual incentive scheme does not distort the employees' allocation of effort in any significant way, adopting it together with group incentives may help balance the overall incentives given to employees while preventing opportunistic behaviors such as free-riding. If so, group incentives and individual incentives may appear to be correlated in the

actual data because they will both tend to be adopted when workers are empowered.

III. Empirical Analysis

Japan Ministry of Economy, Trade and Industry (METI) has been conducting the ICT Workplace Survey (ICTWPS) annually since 2001, which provide data on IT investment and IT-related activities from about half of the 9,500 randomly selected enterprises that use computers in their businesses. As a supplement to the ICTWPS, METI allowed a team of researchers including us and our colleagues at the Tokyo Institute of Technology to conduct a new survey of Japanese firms, the HRMOS (HRM and Organization Survey of Japanese Firms) in November 2005. The sample universe is all firms that responded at least once to the ICTWPS since 2001 and were in seven key industries – general machinery, electrical machinery, information and communication electronics equipment, transportation equipment, precision instruments and machinery, retail, and financial. It turned out that 9,500 firms responded to the ICTWPS at least once since 2001 and that out of them 3,017 firms were in those seven industries.

Specifically, we sent the questionnaires in November 2005 to each of those 3,017 firms, asking the director of management planning and the director of human resource management to fill out the separate sections of questionnaires. We received usable responses from 365 firms (a response rate of 12.1%). Among those, there were 192 firms in manufacturing and 173 firms in non-manufacturing. 80 firms are listed on Japan's stock exchanges. Our response rate is neither particularly high nor unusually low for a mail-in survey of Japanese firms.[7]

[7] For instance, in June of 1991, the Rengo Sogo Seikatsu Kaihatsu Kenkyu Jo (Rengo Research Institute of General Life Development) mailed their questionnaire asking questions on labor conditions and employee participation/involvement to 6,800 firms (including both public and private firms in Japan) and received usable responses from 689 firms (a response rate of 10%). In June of 1989, the Japan Productivity Center mailed their questionnaire asking questions on HRMPs to 1030 firms in Japan and received usable

To study the representativeness of our sample, we first compare the distribution of our sample firms (respondents to the HRMOS) by industry with that of respondents to ICTWPS 2005 that are in the seven industries assuming that the distribution of the latter is similar to our sample universe (respondents to ICTWPS 2001-2005 that are in the seven industries). The industrial make-up of our sample is largely comparable to that of the population except that our sample includes relatively more firms in general machinery and fewer firms in financial service. In addition, we find that the average firm in our sample is smaller than the average firm in the populations (employing 1,103 workers as opposed to 1,659 workers).

Next, it is plausible that firms with more innovative HRMPs are more likely to respond to our survey. To shed some light on the extent of such response bias, we compare the proportion of firms with innovative HRMPs calculated from our survey to what has been calculated from the three earlier and larger surveys. First, regarding Pay For Performance (PFP) and PSP (Profit Sharing Plan), there is a comparable yet larger governmental survey of Japanese firms called the General Survey of Employment Conditions (Syuuro Jyoken Sogo Chosa) conducted by the Ministry of Health, Labor and Welfare in 2004. The proportions of firms with PFP and PSP in our sample are 48.1 percent and 45.4 percent respectively, and the comparable figures from the General Survey of Employment Conditions turn out to be reasonably similar (50.5 percent and 53.6 percent respectively).

Unfortunately, for employee involvement programs, there is no comparable, larger governmental survey. The only governmental survey that provides somewhat similar information is the Survey of Labor-Management Communications (Roshi Komyunikeishon Chosa) conducted by the Ministry of Health, Labor and Welfare. The SLMC reports that in 2004, 37.3

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responses from 203 firms (a response rate of 19.7%). Kato and Morishima (2003)'s HRM Survey of Japanese Firms in 2001, which is perhaps the closest to our survey in terms of the content of the questionnaire, had a response rate of 17%.

percent of establishments had JLMCs; and 49.8 percent with SFCs. According to our survey, 55.4 percent of firms had JLMCs and 38 percent with SFCs in the same year. A simple comparison of the incidence of JLMCs and SFCs between our survey and the SLMC appears to point to an overrepresentation of our sample by firms with JLMCs and underrepresentation by firms with SFCs. However, there is an important difference between the two surveys which may account for the discrepancy in the incidence of JLMCs and SFCs between the two surveys. The SLMC is a survey of establishments while ours is a survey of firms. Being a survey of establishments rather than firms, the SLMC naturally yields lower incidence of JLMCs and higher incidence of SFCs. Thus, some firms have JLMCs only at the headquarter level and their establishments have only SFCs and hence the proportion of establishments with JLMCs is naturally lower than that of firms with JLMCs. On the contrary, SFCs are more prevalent among larger firms than among smaller firms according to the SLMC. Larger firms are more likely to have more establishments. The proportion of establishments with SFCs tends to exceed that of firms with SFCs.[8]

Our survey, HRMOS, is the first survey in Japan which provides comprehensive data on the use of newer forms of innovative work practices by Japanese firms. Specifically, the HRMOS asks Japanese firms about their use of: (i) *Cross-functional off-line teams* (*CFOTs*) in which members from different functions engage in activities to reduce costs and improve quality, services, and delivery performance under specific targets and action plans;[9] (ii) *Self-managed*

[8] To demonstrate this, consider there are two firms; large firm and small firm. The large firm has two establishments and each establishment has a SFC where as the small firm has only one establishment and has no SFC. The survey of firms will yield 50 percent for the proportion of firms with SFC whereas the survey of establishments will yield 66.7 percent for the proportion of establishments with SFC.

[9] Japanese firms (especially in manufacturing) have been known for the extensive use of small group activities, such as Kaizen, Zero Defect, and QC circles (Morita, 2001). The traditional form of such small group activities is rather narrow in its scope and often includes only workers from the same workplace (Kato, 2003). Based on our own field research at multiple firms in Japan, however, the scope of such small group activities appears to have been expanding with increasing involvement of workers from different functions.

on-line teams (*SMOTs*) in which members in the workplace are given autonomy to decide on work processes and task coordination in order to share operational know-how and information and respond to market changes quickly; (iii) *Pay for performance* (*PFP*) through which wage or salary of an individual is linked to his/her own output or some other performance measure under a pre-determined rule; and (iv) *Profit-sharing plans* (*PSPs*) through which the total amount of bonuses is linked to a measure of firm performance, such as profit, sales, production, and value added.[10]

The HRMOS also provides the most updated data on the use of more traditional and well-established forms of HRMPs: (i) *Joint labor-management committees* (*JLMCs*) serving as a mechanism for employee participation/involvement at the top level, covering a large variety of issues ranging from basic business policies to working conditions; and (ii) *Shop-floor committees* (*SFCs*) in which supervisors and employees discuss issues such as shop-floor operations and working conditions.[11]

In addition, the HRMOS also asks Japanese firms about their use of management practices with growing popularity: (i) Benchmarking, or a formal system of learning about practices in other successful firms and used to help clarify where ones' company stands, relative to others, in the practices that matter most in ones' area of business; and (ii) *Management by objectives* (*MBO*) through which objectives are clarified, goals are set, and achievements for

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Such extended small group activities are clearly considered CFOTs in our survey.

[10] Based on the literature which often stresses that much of the Japanese bonus payment system is a disguised regular wage, we are considering only the bonus system with a formal contract stipulating the presence of the profit-sharing plan. Such PSP bonus system is a relatively new and growing innovation in the Japanese pay system (see, for instance, Kato and Morishima, 2003 for PSPs in Japan).

[11] The HRMOS also provides data on another long-established HRMP in Japan: *Employee Stock Ownership Plans* (*ESOPs*) through which employees own shares of the firm for which they work, and keep their shares (and dividends) in trust (the firm matches each employee's contribution by giving 5 to 10 percent of the contribution as well as bearing administrative costs. For the rest of the paper, we ignore ESOPs and focus on JLMCs and SFCs as older HRMPs. Adding ESOPs to the analysis produces no discernable change to our results. These results as well as all other unreported results are available upon request from Takao Kato at tkato@mail.colgate.edu. For these HRMPs, see, for instance, Jones and Kato (1995) and Kato (2003).

individual employee are assessed in a way that would coordinate the activities of employees to attain the firm's strategic goal.

Finally, the HRMOS also provides data on various firm characteristics, such as age of the firm, number of employees, whether the firm is listed in Japan's stock exchanges, industry classifications, and education and training of labor force.

In order to explore possible complementarities among HRMPs, we first look at how the incidence of a practice differs depending on the presence of other practices. Table 1 summarizes such conditional incidence rates (percentage of firms with a certain practice, conditional on the presence of another practice). First, 74% of firms with SMOTs also have CFOTs while the unconditional incidence rate of CFOTs is 54%. Likewise, the incidence rate of SMOTs conditional on the presence of CFOTs is 11 percentage-points higher than the unconditional incidence rate. The difference between the conditional and unconditional incidence rates is statistically significant at the 1 percent level for both CFOTs and SMOTs. This is consistent with our theoretical finding that task bundling and investment in horizontal communication channels are complements (Proposition 1-3).[12]

Second, shop-floor committees seem to complement team activities. Firms with SFCs are more likely to have CFOTs and SMOTs (14 and 8 percentage-points more likely than the average firm respectively). The null hypothesis that either team organizations are introduced independently from SFCs is rejected at the 1% significance level. We argue that SFCs play an important role both as a communication channel and a pre-condition that nurtures participatory corporate culture. Namely, empowered teams may need to coordinate activities and SFCs can

[12] It also may be because both types of work practices often arise in relatively flat organizations with decentralized decision making structure and employees who are accustomed to employee empowerment can adapt to both activities.

work as an effective mechanism for information sharing and horizontal coordination.

Third, profit sharing plans and pay for performance tend to co-exist in the same organizations. 70% of firms with PSP have PFP and likewise 70% of those with PFP have PSP whereas the unconditional incidence rates are a little over 50% for both pay schemes.

Moreover, there is some indication of complementarity between shop-floor committees and pay for performance. The incidence rate of PFP conditional on the presence of SFCs is 8 percentage-points higher than its unconditional incidence rate. Since pay for performance is known to cause potentially negative effects including increased financial risk, less cooperative behavior, multi-tasking agency problems, ratchet effect, etc., it may be equally important to encourage cooperation, share expectation, and provide safeguards through employee organizations such as shop-floor committees.

Fourth, firms with benchmarking are more likely to adopt many of other HRMPs. To the extent that firms with benchmarking tend to copy HRMPs in successful firms with less regard to circumstantial differences, environmental factors may not explain the management decision to adopt new HRMPs in firms with benchmarking as much as other firms (which will be explored further in our probit analysis).

The Survey also confirms our prior expectation that as compared to CFOTs, SMOTs, PFP, and PSPs, JLMCs and SFCs are indeed older and well-established practices. Nearly 80% of JLMCs and over 60 percent of SFCs were introduced before 1985. In contrast, the majority of CFOTs, SMOTs, PFP, and PSPs were introduced after 1985, and many of them were actually in existence for less than 5 years.

When deliberating on the introduction of team organization and performance-based pay schemes in the 2000's, Japanese firms were unlikely to be considering the introduction of JLMCs and SFCs at the same time. As such, the incidence of JLMCs and SFCs can be considered

exogenous determinants of the incidence of team and contingent pay. Also keep in mind that once JLMCs and SFCs are instituted, they are rarely abolished later (Kato, 2003).

Probit Analysis: Exploring the Determinants of the HRMP Adoption

To investigate with more precision the suggestive findings from the previous section, we further specify Probit models. Let $NEWHRM_i$ be a binary variable that assumes the value of 1 if Firm i has NEWHRM, zero otherwise. As we discussed before, for NEWHRM, we consider four newer forms of HRMP; (i) CFOT; (ii) SMOT; (iii) PSP; and (iv) PFP. We begin with the following benchmark probit model:

(1) $Pr(NEWHRM_i = 1) = F(MARKET_i, JLMC_i, SFC_i, FIRM_i,$ industry dummy)

where $MARKET_i$ = a vector of variables capturing output market conditions for Firm i; $JLMC_i$ =1 if Firm i has JLMC, 0 otherwise; SFC_i =1 if Firm i has SFC, 0 otherwise; and $FIRM_i$ = a vector of variables capturing firm characteristics.

A key insight from our theoretical section is the potentially crucial role that output market conditions play in shaping the nature of HRM system. The data will enable us to use three variables to capture such output market conditions: (i) Overseas Sales Ratio; (ii) Customer Concentration (concentration of sales in major customers); and (iii) Extent of Price Changes (magnitude of price changes by competitors for major products). The Overseas Sales Ratio is designed to capture the firm's exposure to stiff global competition which may play a vital role in the adoption of certain HRM practices. For example, accordingly to Proposition 1 and 2 (see Section 2), firms are more likely to invest in communication quality when adaptation to the environment becomes more crucial for them in a highly competitive output market. To the extent to which CFOTs (Cross-functional Offline Teams) are a form of investment in communication quality, we expect that CFOTs are more prevalent in firms with higher Overseas Sales Ratios,

ceteris paribus.

As we discussed also in Section 2, high customer concentration may be a reflection of long-term buyer-supplier relationship and product architecture that makes cross-functional coordination failure more costly than usual (i.e. high β). The positive correlation between customer concentration and the adoption of cross-functional off-line teams may imply that the buyer-supplier transactions supported by long-term relationships may also tend to require tight in-house cross-functional coordination to improve the satisfaction of a small number of buyers.

Proposition 4 in the theory section suggests that in burgeoning market with technological uncertainty or cyclical market with large price fluctuations, fewer firms will adopt self-managed on-line teams for the following two reasons. First, teams which react to on-site information are less likely to possess sufficient information to find systematically optimal solutions in such disruptive environment. Therefore, the advantage of quickly utilizing on-the-spot information will be more than offset by the cost of choosing suboptimal solutions in an imperfectly coordinated manner. Second, self-managed on-line teams require a relatively stable membership and management's commitment so that members can learn their tasks, new skills, and how to work together. This stability is at risk when demand fluctuates widely and the management finds it difficult to commit to maintaining teams. As a result, more hierarchical control system may be chosen and self-managed on-line teams are less likely to be adopted.

Since a non-trivial number of firms failed to provide data on Customer Concentration and Extent of Price Changes, we begin with considering only Overseas Sales Ratio and hence maintaining the largest possible sample size, and then introduce the remaining two market condition measures. Reassuringly our key results turn out to be insensitive to the inclusion of those two additional market condition measures and hence a loss of observations (except for our results on these two additional market condition variables themselves, of course).

Another major insight from our theoretical exploration in the previous section is the potentially vital roles that long-established, more traditional employment practices play in the firm's adoption of newer forms of innovative work practices. JLMCs and SFCs are such pre-existing, long-established work practices that are by now well-known ingredients of the "Japanese management system".[13] Our theoretical exploration provides some guidance on what to expect on the interplay between such long-established practices and newer forms of innovative work practices. For instance, our theoretical exploration suggests that formal shop-floor-based communication channel facilitates the introduction of team-based instruments for information sharing and problem-solving since both are complements in the horizontal coordination system.

Moreover, JLMCs favor vertical control system by reducing labor-management communication errors, and hence firms with well-established JLMCs are less likely to adopt team-based instruments for the horizontal coordination system.

For controls, our data allow for the use of firm age; number of employees as a firm size measure; whether or not the firm is a listed firm in Japan's stock exchanges; and industry dummy variables (see Table 2 for the definitions of these variables).

After estimating the benchmark model, we augment the model with two additional sets of variables. First, Proposition 4 suggests that the scope, nature and quantity of human capital accumulated by the firm's labor force may play an important role in the firm's choice of HRM system. Unfortunately, the scope, nature and quantity of human capital are difficult to quantify and we are left with two rather ordinary variables, College Graduates (percent of labor force with college or postgraduate degrees) and Training for New Hires (days spent in formal training for new hires). Second, our theoretical exploration points to possible interplay between the choice of HRMPs and benchmarking/MBO (e.g., complementarity of PFP and MBO as discussed in the

[13] See for instance Kato (2003) for institutional details on JLMCs and SFCs.

previous section). Thus we consider Benchmarking (=1 if the firm uses benchmarking, 0 otherwise) and MBO (=1 if the firm uses MBO 0 otherwise).

We are somewhat less confident on our results from these additional specifications as compared to those from the benchmark model, for human capital formation and management strategy such as benchmarking and MBO are mostly likely to be endogenous than JLMCs and SFCs, and the results from these augmented specifications ought to be interpreted with caution.[14]

The first two columns of Table 3 present the probit estimates of Eq. (1), our benchmark model with CFOTs as the dependent variable. The first column is a parsimonious specification in which only the overseas sales ratio is used for MARKET whereas the second includes two additional variables for MARKET (and hence with a smaller sample size). The third column summarizes the probit estimates of Eq. (1) augmented by human capital formation variables and the fourth presents the probit estimates of Eq. (1) augmented by management strategy variables.

We find the following three results consistently for all specifications. First, the estimated coefficients on the Overseas Sales Ratio are positive and significant at the 5 percent level, confirming that firms exposed to stiff global competition are more likely to adopt cross-functional off-line teams. Since we control for industries, it is not mere reflection of inter-industry differences in export ratio and diffusion of teams. This result is consistent with Proposition 2 as we discussed earlier. The result is robust to the inclusion of two additional variables for MARKET in the benchmark model as well as to the use of two augmented specifications (one with human capital and the other with management strategies).

Second, the estimated coefficients on Customer Concentration are positive and significant at the 5 percent level. Firms with higher concentration of sales in top five customers is more likely to have cross-functional off-line teams, suggesting that the buyer-supplier transactions

[14] Unfortunately, no reliable instrument is available in our dataset.

supported by long-term relationships may also tend to require tight in-house cross-functional coordination to improve the satisfaction of a small number of buyers.

Third, the estimated coefficients on SFC are positive and significant at the 1 percent level, confirming our expectation that formal shop-floor-based communication channels facilitate the introduction of team-based instruments for information sharing and problem-solving. As such the result is consistent with what our theoretical exploration suggests about complementary practices in the horizontal coordination system.

The estimated coefficients on the human capital variables are of expected sign yet not statistically significant even at the 10 percent level. As we argued earlier, we suspect the lack of significance may be due to the imprecise measure of the scope, nature and quantity of human capital accumulated by the firm's labor force. Finally, we find no statistically significant association between management strategies (benchmarking/MBO) and the use of CFOTs.

Table 4 reports the probit estimates with SMOT as the dependent variable. The most robust results on the incidence of the SMOT are the statistically significant estimated coefficients on JLMCs and SFCs. For all specifications, the estimated coefficients on JLMCs are negative and statistically significant at the 5 percent level, confirming our expectation that JLMCs favor vertical control system by reducing labor-management communication errors, and hence make firms less likely to adopt SMOT. Likewise, to be consistent with our theoretical prediction that SMOTs and SFCs are complements and facilitate horizontal coordination, the estimated coefficients on SFCs are positive and statistically significant (the significance level varies from 1 percent to 10 percent).

Regarding the MARKET variables, we find that the estimated coefficients on Range of Price Changes are negative and significant at the 5 percent level for two out of the three specifications. As we discussed earlier, price volatility reflects the variance of the market

environment, which will be better monitored by the management than by lower-level managers or employees. The negative coefficients on Range of Price Changes are congruent with our theoretical exploration (Proposition 4): vertical control dominates horizontal coordination when systematic information is sufficiently important.

Our human capital variables appear to do slightly better here than in the case of CFOTs. Thus, the estimated coefficient on Training for New Hires is positive and significant at the 10 percent level, pointing to complementarity between training and SMOTs. The management practice variables (benchmarking/MBO) are again found to be not significantly associated with the incidence of SMOTs.

Tables 5 and 6 report the probit estimates with PFP, and PSP as the dependent variable respectively. Table 5 shows that the estimated coefficient on MBO is positive and highly significant (significant at the 1 percent level), supporting our theoretical discussion that MBO is a reasonable complement for PFP since MBO involves elaborate evaluation process of employees' achievement of their individual goals. Furthermore, even if some objective performance measures are available without cost, MBO may be necessary for the following reason. It is well-known that PFP is subject to multi-tasking agency problems (Holmstrom and Milgrom 1991). Namely, employees working on multiple tasks may distort their allocation of efforts when facing strong incentives. One solution to this problem is to use additionally more comprehensive subjective evaluation.

In addition, the estimated coefficients on SFCs are positive and statistically significant at the 5 percent level for two out of the four specifications, suggesting a possible complementarity between SFCs and PFP. As we discussed in the theory section and confirmed empirically above, in the Japanese context, PFP is often used along with MBO to mitigate the free-rider problem of the horizontal coordination system with group incentive. As confirmed empirically earlier, SFCs

facilitate the horizontal coordination system and hence it is not surprising that we find the positive coefficients on SFCs.

Table 6 shows very few significant results on the incidence of PSPs. The only consistently significant estimates are obtained for Benchmarking, suggesting that firms with benchmarking are more likely to use PSPs. It is somewhat surprising that SFCs does not have a significant positive effect on the adoption of group incentives given the theoretical implication that group incentives are complementary with the horizontal coordination system, which often appear in the firms with SFCs according to our earlier probit estimates. Possible explanation for this puzzle is as follows: the bulk of regular pay for Japanese workers is determined by their skill grades and merit rating by their supervisors in a majority of large Japanese firms (see Koike, 2005 for example).[15] Promotion to a higher skill grade does depend on seniority yet it is hardly automatic. An active and successful participation in collective problem solving activities is a key criterion for promotion to a higher skill grade and hence a higher regular pay. In short, the typical regular pay system for Japanese workers already contains an element of group incentive, and perhaps need for the introduction of a formal and separate group incentive pay (such as gainsharing) is less acute in Japan.

Cluster Analysis: Identifying Systems of HRMPs

Finally, to explore further a key message of our theoretical exploration that complementary elements of a HRM system are introduced together to maximize the benefits of each system, we conduct cluster analysis to identify the most common combinations of HRMPs. Using Ward' method, we sort firms into four groups with distinct sets of work organization and pay

[15] A share of firms with a skill grade system, however, seems to be declining recently according to numerous business reports.

schemes.[16] In the clustering algorithm, distances are based only on the proportions of employees (measured by five-point scale) in four newer HRMPs: cross-functional off-line teams, self-managed teams, pay-for-performance, and profit sharing plans. Namely, the characteristics of firm *i* takes the vector $(x^i_{CFOT}, x^i_{SMOT}, x^i_{PFP}, x^i_{PSP})$ where x^i_k (k = CFOT, SMOT, PFP, PSP) can take any integer between 0 and 4. Each variable has 0 for "not adopted," 1 for "less than 25% of employees participate," 2 for "25% or more but less than 50% of employees participate," 3 for "50% or more but less than 75% of employees participate," or 4 for "75% or more employees participate."

Table 7 shows the results. System 1 is the traditional HRM and work system and does not employ any of the team organizations or new pay schemes to a great extent (each variable is either 0 or 1 for most firms). System 2 uses contingent pay schemes to a great extent but without introducing team organizations to a great extent. System 3 widely adopts cross-functional off-line teams but not self-managed on-line teams to any great extent. Finally, System 4 adopts both types of teams and also uses profit sharing plans and/or pay for performance. To relate the results with our theoretical model, we interpret System 1 and 2 as the vertical control systems, System 3 as the hybrid coordination system, and System 4 as the horizontal coordination system.

Note that all firms in System 3 have joint labor-management committees. This result is consistent with our interpretation that system 3 is the hybrid coordination system. If management maintains a substantial level of formal authority in many decision problems but employ teams to improve information acquisition and adaptation capability, the firm will introduce off-line teams which do not require substantial changes in production procedure and training programs. In such organizations, JLMCs are essential mechanism that management uses to convey their mission,

[16] Ward' method attempts to minimize the sum of squares of any two (hypothetical) clusters that can be formed at each step of tree clustering algorithm. In general, this method is regarded as very efficient.

strategy, and long-term plans to their employees who are somewhat empowered to adjust their implementation in order to adapt to changing environment.

Another noteworthy finding is that all firms in System 4 have shop-floor committees. As theory suggests, the horizontal coordination system should have a flat structure with least layers in the organization and provide teams with highest autonomy. Such organizations with highly self-directed teams may not necessarily require JLMCs since management has to commit to the empowerment strategy. Rather, the horizontal coordination system will require close and frequent communication among work units which may necessitate formal structure such as SFCs.

The rest of the Table provides rather straightforward support for our theoretical explorations. First, the number of layers of organization is 6.16 on average in System 4 (the horizontal coordination system), the lowest among the four systems. Second, a higher percentage of firms in System 4 choose multi-divisional form (or M-form) rather than functional form (or unitary form/U-form). Third, both CFOTs and SMOTs are more autonomous in System 4 than in other systems except that SMOTs in System 1 are more autonomous than those in System 4.[17] Since none of System 1 firms adopt SMOTs to a great extent and only 20% of them use them only to a limited extent, comparing System 1 to System 4 is not very meaningful. The levels of organizations at which various decisions are made are also the lowest in System 4.[18] As a result,

[17] We asked the question, "How much do teams receive directions from middle managers (supervisors or those who evaluate the performance of teams) in deciding on the work process within the teams?", and the respondents were requested to answer in the five-point Likert scale, "1: Teams *rarely* receive directions from middle managers," "2: Teams *very occasionally* receive directions from middle managers," "3: Teams *sometimes* receive directions from middle managers," "4: Teams often receive directions from middle managers," and "5: Middle managers determine the work process."

[18] We asked "Who has the real authority over the following decision problems among (1) president, (2) executives, division managers, or plant managers, (3) general managers, or foreman, (4) section chief, group managers, line managers (5) line workers?: ① development of new businesses, ② investment and procurement of 5 million yen, ③ selection of suppliers for primary material, ④ price changes of primary products and services, ⑤ dealing with claims from buyers such as returns of defect products, ⑥ determination

decision making is fastest in System 4.[19]Other findings are: (1) System 4 firms are most likely to adopt differentiation strategy and, compared with System 3, less likely to adopt cost leadership strategy; (2) System 4 firms offer more training on average than firms in any other system.

IV. Concluding remarks

This paper has explored theoretically and empirically a potentially important yet often-neglected interplay between task coordination within the organization and the structure of organization and HRMP bundling. In so doing, we have also provided fresh insights on linkage between the firm's technological and output market characteristics and its choice of HRMP system, for the firm's technological and market conditions affect how the firm coordinates various tasks within the organization. Furthermore, such technological and output market conditions also influence the firm's decision about its hiring and training policy and its market strategy. In sum, we have explored complementarity among strategies, human capital, and organizational choices as suggested by Bresnahan, Brynjolfsson and Hitt (2002).

Our model built on the works by Dessein and Santos (2006) and Aoki (1986) has two important implications: (1) as the value of adaptation versus coordination increases, the firm is more likely to rely on horizontal coordination rather than vertical control and utilize teams and invest in horizontal communication channels; (2) as the technological and market environment becomes more disruptive, the firm is more likely to adopt a vertical control system and hence

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of work pace and schedule in primary operations, ⑦ determination of task allocation and work methods."

[19] We asked "How long does it normally take to make the following types of decisions: ① after getting proposals for new products and services until starting them as formal business projects, ② after getting requests for investment and procurement of 5 million yen until approving or disapproving them, ③ after receiving attractive offers from potential suppliers for primary material until deciding on switching suppliers, ④ after knowing changes in price of primary inputs or price of competitors' products until revising your own product prices when necessary, ⑤ after receiving the report of defect products until taking necessary measures such as recall and refund: choices are (1) less than one week, (2) one week or longer and less than one month, (3) one month or longer and less than three months, (4) three months or longer and less than six months (5) six months or longer.

develop labor-management communication channels. A rise in the value of coordination may or may not induce more use of teams and horizontal coordination.

Guided by the theoretical exploration, we have conducted an empirical analysis of new data from Japan, which provide for the first time data on newer forms of organizational innovation, such as self-managed online teams and cross-functional offline teams as well as pay for performance in addition to data on longer-established practices including joint labor-management committees and shopfloor committees.

One novel finding is that the adoption of both self-managed online teams and cross-functional offline teams usually arises in firms with shop-floor committees while the introduction of cross-functional offline teams alone often takes place in firms with labor-management committees. This finding is consistent with the view that: (1) organizations where activities or decisions are coordinated differently tend to adopt different work organization; and (2) communication channels such as labor-management committees and shop-floor committees play an important role in intra-firm coordination.

We have also confirmed empirical patterns that are consistent with the implications from our theory about the relationships between market structure/environment and the adoption of team organizations. Specifically, firms in more competitive markets are more likely to adopt both types of teams while firms facing more erratic price movement tend not to adopt self-managed online teams.

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Table 1 Proportion of firms with each HRMP

		%firms with							
		CFOT	SMOT	PFP	PSP	JLMC	SFC	Bench-marking	MBO
Among all firms		54%	31%	53%	52%	60%	41%	15%	65%
Among all firms with	CFOT		*** 42%	53%	51%	* 63%	*** 51%	15%	67%
	SMOT	*** 74%		* 58%	57%	57%	*** 51%	14%	62%
	PFP	56%	* 35%		*** 70%	** 64%	*** 48%	*** 19%	*** 72%
	PSP	55%	34%	*** 70%		* 63%	* 45%	* 17%	*** 69%
	JLMC	* 58%	30%	** 56%	* 55%		*** 52%	*** 18%	*** 70%
	SFC	*** 68%	*** 39%	*** 61%	* 56%	*** 76%		*** 20%	** 70%
	Bench-marking	58%	31%	*** 69%	* 62%	*** 75%	*** 58%		*** 83%
	MBO	58%	30%	*** 59%	*** 56%	*** 65%	** 45%	*** 19%	

Note: We conducted the likelihood ratio test to investigate the null hypothesis that each pair of practices is employed independently from each other. *, ** and *** indicate that the null hypothesis is rejected at the significance levels of 10%, 5%, and 1% respectively.

Table 2 List of Independent Variables

Variables	Measures	Values/units
Listed	The firm is listed in one of TSE, OSE, or NSE (stock exchanges in Tokyo, Osaka, and Nagoya)	1 or 0
Number of Employees	Number of regular employees on a non-consolidated basis	in thousands
Overseas Sales Ratio	Level of overseas sales ratio rated on the 5-point scale: 1 for 0%, 2 for more than 0% but less than 10%, 3 for 10% or more and less than 30%, 4 for 30% or more and less than 50%, and 5 for 50% or more	1,2,3,4,5
Customer Concentration	Share of sales to five major customers in total sales rated on the 5-point scale: 1 for less than 10%, 2 for 10% or more and less than 30%, 3 for 30% or more and less than 50%, 4 for 50% or more and less than 80%, and 5 for 80% or more	1,2,3.4,5
Extent of Price Changes	Typical changes of market price or prices set by major competitors for the firm's core products or services rated on the 5-point scale: 1 for within 3%, 2 for within 5%, 3 for within 10%, 4 for within 20%, 5 for more than 20%	1,2,3,4,5
College Graduates	Share of employees with college or postgraduate degrees in total regular workforce	%
Training for New Hires	Number of days spent in formal training for new hires	days
Layers of Organization	Number of layers of organization from president to front-line workers in the firm's core business	positive integers
M-form Organization	The firm is organized not by functions but by production lines, customer types, or regions	1 or 0
Autonomy of CFOTs	Degrees to which *cross-functional offline* teams receive directions from middle managers in deciding on the work process rated on a 5-point scale: 1for *rarely*, 2 for *very occasionally*, 3 for *sometimes*, 4 for *often*, and 5 for *always*.	1,2,3,4,5
Autonomy of SMOTs	Degrees to which *self-managed online* teams receive directions from middle managers in deciding on the work process rated on a 5-point scale: 1for *rarely*, 2 for *very occasionally*, 3 for *sometimes*, 4 for *often*, and 5 for *always*.	1,2,3,4,5
Decision Making Speed	Average length of time period the firm normally takes to make five types of decisions rated on a 5-point scale: 1 for less than one week, 2 for one week or longer and less than one month, 3 for one month or longer and less than three months, 4 for three months or longer and less than six months, and 5 for six months or longer	1,2,3,4,5
Decision Making Level	Average level of people who has the real authority over 7 decision problems rated on a 5-point scale: 1 for president, 2 for executives, division managers or plant managers, 3 for general managers or foreman, 4 for section chief, group managers, or line managers, and 5 for line workers	1,2,3,4,5
Differentiation Strategy	Degree to which the firm sees its strategy as classified as differentiation strategy rated on a 5-point scale: 1 for *strongly disagree*, 2 for *disagree*, 3 for *somewhat agree*, 4 for *agree*, 5 for *strongly agree*	1,2,3,4,5
Cost Leadership Strategy	Degree to which the firm sees its strategy as classified as cost leadership strategy rated on a 5-point scale: 1 for *strongly disagree*, 2 for *disagree*, 3 for *somewhat agree*, 4 for *agree*, 5 for *strongly agree*	1,2,3,4,5

Table3　Probit Estimates of the Incidence of Cross-functional Off-line Teams

Dependent Variable: CFOT

Variables	(1)	(2)	(3)	(4)
Overseas Sales Ratio	0.164**	0.188**	0.199**	0.181**
	(0.081)	(0.087)	(0.096)	(0.089)
Customer Concentration		0.137**	0.184***	0.145**
		(0.058)	(0.064)	(0.060)
Range of Price Changes		-0.088	0.027	-0.118
		(0.085)	(0.095)	(0.087)
JLMCs	-0.145	-0.068	0.049	-0.024
	(0.161)	(0.178)	(0.196)	(0.181)
SFCs	0.569***	0.612***	0.623***	0.632***
	(0.156)	(0.171)	(0.191)	(0.178)
College Graduates			0.005	
			(0.004)	
Training for New Hires			0.000	
			(0.004)	
Benchmarking				-0.099
				(0.091)
MBO				0.062
				(0.082)
Listed	-0.028	-0.027	-0.070	-0.026
	(0.187)	(0.205)	(0.248)	(0.206)
Number of Employees	0.002	-0.002	0.027	0.000
	(0.020)	(0.021)	(0.032)	(0.023)
Firm Age	0.005	0.008	0.006	0.009
	(0.006)	(0.006)	(0.007)	(0.006)
Industry Dummies	Yes	Yes	Yes	Yes
Prob > chi2	0.0006	0.0039	0.0026	0.0078
Pseudo R-squared	0.0758	0.0932	0.1163	0.0991
# of Observations	332	284	234	279

Notes:

Robust standard errors are in the parentheses.

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 4 Probit Estimates of the Incidence of Self-managed On-line Teams

Dependent Variable: SMOT

Variables	(1)	(2)	(3)	(4)
Overseas sales Ratio	0.092	0.070	0.153*	0.088
	(0.076)	(0.080)	(0.090)	(0.083)
Customer Concentration		0.016	0.045	0.019
		(0.061)	(0.066)	(0.064)
Range of Price Changes		-0.183**	-0.090	-0.178**
		(0.086)	(0.098)	(0.089)
JLMCs	-0.404**	-0.399**	-0.484**	-0.401**
	(0.170)	(0.189)	(0.212)	(0.193)
SFCs	0.373**	0.452***	0.326*	0.402**
	(0.162)	(0.173)	(0.196)	(0.182)
College Graduates			0.006	
			(0.004)	
Training for New Hires			0.006*	
			(0.003)	
Benchmarking				-0.030
				(0.092)
MBO				-0.077
				(0.089)
Listed	-0.392*	-0.337	-0.378	-0.307
	(0.207)	(0.216)	(0.264)	(0.220)
Number of Employees	0.041**	0.030	0.020	0.036
	(0.020)	(0.021)	(0.037)	(0.022)
Firm Age	-0.004	-0.002	-0.005	0.000
	(0.006)	(0.006)	(0.007)	(0.007)
Industry Dummies	Yes	Yes	Yes	Yes
Prob > chi2	0.0015	0.0083	0.1458	0.0253
Pseudo R-squared	0.081	0.0825	0.0851	0.0847
# of Observations	327	280	224	275

Notes:

Robust standard errors are in the parentheses.

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 5 Probit Estimates of the Incidence of Pay for Performance

Dependent Variable: PFP

Variables	(1)	(2)	(3)	(4)
Overseas sales Ratio	0.034	0.046	0.101	-0.007
	(0.078)	(0.083)	(0.092)	(0.085)
Customer Concentration		-0.082	-0.100	-0.079
		(0.060)	(0.065)	(0.061)
Range of Price Changes		0.002	-0.004	0.015
		(0.082)	(0.093)	(0.086)
JLMCs	0.101	0.204	0.132	0.186
	(0.169)	(0.187)	(0.205)	(0.191)
SFCs	0.323**	0.376**	0.236	0.271
	(0.158)	(0.171)	(0.190)	(0.179)
College Graduates			0.000	
			(0.004)	
Training for New Hires			0.006	
			(0.003)	
Benchmarking				0.110
				(0.091)
MBO				0.229***
				(0.085)
Listed	-0.216	-0.308	-0.461*	-0.263
	(0.209)	(0.221)	(0.262)	(0.224)
Number of Employees	0.224***	0.194**	0.239***	0.145**
	(0.085)	(0.077)	(0.087)	(0.075)
Firm Age	-0.002	-0.004	-0.006	-0.007
	(0.006)	(0.006)	(0.007)	(0.006)
Industry Dummies	Yes	Yes	Yes	Yes
Prob > chi2	0.0067	0.0066	0.02	0.0006
Pseudo R-squared	0.0757	0.0916	0.0962	0.1200
# of Observations	328	281	232	276

Notes:

Robust standard errors are in the parentheses.

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 6 Probit Estimates of the Incidence of Profit Sharing Plans

Dependent Variable: PSP

Variables	(1)	(2)	(3)	(4)
Overseas sales Ratio	0.136*	0.097	0.140	0.063
	(0.075)	(0.079)	(0.089)	(0.081)
Customer Concentration		-0.025	0.001	-0.034
		(0.058)	(0.064)	(0.059)
Range of Price Changes		-0.051	0.042	-0.029
		(0.082)	(0.092)	(0.085)
JLMCs	0.051	0.033	-0.046	0.020
	(0.162)	(0.180)	(0.200)	(0.184)
SFCs	0.156	0.161	0.043	0.053
	(0.153)	(0.165)	(0.186)	(0.173)
College Graduates			0.002	
			(0.004)	
Training for New Hires			0.000	
			(0.003)	
Benchmarking				0.184**
				(0.087)
MBO				0.052
				(0.082)
Listed	0.068	-0.043	-0.168	-0.062
	(0.181)	(0.196)	(0.235)	(0.199)
Number of Employees	0.010	-0.017	0.018	0.032
	(0.019)	(0.020)	(0.037)	(0.021)
Firm Age	0.006	0.008	0.006	0.006
	(0.005)	(0.006)	(0.007)	(0.006)
Industry Dummies	Yes	Yes	Yes	Yes
Prob > chi2	0.0732	0.1767	0.4713	0.0933
Pseudo R-squared	0.0474	0.0501	0.0529	0.0633
# of Observations	331	283	234	278

Notes:

Robust standard errors are in the parentheses.

*, ** and *** indicate significance levels of 10%, 5%, and 1% respectively.

Table 7 Systems of HRM Practices

Clusters	System 1		System 2		System 3		System 4	
	Little use of teams and incentive pay		Wide use of incentive pay without teams		Wide use of cross-functional offline teams		Wide use of all kinds of teams and incentive pay	
# of observations	149		101		55		63	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Participation in CFOTs (5 pt scale bet. 0 & 4)	0.49	0.63	0.40	0.53	3.29	0.85	1.73	1.57
Participation in SMOTs (5 pt scale bet. 0 & 4)	0.21	0.48	0.19	0.45	0.14	0.35	3.35	0.85
Participation in PSPs (5 pt scale bet. 0 & 4)	0.20	0.58	3.86	0.37	1.64	1.85	2.29	1.87
Participation in PFP (5 pt scale bet. 0 & 4)	0.96	1.53	2.76	1.79	1.49	1.79	2.44	1.83
Listed	0.21	0.41	0.26	0.44	0.27	0.45	0.13	0.34
Number of Employees	728.6	1550.5	915.6	1770.2	1963.5	5625.4	1383.6	5963.5
JLMCs	0.42	0.50	0.39	0.49	1.00	0.00	0.68	0.47
SFCs	0.17	0.38	0.18	0.39	0.14	0.35	1.00	0.00
Layers of Organization	6.43	1.35	6.35	1.62	6.29	1.84	6.16	1.71
M-form Organization (yes: 1, no: 0)	0.36	0.48	0.32	0.47	0.36	0.49	0.43	0.50
Autonomy of CFOTs (5 pt scale bet. 1 & 5)	2.49	1.05	2.67	1.22	2.56	0.86	2.74	0.94
Autonomy of SMOTs (5 pt scale bet. 1 & 5)	2.88	1.05	2.39	0.92	2.14	1.07	2.44	0.80
Decision Making Speed (1:fast-5:slow)	2.57	0.70	2.50	0.74	2.60	0.66	2.36	0.58
Decision Making Level (1:low-5:high)	2.55	0.55	2.58	0.53	2.62	0.49	2.50	0.60
Differentiation Strategy (1: absolutely not, 7: absolutely yes)	3.20	1.06	3.47	0.91	3.32	1.09	3.53	0.88
Cost Leadership Strategy (1: absolutely not, 7: absolutely yes)	3.01	0.91	3.18	0.87	3.46	0.91	3.22	0.86
Days of Formal Training for New Employess	20.3	27.7	18.2	23.5	20.0	37.2	27.7	30.4

Figure 1. Relative Efficiency among Three Organizations: the Effect of Adaptation Loss Parameter α

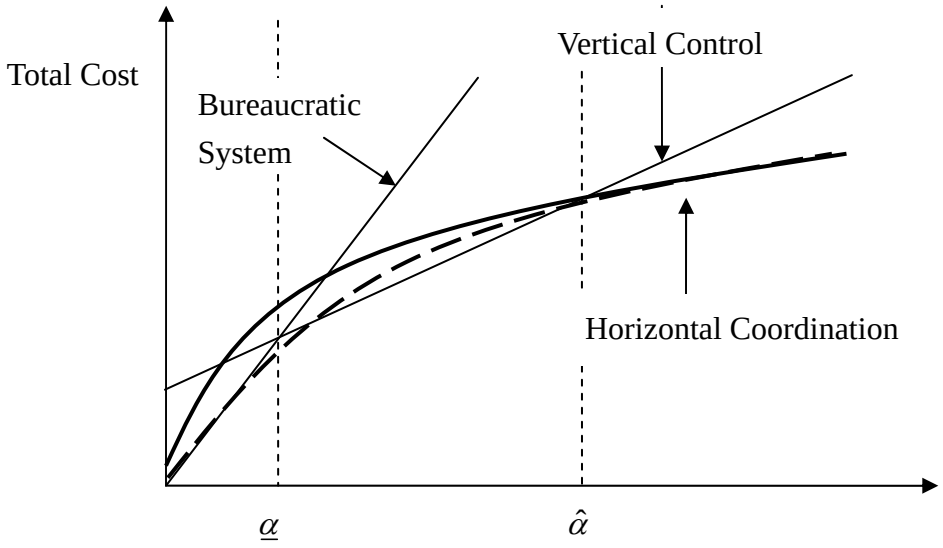
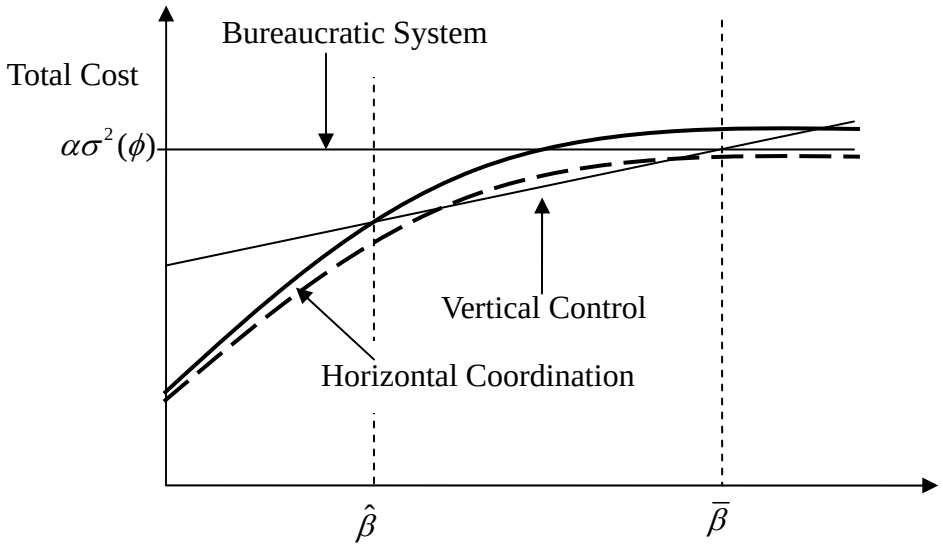


Figure 2. Relative Efficiency among Three Organizations: the Effect of Adaptation Loss Parameter β



Appendix

Proof of Proposition 1:

Let $\Pi(t, p \mid \alpha, \sigma^2(\phi), \tau) = -\sum_{i=1}^{n} \underset{\theta}{E}[C^i(a^{1i}, a^{2i}, \ldots, a^{ni}, T, p) \mid \phi]$

$= -n\dfrac{\alpha\beta(n-t)(1-p)}{\alpha+\beta(n-t)(1-p)}\sigma^2(\phi) - nh(t, p, \tau)$. Then,

$\dfrac{\partial^2\Pi(t, p \mid \alpha, \sigma^2(\phi), \tau)}{\partial t \partial z} \geq 0$ and $\dfrac{\partial^2\Pi(t, p \mid \alpha, \sigma^2(\phi), \tau)}{\partial t \partial z} \geq 0$ for any $z \in \{\alpha, \sigma^2(\phi), \tau\}$. Hence, if

$\dfrac{\partial^2\Pi(t, p \mid \alpha, \sigma^2(\phi), \tau)}{\partial t \partial p} \geq 0$, the result is immediate from the comparative statics analysis of supermodular functions. The last inequality, however, does not hold in general. In order to apply the theory of supermodular optimization to this case, we define $\pi(t, \hat{p}) = \max_{p \geq \hat{p}} \Pi(t, p)$.

Let $p^*(t) = \arg\max_{p} \Pi(t, p)$, the optimal communication quality given the degree of task bundling in teams *t*. From assumption 2, $p^*(t)$ is uniquely determined and the highest optimal value of $\hat{p}$ is always equal to $p^*(t)$. Therefore, from the theory of supermodular optimization, in order to obtain the monotone comparative statics result, it suffices to show that

$$\frac{\partial\pi(\overline{t}, \hat{p})}{\partial\hat{p}} - \frac{\partial\pi(\underline{t}, \hat{p})}{\partial\hat{p}} \geq 0 \qquad (1.1)$$

for any $\overline{t} > \underline{t} \in T$, namely *t* and $\hat{p}$ have non-decreasing differences with π.

First, we need to show $p^*(\overline{t}) > p^*(\underline{t})$. Given assumption 3, the supermodularity of $-\dfrac{h(t, p, \tau)}{n-t}$,

$$
\begin{aligned}
0 &= \frac{\partial \Pi}{\partial p}(\underline{t}, p^*(\underline{t})) \\
&= n(n-\underline{t})[\frac{\alpha^2\beta}{\{\alpha+\beta(n-\underline{t})(1-p^*(\underline{t}))\}^2}\sigma^2(\phi) - \frac{h_p(\underline{t}, p^*(\underline{t}), \tau)}{n-\underline{t}}] \\
&< n(n-\underline{t})[\frac{\alpha^2\beta}{\{\alpha+\beta(n-\underline{t})(1-p^*(\underline{t}))\}^2}\sigma^2(\phi) - \frac{h_p(\overline{t}, p^*(\underline{t}), \tau)}{n-\overline{t}}] \\
&= n(\frac{n-\underline{t}}{n-\overline{t}})[\frac{\alpha^2\beta(n-\overline{t})}{\{\alpha+\beta(n-\underline{t})(1-p^*(\underline{t}))\}^2}\sigma^2(\phi) - h_p(\overline{t}, p^*(\underline{t}), \tau)] \\
&< n(\frac{n-\underline{t}}{n-\overline{t}})[\frac{\alpha^2\beta(n-\overline{t})}{\{\alpha+\beta(n-\overline{t})(1-p^*(\underline{t}))\}^2}\sigma^2(\phi) - h_p(\overline{t}, p^*(\underline{t}), \tau)] \\
&= (\frac{n-\underline{t}}{n-\overline{t}})\frac{\partial \Pi}{\partial p}(\overline{t}, p^*(\underline{t})),
\end{aligned}
$$

and $\frac{\partial \Pi}{\partial p}(\overline{t}, p^*(\underline{t})) > 0$. By assumption 2, the strict inequality of $\Pi(t, p)$, $p^*(\overline{t}) > p^*(\underline{t})$.

We prove the inequality (1.1) in the following three cases:

(1) When $p^*(\overline{t}) > p^*(\underline{t}) > \hat{p}$, $\frac{\partial \pi(\overline{t}, \hat{p})}{\partial \hat{p}} - \frac{\partial \pi(\underline{t}, \hat{p})}{\partial \hat{p}} = \frac{\partial}{\partial \hat{p}}(\Pi(\overline{t}, p^*(\overline{t})) - \Pi(\underline{t}, p^*(\underline{t}))) = 0$;

(2) When $p^*(\overline{t}) > \hat{p} > p^*(\underline{t})$,

$$\frac{\partial \pi(\overline{t}, \hat{p})}{\partial \hat{p}} - \frac{\partial \pi(\underline{t}, \hat{p})}{\partial \hat{p}} = \frac{\partial}{\partial \hat{p}}(\Pi(\overline{t}, p^*(\overline{t})) - \Pi(\underline{t}, \hat{p})) = -\frac{\partial \Pi(\underline{t}, \hat{p})}{\partial \hat{p}} > 0$$ by assumption 2.

(3) When $\hat{p} > p^*(\overline{t}) > p^*(\underline{t})$,

$$
\begin{aligned}
&\frac{\partial \pi(\overline{t}, \hat{p})}{\partial \hat{p}} - \frac{\partial \pi(\underline{t}, \hat{p})}{\partial \hat{p}} = \frac{\partial}{\partial \hat{p}}(\Pi(\overline{t}, \hat{p}) - \Pi(\underline{t}, \hat{p})) \\
&= n\frac{\alpha^2\beta(n-\overline{t})}{\{\alpha+\beta(n-\overline{t})(1-\hat{p})\}^2}\sigma^2(\phi) - n\frac{\alpha^2\beta(n-\underline{t})}{\{\alpha+\beta(n-\underline{t})(1-\hat{p})\}^2}\sigma^2(\phi) \\
&- nh_p(\overline{t}, \hat{p}, \tau) + nh_p(\underline{t}, \hat{p}, \tau)
\end{aligned}
$$

$$> -n\frac{\alpha^2\beta(\bar{t}-\underline{t})}{\{\alpha+\beta(n-\bar{t})(1-\hat{p})\}^2}\sigma^2(\phi)+n(n-\underline{t})[\frac{h_p(\underline{t},\hat{p},\tau)}{n-\underline{t}}-\frac{n-\bar{t}}{n-\underline{t}}\frac{h_p(\bar{t},\hat{p},\tau)}{n-\bar{t}}]$$

$$> -n\frac{\bar{t}-\underline{t}}{n-\bar{t}}\frac{\alpha^2\beta(n-\bar{t})}{\{\alpha+\beta(n-\bar{t})(1-\hat{p})\}^2}\sigma^2(\phi)+n(n-\underline{t})(1-\frac{n-\bar{t}}{n-\underline{t}})\frac{h_p(\bar{t},\hat{p},\tau)}{n-\bar{t}}$$

$$= -n\frac{\bar{t}-\underline{t}}{n-\bar{t}}[\frac{\alpha^2\beta(n-\bar{t})}{\{\alpha+\beta(n-\bar{t})(1-\hat{p})\}^2}\sigma^2(\phi)-h_p(\bar{t},\hat{p},\tau)]$$

$$= -n\frac{\bar{t}-\underline{t}}{n-\bar{t}}\Pi_p(\bar{t},\hat{p})>0$$

The last inequality is from $\hat{p} > p^*(\bar{t})$. This concludes the proof. ∎

Proof of Proposition 2: The right-hand side of the inequality(1.8), the adaptation and coordination losses for the horizontal coordination system, approaches to $\min_{t,p}\beta(n-t)(1-p)\sigma^2(\phi)+h(t,p,\tau)+d$ as α increases to the infinity. Since the left-hand side of the inequality is an increasing linear function of α, the latter always eventually exceeds the former. Let $\hat{\alpha}$ be the greatest intersection of the cost functions of the two systems.∎

Proof of Proposition 3: The right-hand side of the inequality(1.8), the adaptation and coordination losses for the horizontal coordination system, approaches to d as β decreases to zero, while the left-hand side of the inequality is a linear function of β and is $\alpha(\sigma^2(\eta)+\sigma_v^2)$ for $\beta = 0$. If $d < \alpha(\sigma^2(\eta)+\sigma_v^2)$, the horizontal coordination system always becomes more efficient for sufficiently small β. Let $\hat{\beta}$ be the lowest intersection of the cost functions of the two systems.

Proof of Proposition 5: When $t^{**} = 1$ and $p^{**} = 0$ are substituted in, the expression (1.9) becomes smaller than the adaptation and coordination losses in the vertical control system.

Proof of Proposition 6: Since raising t and p has a smaller impact on $\frac{\alpha(n-t)(1-p)}{\alpha/\beta+(n-t)(1-p)}\sigma^2(\eta)$ than $\frac{\alpha(n-t)(1-p)}{\alpha/\beta+(n-t)(1-p)}\sigma^2(\phi)$, the result is immediate.∎