Abstract

Team-based work organizations typically involve a bundle of human resource and work practices which help workers to acquire broad skills and share information, and which shift more responsibilities from managers to lower-level workers. The existing literature has not explained why workers could be better motivated under these practices, nor has it answered why firms delegate considerable decision rights to workers given that this may increase workers’ bargaining power. We consider the incentive aspects of “multiskilling” and compare them with traditional specialization. The key is that, with information-sharing by multiskilled workers, their investments in firm-specific human capital become strategic substitutes. Because of this, unless specialization offers a substantial technological advantage, (1) workers’ incentives to invest in firm-specific human capital tend to be stronger; (2) the optimal level of delegation is typically higher; and (3) firms’ ex post payoffs tend to be higher, with “multiskilling” than with specialization.

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1 Introduction

The introduction of the team-based flexible production system substantially enhanced productivity and product quality at some progressive plants.\(^1\) Most of these plants adopted a bundle of human resource and work practices including contingent compensation, job rotation, extensive training to develop multiskilled workers, and worker involvement for quality improvement. The common features seen in those workplaces are emphases on development of multiskilled workers, sharing of information, and delegation of responsibilities to teams. The past studies have shown that these innovative practices affect performance not individually, but collectively as interrelated elements of an internally consistent work system. Thus, these systems contribute most to productivity and quality improvement when they are introduced all together in a well-coordinated fashion (See Macduffie [24], Ichniowski et al. [14], and Black and Lynch [5]).\(^2\)

A formal framework which explains these phenomena has been developed by Milgrom and Roberts [25] and [26]. Their theories of supermodular optimization have been quite successful in explaining paradigm shifts where a wide variety of organizational features covary mono-

\(^1\)Osterman [27] finds that about the 35% of the U.S. private sector establishments with 50 or more employees made substantial use of flexible work organization in 1992. See Macduffie [24], Arthur [3], Boning et al. [6] and Dunlop and Weil [8] for some empirical evidence of productivity improvement.

\(^2\)The other motivation of our work is the comparison of the Japanese and American human resource management practices. Training for multiskilled workers and job rotation, which are among the core elements of flexible production system, were already observed in many Japanese steel plants in the late 1950s and 1960s and presumably diffused to many industries in the post-war period. The emphasis on broad skills and decentralization of responsibilities in the Japanese firms have been noted by many authors including Cole [7], Aoki [2], Koike [20] and [21], Lincoln and Kalleberg [23] and Kagono et al. [18].
tonically. For example, Milgrom and Roberts [26] show that a fall in the costs of flexible manufacturing equipment or of computer-aided design equipment will lead to a systematic response of many features including (1) more frequent product and process innovations, (2) higher levels of training, (3) greater autonomy for workers and increased horizontal communication, (4) more cross training, use of teams, pay-for-skills, etc. Incentive effects of teamwork or tasksharing have also been extensively analyzed by Holmstrom and Milgrom [12] and Itoh [15], [16], [17]. Itoh shows that teamwork is more likely to be optimal when (1) cost substitution does not exist among an agent’s efforts allocated to multiple tasks; (2) complementarity exists among agents’ efforts allocated to the same task; or (3) stochastic correlation among task-specific performance measures is low.

This work aims at offering an alternative framework to analyze the incentive effects of team-based work organization. It studies how broadening the workers’ skills affect their bargaining power and their incentive to acquire skills, and how the design of skill development and allocation of decision authority interact with each other in the profit-maximizing firm. We adopt the incomplete contracting perspective and assume ex post wage negotiation in the presence of contractible decision authority and unverifiable firm-specific human capital.\textsuperscript{3} Our work is closely related to that of Stole and Zwiebel [32], which has studied how organizational design and technology choice by a firm with no binding employment contracts differ from those of a neo-classical firm with no ex post wage bargaining. We have demonstrated that we can further enrich this line of research by endogenizing skill formation and allocation of decision rights.

\textsuperscript{3}Therefore, our formulation is similar to that of Grossman and Hart [10] and Hart and Moore [11], but our attention is focused on allocation of decision authority instead of ownership.
We show that the organizational form which relies on multiskilled workers and their sharing of information, which is called “M-organization”, significantly changes the workers’ bargaining power and their incentive to acquire firm-specific skills. All of the main results in the paper come from the implication that the workers’ acquired skills are more likely to be substitutes in the M-organization. It will be easily understood that, with this substitutability, the workers’ bargaining power relative to the owner-manager is weaker in the M-organization than in one with a specialized work force if other things are equal. It will be less intuitive, however, that the workers are more motivated to invest in skills in the M-organization. This is because, in the M-organization, increasing a worker’s investment in firm-specific skills not only improves his contribution to the firm’s output but also weakens the other workers’ threat points in the ex post negotiation. As a result, a worker’s bargaining power relative to that of the other workers is more sensitive to his acquisition of skills in the “M-organization”. Or more intuitively, workers’ competition for bargaining power is much more intense when their skills overlap than when they don’t.

This framework is also effective in analyzing the managers’ decision problem of how much authority they should delegate to the workers. Aghion and Tirole [1] have developed a theory of the allocation of decision rights (formal authority) in situations where the decision-maker, if uninformed, can communicate with the informed party, who in such a case has the effective control over decisions (real authority). In their setting, an increase in an agent’s chance of gaining real authority promotes initiative. The principal can provide more incentives to the agent by delegating to him the formal authority, but loses control by doing so (i.e., the agent maximizes his private benefit). In contrast to Aghion and Tirole, this study allows communication among the workers (while neglecting communication between the manager and the
workers) and analyzes how this possibility of information sharing affects the optimal allocation of decision rights. The cost of delegating decision rights is the increased bargaining power that the workers have in the stage of *ex post* wage negotiation. We show that a difference in the structure of skill formation affects the relative strength of the owner-manager’s bargaining power and the workers’ incentives to acquire skills, leading to a different degree of optimal delegation. For a large set of production technology, the optimal level of delegation is typically higher in the M-organization.

2 Basic Model

In this section, a model is constructed with the following features in the incomplete contract framework:

- The manager has discretion to allocate decision rights.
- After observing the decision rights assigned, the workers invest in firm-specific skills.
- Value of firm-specific skills depends on the set of decision rights assigned.
- Wages are determined by *ex post* bargaining.

The study focuses on the following two extreme forms of organizations: (1) those where workers acquire deep, narrow skills and do not communicate with each other; and (2) those where workers’ skills are broad and overlap with all other workers, and workers share their knowledge. We call the former the “S-organization” and the latter the “M-organization.” Unlike Grossman and Hart [10] and Hart and Moore [11], ownership structure is not our concern. Hence, simply assume that there is an owner-manager who owns assets for production and
hires two workers in the market. For a more general \( n \) worker case, see Owan [28]. The owner-manager is denoted by \( M \) and workers are denoted by \( i \) \((i = 1, 2)\). Both the manager and the workers are risk-neutral.

### 2.1 Technology

Let \( S \) be the set of all decision problems in the firm. For each problem \( a \in S \), the outcome is either success or failure. There exists a partition \( S = S_1 \cup S_2 \) and the workers can acquire firm-specific and task-specific skills, skill 1 and skill 2, where skill \( j \) improves a worker’s ability to solve problems in \( S_j \). The task-specificity is clearly defined later. Let \( x_{i,j} \) be the worker \( i \)'s investment in skill \( j \). The personal cost of investment is \( c(x_{i,1}, x_{i,2}) \). Let \( X = (x_{1,1}, x_{1,2}, x_{2,1}, x_{2,2}) \).

The manager delegates the sets of decision problems, or equivalently the sets of decision rights, \( A_1 \) and \( A_2 \) to worker 1 and worker 2 and retains the rest. Hence, \( S = A_M \cup A_1 \cup A_2 \) and \( A_M \cap (A_1 \cup A_2) = \emptyset \).\(^4\) A random variable \( y_{i,a} \) is the outcome of worker \( i \)'s decision on \( a \in A_i \), and \( y_{i,a} = 1 \) indicates success and 0 otherwise. The distribution of \( y_{i,a} \) is fully described by \( P_i(A_i, a, x_{i,1}, x_{i,2}) \), the probability that worker \( i \) with skill level \((x_{i,1}, x_{i,2})\) makes a successful decision on \( a \in A_i \) when he is allocated the set of decision problem \( A_i \). Let \( P_i(A_i, a, x_{i,1}, x_{i,2}) = 0 \) when \( a \notin A_i \).

The next assumption states that the discovery of a solution is stochastically independent between the workers. This formalizes the idea that the workers obtain solutions based on their idiosyncratic private information observed in the workplace.

\(^4\)A sufficient condition that sharing responsibilities is not optimal for the owner-manager and the workers will be provided later.
The two events $y_{1,a} = 1$ and $y_{2,a} = 1$ are independent for $a \in A_1 \cap A_2$.

When $A_1 \cap A_2 \neq \emptyset$, the workers share ideas, and whichever worker has found the right solution will implement the decision. Thus, it is assumed that when a worker finds a good solution, he can show some evidence to his co-worker and implement it. When both workers find the right solution, the person who can implement it better will be assigned the task. (A.1) implies that the probability that either worker finds a right solution to $a \in A_1 \cap A_2$ is

$$1 - (1 - P_1(A_1, a, x_{1,1}, x_{1,2}))(1 - P_2(A_2, a, x_{2,1}, x_{2,2})).$$

Let $\lambda$ be a measure in $S$ and $\mu(A_i)$ be the incremental value created by a successful decision on $a \in A_i$ that is implemented by worker $i$. Let $V(A_M)$ be the total value created by the manager when he retains $A_M$. Suppose $P_i$'s are measurable functions in $S$ and $A_i$'s are measurable sets. Then, the total expected value created in the firm is expressed by

$$Y(A_M, A_1, A_2, X) = V(A_M) + \int_{a \in A_1} \mu(A_1)P_1(A_1, a, x_{1,1}, x_{1,2})(1 - P_2(A_2, a, x_{2,1}, x_{2,2}))d\lambda$$

$$+ \int_{a \in A_2} \mu(A_2)P_2(A_2, a, x_{2,1}, x_{2,2})(1 - P_1(A_1, a, x_{1,1}, x_{1,2}))d\lambda$$

$$+ \int_{a \in A_1 \cap A_2} \max\{\mu(A_1), \mu(A_2)\}P_1(A_1, a, x_{1,1}, x_{1,2})P_2(A_2, a, x_{2,1}, x_{2,2})d\lambda$$

The next assumption indicates that the workers are homogeneous, that all decisions on $A_i$ made by worker $i$ are equally likely to be successful, and that $P_i$ is independent of $A_i$ as long as $a \in A_i$. This assumption allows us to significantly simplify our derivation while keeping most intuitions we could obtain without (A.2).

(A.2) $P_1 = P_2$, and they do not depend on $a$ or $A_i$ as long as $a \in A_i$.

We denote $P(x_{i,1}, x_{i,2}) = P_i(A_i, a, x_{i,1}, x_{i,2})$ when it is clear that $a \in A_i$. The assumption that the size of assigned responsibilities does not affect the quality of decisions may sound unreasonable at first. But we instead argue that the size and content of the responsibilities affects
the quality of implementation: the value created by successful decisions, \( \mu(A) \), is decreasing in the size of \( A \) if decision problems have little complementarity, and is increasing if they have strong complementarity.

Next, we assume that both skills are task-specific in the sense that \( x_{i,j} \) does not affect the chance of solving \( a \in S_{j'} \) when \( j' \neq j \). Furthermore, there is perfect cost substitution.

(A.3) There exists a partition \( S = S_1 \cup S_2 \) such that \( P(x_{i,j}, x_{i,j'}) = P(x_{i,j}, 0) \) for \( a \in S_j \).

(A.4) \( c(x_{i,1}, x_{i,2}) = c(x_{i,1} + x_{i,2}) \).

We can now define \( P \) as a single-variable function by \( P(x_{i,j}) = P(x_{i,j}, x_{i,j'}) \) for \( a \in S_j \). We add the following conditions for this \( P \) and \( c \) to guarantee and obtain the well-behaved solution.

(A.5) \( P \) and \( c \) are twice continuously differentiable. \( P(0) = 0, P' > 0, P'' < 0, c(0) = 0, c' \geq 0, c'' \geq 0, c'(0) = 0, \lim_{x \to \infty} c'(x) = +\infty \) and \( c''(x)/c'(x) \) is non-increasing.

One example of \( P \) is \( P(x) = 1 - e^{-x} \), which will be frequently used throughout the paper.

2.2 Specialization and Multiskilling

Now, we restrict our attention to the following two types of organization. Let \( A_W \equiv A_1 \cup A_2 = S \setminus A_M \).

**Definition 1** The firm is called \( S \)-organization if \( A_i = A_W \cap S_i \), and is called \( M \)-organization if \( A_1 = A_2 = A_W \).

Note, in the \( S \)-organization, \( A_1 \cap A_2 = \emptyset \). So, the workers do not communicate with each other in the \( S \)-organization. Lack of communication can be justified by assuming that the communication between the workers is not facilitated and is significantly costly to them in
the S-organization. Or we can alternatively assume that the workers’ skills are revealed to the owner-manager only when they implement their solutions and, therefore, worker $i$ has no incentives to acquire skill $j$ and communicate his findings to worker $j$.

Let $Y^k(A_W, X)$ be the expected production by the $k$-organization ($k = S, M$) given $A_W$ and $X$. Then,

\[
Y^S(A_W, X) = V(S \setminus A_W) + \lambda(A_W \cap S_1)\mu(A_W \cap S_1)P(x_1) + \lambda(A_W \cap S_2)\mu(A_W \cap S_2)P(x_2)
\]

where $x_i$ is the worker $i$’s total investment. In the $M$-organization,

\[
Y^M(A_W, X) = V(S \setminus A_W) + \lambda(A_W \cap S_1)\mu(A_W)\{1 - (1 - P(x_{1,1}))(1 - P(x_{2,1}))\} + \lambda(A_W \cap S_2)\mu(A_W)\{1 - (1 - P(x_{1,2}))(1 - P(x_{2,2})))\}
\]

The key difference between these two functions is that there is no interaction between $x_1$ and $x_2$ in $Y^S$ while $x_{1,j}$ and $x_{2,j}$ are Edgeworth substitutes in $Y^M$ (i.e., $\frac{\partial^2 Y^M}{\partial x_{1,j} \partial x_{2,j}} < 0$).\(^5\) This feature drives most of our results that follows.

Let us see what factors affect the relative efficiency of the $S$-organization and the $M$-organization given the same degree of decentralization and the same amount of investment. In order to simplify the comparison, assume the symmetric allocation of decision rights, $\lambda(A_i) = \frac{1}{2}\lambda(A_W)$ for both $i$, and the symmetric investment in skills, $x_1 = x_2 = x$ in the S-organization and $x_{1,1} = x_{1,2} = x_{2,1} = x_{2,2} = x/2$ in the M-organization. Then,

\(^5\)It may be often more realistic to assume Edgeworth complementarity between $x_1$ and $x_2$ in the S-organization. Most qualitative results in this paper hold for such a case. See Owan [28] for discussions.
\[ Y^M > Y^S \text{ if } 2\mu(A_W)P\left(\frac{x}{2}\right)(1 - \frac{1}{2}P\left(\frac{x}{2}\right)) > \mu(A_i)P(x). \]

Thus, the \textit{M-organization} produces more if there is strong complementarity between two sets of decision problems, \textit{i.e.} \( \frac{\mu(A_W)}{\mu(A_i)} \) is high, and/or there are strong decreasing returns to learning, \textit{i.e.} \( \frac{P(x)}{P(x/2)} \) is low. When we assume \( P(x) = 1 - e^{-x} \), the result is further simplified to

\[ Y^M > Y^S \text{ if } \mu(A_W) > \mu(A_i). \]

Hence, if handling different tasks enable more coordinated implementation of decisions and the value of coordination is high enough, the \textit{M-organization} is more efficient.

### 2.3 Contractibility and Wage Bargaining

First of all, we want to rule out the owner-manager’s opportunistic behavior: she might promise to delegate large authority to the workers to motivate them and then reneges on it. This can be done by assuming \( A_i \) is contractible. For example, think of \( A_i \) as the job description in employment contracts.\(^6\) We also presume that \( X \) is observable but that none of \( y_{i,a}, Y^k \) and \( X \) is verifiable, so that the manager cannot design a contingent contract on any of these variables.\(^7\) The assumption that \( y_{i,a} \) is not verifiable also makes it infeasible to sell decision rights to the workers. Our assumption that a worker with no firm-specific human capital produces nothing (\textit{i.e.,} \( P(0) = 0 \)) implies that the worker’s outside option value is normalized to zero.\(^6\)

\(^6\)Alternately, we can exclude such opportunistic behavior by: (1) introducing the reputation mechanism based on the repeated interactions between a long-lived manager and short-lived workers; or (2) assuming that people can acquire skills only by actually implementing the decision problems themselves repeatedly.\(^7\) Whether \( y_{i,a} \) or \( Y^k \) is observable does not matter.
After $A_i$s are assigned, the workers decide how much they should invest in each skill. After the investment vector $X$ is observed, the owner-manager and the workers negotiate wages. Finally, after wages are determined, the owner-manager and the workers make decisions and create revenue. In the wage bargaining stage, we consider two kinds of bargaining procedures: collective bargaining and individual bargaining, although our main results focus on the latter.

### 2.3.1 Collective Bargaining

Under collective bargaining, the workers collectively negotiate with the owner-manager and split the workers' share half and half. We adopt the Nash bargaining solution between the manager and the workers, as is standard in the literature. Then,

$$w^{C,S,i}(A_W, X) = \frac{1}{4}(\lambda(A_W \cap S_1)\mu(A_W \cap S_1)P(x_1) + \lambda(A_W \cap S_2)\mu(A_W \cap S_2)P(x_2)).$$

$$w^{C,M,i}(A_W, X) = \frac{1}{4}\lambda(A_W \cap S_1)\mu(A_W)\{1 - (1 - P(x_{1,1}))(1 - P(x_{2,1}))\}$$

$$+ \frac{1}{4}\lambda(A_W \cap S_2)\mu(A_W)\{1 - (1 - P(x_{1,2}))(1 - P(x_{2,2}))\}$$

where $w^{C,k,i}$ is the worker $i$'s wage from collective bargaining in the $k$-organization. Let $\pi^{C,k}$ be the corresponding owner-manager’s profit.

$$\pi^{C,S}(A_W, X) = V(S \setminus A_W) + \frac{1}{2}\lambda(A_W \cap S_1)\mu(A_W \cap S_1)P(x_1)$$

$$+ \frac{1}{2}\lambda(A_W \cap S_2)\mu(A_W \cap S_2)P(x_2).$$

$$\pi^{C,M}(A_W, X) = V(S \setminus A_W) + \frac{1}{2}\lambda(A_W \cap S_1)\mu(A_W)\{1 - (1 - P(x_{1,1}))(1 - P(x_{2,1}))\}$$

$$+ \frac{1}{2}\lambda(A_W \cap S_2)\mu(A_W)\{1 - (1 - P(x_{1,2}))(1 - P(x_{2,2}))\}.$$
2.3.2 Individual Bargaining

Under individual bargaining, we assume that the manager and the workers play the extensive-form bargaining game developed by Stole and Zwiebel [31]. In their model, the manager and the workers bargain pairwise sequentially and, in each session, play the alternating-offer bargaining game of Binmore, Rubinstein and Wolinsky [4] in which there is an exogenous probability of breakdown. The solution for this game is the Shapley value for the corresponding cooperative game. Hence, the workers’ wages in both organizations are expressed by

\[
\begin{align*}
    w^{I,S,i}(A_W, X) &= \frac{1}{2} \lambda(A_W \cap S_i) \mu(A_W \cap S_i) P(x_i), \\
    w^{I,M,i}(A_W, X) &= \frac{1}{3} \lambda(A_W \cap S_1) \mu(A_W) P(x_{i,1})(1 - P(x_{j,1})) \\
    &\quad + \frac{1}{3} \lambda(A_W \cap S_2) \mu(A_W) P(x_{i,2})(1 - P(x_{j,2})) \\
    &\quad + \frac{1}{6} \{ \lambda(A_W \cap S_1) \mu(A_W) P(x_{i,1}) + \lambda(A_W \cap S_2) \mu(A_W) P(x_{i,2}) \}
\end{align*}
\]

where \( w^{I,k,i} \) is the worker \( i \)'s wage from individual bargaining in the \( k \)-organization. Let \( \pi^{I,k} \) be the corresponding owner-manager’s profit. Then,

\[
\begin{align*}
    \pi^{I,S}(A_W, X) &= V(S \setminus A_W) + \frac{1}{2} \lambda(A_W \cap S_1) \mu(A_W \cap S_1) P(x_1) + \\
    &\quad + \frac{1}{2} \lambda(A_W \cap S_1) \mu(A_W \cap S_1) P(x_1), \\
    \pi^{I,M}(A_W, X) &= V(S \setminus A_W) + \frac{1}{3} \lambda(A_W \cap S_1) \mu(A_W) \{ 1 - (1 - P(x_{1,1}))(1 - P(x_{2,1})) \} + \\
    &\quad + \frac{1}{3} \lambda(A_W \cap S_2) \mu(A_W) \{ 1 - (1 - P(x_{1,2}))(1 - P(x_{2,2})) \} + \\
    &\quad + \frac{1}{6} \lambda(A_W \cap S_1) \mu(A_W) (P(x_{1,1}) + P(x_{2,1})) + \\
    &\quad + \frac{1}{6} \lambda(A_W \cap S_2) \mu(A_W) (P(x_{1,2}) + P(x_{2,2})).
\end{align*}
\]
2.4 Symmetric Delegation and Symmetric Nash Equilibrium

We now introduce a specific structure into $S$ to facilitate mathematical derivation in the following sections. Each decision problem in $S$ is indexed by a point $(s_1, s_2)$ in $I^2 = [0, 1] \times [0, 1] \subset \mathbb{R}^2$ and a measure $\lambda$ is derived from Lebesgue measure in $\mathbb{R}^2$ by this transformation. In other words, each point in $I^2$ corresponds to a particular decision problem. Abusing notation, let us denote $S = I^2$. We assume $S_1 = [0, 1/2] \times [0, 1]$ and $S_2 = [1/2, 1] \times [0, 1]$ (see Figure 1). The second variable $s_2 \in [0, 1]$ denotes an order that indicates the relative advantage of the manager versus the workers in making decisions for each problem. The decision problems that are high in this ordering are more strategic decisions, and the manager’s ability to coordinate decisions between $S_1$ and $S_2$ gives her relatively high productivity, while those that are low in the ordering are more operational decisions, and the workers’ engagement in the production process enables them to create relatively high value on these problems. We confine our analysis to the case in which allocating a symmetric set of decision rights to the workers is always optimal and the optimal delegation takes the form, $A_r = \{(s_1, s_2) \in I^2 | s_2 \leq r\}$. So, the owner-manager’s problem is simply choosing $r$, the size of the set of delegated decision rights.

![Figure 1: Set of Decision Problems](image-url)
The following assumptions (A.6), (A.7) and (A.8) are sufficient to show that there exists \( r \in [0, 1] \) such that \( A_r \) is optimal. See the appendix for the proof.

\textbf{(A.6)} \( \mu(A_r \cap S_1) = \mu(A_r \cap S_2) \) for all \( r \).

\textbf{(A.7)} For any \( A \subset S \), there exist \( r, r_1 \) and \( r_2 \) such that

\[
\begin{align*}
    r\mu(A_r) &\geq \lambda(A)\mu(A), \\
    V(A^c_r) &\geq V(A^c), \\
    \frac{r_1}{2} \mu(A_{r_1} \cap S_1) &\geq \lambda(A \cap S_1)\mu(A \cap S_1), \\
    \frac{r_2}{2} \mu(A_{r_2} \cap S_2) &\geq \lambda(A)\mu(A \cap S_2), \text{ and } V((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c \geq V(A^c)
\end{align*}
\]

(A.7) indicates that it is efficient to allocate relatively strategic decisions to the owner-manager and relatively operational decisions to the workers.

\textbf{(A.8)} \( V(A^c_{r_1}) - V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) > V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) - V(A^c_{r_2}) \) for \( r_1 \neq r_2 \).

Let \( v(r_1, r_2) = V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) \). When \( v \) is symmetric, (A.8) is equivalent to assuming that \( v \) is supermodular. Assuming that there are gains from coordinating decisions between \( S_1 \) and \( S_2 \) around the same vertical level (with similar strategic or operational significance), \( r_1 \) and \( r_2 \) should become Edgeworth complements in \( V \). In other words, retaining additional decision rights in \( S_1 \) should make it more profitable, or less costly, to retain decision rights around the same vertical level in \( S_2 \).

In the \textit{S-organization}, (A.5) and the additive form of production technology imply that workers’ investment is uniquely determined for each \( A_W \) and it is symmetric if \( A_W \) is symmetric. In contrast, in the \textit{M-organization} where the workers’ skills constitute strategic substitutes, there could be multiple equilibria. In order to simplify our analysis, we restrict our attention to symmetric Nash equilibrium (SNE) where \( x_{1,j} = x_{2,j} \) for \( j = 1, 2 \) throughout the paper.

The following lemma ensures the uniqueness of the symmetric Nash equilibrium in the \textit{M-
organization. The result comes from the strategic substitutability in the game and the cost substitution.

**Lemma 1** In the S-organization, workers’ investment is uniquely determined and symmetric while there could be multiple Nash equilibria in the M-organization. Symmetric Nash equilibrium in the M-organization is unique and \( x_{11} = x_{12} = x_{21} = x_{22} \). The result does not depend on the bargaining procedure.

**Proof:** See the Appendix.

3 Main Results

3.1 Workers’ Bargaining Power

We first compare the wages in both organizations and with different bargaining processes given the same level of skill investment and the same allocation of decision rights. Proposition 1 implies that the workers in the M-organization can increase their bargaining power by collectively bargaining, but those in the S-organization cannot.\(^8\) The difference is generated by the human capital substitutability in the M-organization and it has already been noted by Horn and Wolinsky [13] and Stole and Zwiebel [32].\(^9\)

\(^8\)This result may be consistent with the fact that enterprise unions are rare in the U.S. where traditional firms have maintained a specialized job structure. A typical union’s goal of increasing the workers’ bargaining power probably necessitated the use of monopoly power in the industry-wide labor market. On the contrary, most unions are enterprise unions in Japan where large firms have adopted many multiskilling practices.

\(^9\)Proposition 1 is a direct corollary of Result 6 in Stole and Zwiebel [32] because substitutable human capital stocks should induce a higher front load factor than additive technology implying a higher profit and lower wages in the M-organization.
Proposition 1  Collective bargaining increases the workers’ wage in the M-organization while the workers in the S-organization do not benefit from collective bargaining.

\[ w^{I,S,i} = w^{C,S,i}, \quad w^{I,M,i} < w^{C,M,i} \text{ for } \forall x_1 = x_2 = x \text{ and } \forall A_W. \]

Proof:  \[ w^{I,S,i} = w^{C,S,i} \] is trivial. To show \( w^{I,M,i} < w^{C,M,i} \), let \( X = (\frac{x}{2}, \frac{x}{2}, \frac{x}{2}, \frac{x}{2}) \)

\[
\begin{align*}
  w^{I,M,i}(A_W, X) & = \frac{1}{4} \lambda(A_W) \mu(A_W) P(\frac{x}{2}) (2 - \frac{4}{3} P(\frac{x}{2})) \\
  & < \frac{1}{4} \lambda(A_W) \mu(A_W) \{ 1 - (1 - P(\frac{x}{2}))^2 \} \\
  & = w^{C,M,i}(A_W, X)
\end{align*}
\]

With collective bargaining, the workers’ share of the rent created by their skills is always half regardless of the organizational form. Hence, \( w^{C,S,i}(A_W, X) > w^{C,M,i}(A_W, X) \) if and only if \( Y^S(A_W, X) > Y^M(A_W, X) \). In contrast, the proposition indicates that, under individual bargaining, the workers’ share of the rent created by their skills is higher in the S-organization, where the share is half, than in the M-organization, where the share is less than half. This should be understood very easily as follows. In the M-organization, when one worker quits, the output does not drop as sharply as in the S-organization because the other multiskilled worker will implement more of his solutions. In other words, the other worker’s broad skills will be utilized more efficiently. Because a worker turnover is less costly, the M-organization should give the workers lower wage given the same amount of investment. Therefore, \( w^{I,S,i} > w^{I,M,i} \) may be the case even if \( Y^S < Y^M \). We will restate this point by using the function \( P(x) = 1 - e^{-x} \).
**Corollary 1** Let \( P(x) = 1 - e^{-x} \). \( w^{I,S,i} > w^{I,M,i} \) if and only if

\[
\mu(A_W \cap S_i) > \left\{ 1 - \frac{(1 - e^{-\frac{x}{2}})^2}{3(1 - e^{-x})} \right\} \mu(A_W)
\]

Hence, when the complementarity between the two types of decision problems is moderate, i.e. \( \mu(A_W) > \mu(A_W \cap S_i) > \left\{ 1 - \frac{(1 - e^{-\frac{x}{2}})^2}{3(1 - e^{-x})} \right\} \mu(A_W) \), the workers's wage is lower despite that the \( M\)-organization produces more.

### 3.2 Workers’ Skill Investment

Let \( x^S(A_W) \) and \( x^M(A_W) \) be the efficient investment, \( x^{I,S}(A_W) \) and \( x^{I,M}(A_W) \) be the equilibrium investment with individual bargaining, and \( x^{C,S}(A_W) \) and \( x^{C,M}(A_W) \) be the equilibrium investment with collective bargaining, for the \( S \) and \( M\)-organization, respectively. We often omit the argument \( A_W \), but keep in mind that the results in this section are all for the same amount of allocation \( A_W \). (A.5) ensures the uniqueness of those values. The usual hold-up argument and the free-rider problem in the collective bargaining imply that \( x^S > x^{I,S} > x^{C,S} \).

However, the first inequality does not necessary hold for the M-organization where the workers’ skills are substitutes.

The efficient investment \( x^M \) is obtained by solving

\[
\frac{\partial Y^M}{\partial x^i} - c'(x) = \frac{1}{2} \lambda(A_W) \mu(A_W) P'\left(\frac{x}{2}\right)(1 - P\left(\frac{x}{2}\right)) - c'(x) = 0
\]  

(1)

\( x^{I,M} \) solves

\[
\frac{\partial w^{I,M,i}}{\partial x^i} - c'(x) = \frac{1}{6} \lambda(A_W) \mu(A_W) P'\left(\frac{x}{2}\right)(1 - P\left(\frac{x}{2}\right)) + \frac{1}{12} \lambda(A_W) \mu(A_W) P'\left(\frac{x}{2}\right) P\left(\frac{x}{2}\right) - c'(x) = 0
\]  

(2)

Let me rewrite (2) as follows:

\[
\frac{\partial w^{I,M,i}}{\partial x^i} - c'(x) = \frac{\partial Y^M}{\partial x^i} - c'(x) - \underbrace{\frac{1}{2} \frac{\partial Y^M}{\partial x^i}}_{\text{Hold-up effect}} + \underbrace{\frac{1}{12} \lambda(A_W) \mu(A_W) P'\left(\frac{x}{2}\right) P\left(\frac{x}{2}\right)}_{\text{Substitution effect}} \]  

(3)
In the *M-organization*, an increase in one worker’s investment makes it more likely that the other’s discovery of the solution becomes redundant reducing the value of the other’s skills. Therefore, a marginal increase in a worker’s investment not only increase his contribution but also weaken the threat by the other worker in his bargaining with the owner-manager, further increasing the residual left for the former worker. I will call this impact “substitution effect.”

The next proposition suggest that the substitution effect could dominate the hold-up effect. Then, workers overinvest in their skills.

**Proposition 2** Individual bargaining gives a higher incentive to acquire skills than collective bargaining in general. However, the workers always underinvest compared with the efficient level in the *S-organization* while the workers in the *M-organization* could overinvest.

\[ \bar{x}^S > x^{I,S} > x^{C,S} \text{ for any } A_W. \]

Let \( c(X) = \frac{1}{2} cx \). For any \( A_W \), there exists a cost parameter \( c > 0 \) such that

\[ \bar{x}^M > x^{I,M} > x^{C,M} \text{ for } c > \bar{c} \]

\[ x^{I,M} > \bar{x}^M > x^{C,M} \text{ for } c < \bar{c} \]

**Proof:** The first inequality is straight-forward from \( \frac{\partial w^{I,S,i}}{\partial x^i} = \frac{1}{2} \frac{\partial Y^S}{\partial x^i} \) and \( \frac{\partial w^{C,S,i}}{\partial x^i} = \frac{1}{4} \frac{\partial Y^S}{\partial x^i} \).

Similarly, \( \bar{x}^M > x^{C,M} \) and \( x^{I,M} > x^{C,M} \) are trivial from \( \frac{\partial w^{C,M,i}}{\partial x^i} = \frac{1}{4} \frac{\partial Y^M}{\partial x^i} \) and (3).

\[ x^{I,M} > \bar{x}^M \text{ iff } \frac{\partial w^{I,M,i}}{\partial x^i} > \frac{\partial Y^M}{\partial x^i} \text{ at } x = \bar{x}^M. \]

\[
\frac{\partial w^{I,M,i}}{\partial x^i} \bigg|_{x = \bar{x}^M} > \frac{\partial Y^M}{\partial x^i} \bigg|_{x = \bar{x}^M} \\
\iff \frac{1}{3} \lambda(A_W) \mu(A_W) P^I(\bar{x}^M/2) P(\bar{x}^M/2) > \lambda(A_W) \mu(A_W) P^I(\bar{x}^M/2) (1 - P(\bar{x}^M/2)) \\
\iff P(\bar{x}^M/2) > \frac{3}{4}
\]
The last inequality is actually true if \( c \) is sufficiently small. ■

Because of the substitution effect discussed earlier, the \( M\)-organization tend to give the workers stronger incentives to acquire skills if individual bargaining procedure is adopted. This is more clearly stated when we assume \( P(x) = 1 - e^{-x} \) and \( \mu(A_W) = \mu(A_W \cap S_i) \). Given those assumptions, \( Y^S = Y^M \) for any symmetric investment \( x_1 = x_2 \) and any allocation \( A_W \). Therefore, \( \bar{x}^S = \bar{x}^M \) and \( x^{C,S} = x^{C,M} \). But the \( M\)-organization outperforms the \( S\)-organization under individual bargaining.

**Proposition 3** When the two organizations have the identical production frontier for the symmetric investment and, thus, either one has no technological advantage over the other, the \( M\)-organization induces higher investment in skills than the \( S\)-organization.

More specifically, suppose \( P(x) = 1 - e^{-x} \). Then, \( x^{I,M} > x^{I,S} \) if \( \frac{\mu(A_W)}{\mu(A_W \cap S_i)} > \frac{3}{2+e^{x_I,S}}\) (\(< 1\)).

When \( \mu(A_W) = \mu(A_W \cap S_i) \) is assumed additionally, \( \bar{x}^S = \bar{x}^M \) and \( x^{C,S} = x^{C,M} \), but \( x^{I,M} > x^{I,S} \).

**Proof:** Suppose \( P(x) = 1 - e^{-x} \). When \( \frac{\mu(A_W)}{\mu(A_W \cap S_i)} > \frac{3}{2+e^{x_I,S}} \),

\[
\frac{\partial w^{I,M,i}}{\partial x_i} \bigg|_{x=x^{I,S}} - \frac{\partial w^{I,S,i}}{\partial x_i} \bigg|_{x=x^{I,S}} = \lambda(A_W \cap S_i) \times \left\{ \frac{1}{2} (\mu(A_W) - \mu(A_W \cap S_i)) e^{-x^{I,S}} + \frac{1}{6} \mu(A_W) (e^{-x^{I,S}} - 1) \right\}
\]

\[> 0\]

Hence, \( \frac{\partial w^{I,M,i}}{\partial x_i} \bigg|_{x=x^{I,S}} - c(x^{I,S}) > 0 \) implying that \( x^{I,M} > x^{I,S} \). ■

In the previous analysis, we have assumed that the workers choose their investment in skills non-cooperatively regardless of whether they bargain individually or collectively. When the
workers work in teams, they may be able to cooperate, or collude, in choosing their investment level if workers can successfully enforce a certain team norm. Let $\tilde{x}$ be the workers’ investment when they jointly optimize their total payoff: $w^1 + w^2 - c(x_1) - c(x_2)$.

**Proposition 4** The workers’ cooperation in setting their investment in skills benefits the owner-manager under collective bargaining. Under individual bargaining, cooperation hurts the firm profit in the M-organization while it does not in the S-organization.

$$x^{I,S} = \tilde{x}^{I,S} = \tilde{x}^{C,S} > x^{C,S}$$

Let $c(X) = \frac{1}{2}cx^2$. There exists $c$ such that

$$x^{I,M} > \tilde{x}^{C,M} > \tilde{x}^{I,M} > x^{C,M} \text{ for } c > c$$

$$x^{I,M} > \tilde{x}^{C,M} > x^{C,M} > \tilde{x}^{I,M} \text{ for } c < c$$

**Proof:** See the Appendix.

Cooperation is beneficial under collective bargaining because it eliminates free-riding. Under individual bargaining, however, cooperation and autonomy in setting skill standard in the M-organization could be substantially damaging for the efficiency. This is because the strategic substitutability of workers’ investments creates negative externality on their wages, and internalizing this externality while neglecting the positive externality on the owner-manager’s payoff could cause significant underinvestment in skills.\(^{10}\)

---

\(^{10}\)This problem may be negligible if there are many teams competing with each other. Also, frequent job rotation among teams working on similar tasks should alleviate this problem because the possibility that you move to another team or a worker from another team come to your team reduces the incentive to collude.
3.3 Allocation of Decision Rights

In this section, we analyze how the optimal allocation of decision rights differs between the two different forms of organization. We redefine $V$ and $\mu$ as functions of $r$. Let $v(r) = V(A_r^c)$, $\mu^S(r) \equiv \mu(A_r \cap S_i)$ and $\mu^M(r) \equiv \mu(A_r)$.

The following assumptions ensure the existence and uniqueness of interior solutions.

(A.9) $v$ is twice continuously differentiable and $v'' \leq 0$, $v'(0) > 0$, $v'(1) < 0$.

(A.10) $\mu^S$ and $\mu^M$ are twice continuously differentiable and $\mu^{k''} \leq 0$, $\mu^k(0) > 0$, $\mu^k(1) + \mu^k(1)^+ < 0$ for $k = S, M$.

We can prove that the concavity of $v$, $\mu^S$ and $\mu^M$ makes it suboptimal for the owner-manager and the workers share authority and exchange information in the first place. (A.9) and (A.10) allow us to ask the question: how an increase in decision authority affects the workers’ incentives to acquire skills. Consider the $S$-organization under individual bargaining. The workers solve

$$\max_x w^{I,S,j}(r,x_i,x_j) - c(x_i) = \frac{1}{4} r \mu^S(r) P(x_i) - c(x_i)$$

From the first-order condition

$$\frac{1}{4} r \mu^S(r) P'(x_i) = c'(x_i)$$

we get

$$\frac{dx^{I,S}}{dr} = \frac{(\mu^S(r) + r \mu^S(r)) P'(x^{I,S})}{4 c''(x^{I,S}) - r \mu^S(r) P''(x^{I,S})}$$

Thus, $\frac{dx^{I,S}}{dr} > 0$ if and only if $\mu^S(r) + r \mu^S(r) > 0$.

The owner-manager will optimize with respect to $r$ assuming that $x$ will be chosen optimally.
by the workers. Let us rewrite the profit functions using the notation we have introduced here.

\[
\begin{align*}
\pi^{I,S}(r) &= v(r) + \frac{1}{2} r \mu^S(r) P(x^{I,S}). \\
\pi^{C,S}(r) &= v(r) + \frac{1}{2} r \mu^S(r) P(x^{C,S}) \\
\pi^{I,M}(r) &= v(r) + r \mu^M(r) (P\left(\frac{x^{I,M}}{2}\right) - \frac{1}{3} P\left(\frac{x^{I,M}}{2}\right)^2) \\
\pi^{C,M}(r) &= v(r) + r \mu^M(r) (P\left(\frac{x^{C,M}}{2}\right) - \frac{1}{2} P\left(\frac{x^{C,M}}{2}\right)^2)
\end{align*}
\]

\(v' > 0\) implies that the owner-manager’s productivity increases as his responsibilities decrease. This means that the owner-manager is overloaded in the range where \(v' > 0\). Similarly, the workers are overloaded when \(\mu^k (r) + r \mu^k'(r) < 0\) \((k = S, M)\). In (A.11), we assume that the owner-manager and the workers cannot be overloaded at the same time. In order words, the set of decision rights \(S\) should not be too large for three people to handle.

**(A.11)** If \(\mu^k(r) + r \mu^k'(r) \leq 0, v'(r) < 0\).

The manager solves \(\max_r \pi^{l,k}(r)\) where \(l = I, C\) and \(k = S, M\). The first-order condition take the following form.

\[
\frac{d\pi^{l,k}}{dr} = \frac{\partial \pi^{l,k}}{\partial r} + \frac{\partial \pi^{l,k}}{\partial x} \frac{dx^{l,k}}{dr} = 0 
\]

There are two channels through which an increase in \(r\) affects the owner-manager’s profit: (1) direct impact on efficiency and bargaining power; and (2) indirect impact through changes in worker incentives. Let \(r^{l,k}\) be the optimal degree of delegation.

The next lemma is used in the following results.

**Lemma 2** \(\mu^k(r^{l,k}) + r^{l,k} \mu^k'(r^{l,k}) > 0\) for \(l = I, C\) and \(k = S, M\).
Proof: We prove only for the $S$-organization and individual bargaining. The proof is basically the same for the other cases.

\[
\frac{d\pi_{I,S}}{dr} = v'(r) + \frac{1}{2}(\mu^S(r) + r\mu^S'(r))P(x_{I,S}) + \frac{1}{2}r\mu^S(r)P'(x_{I,S}) \frac{dx_{I,S}}{dr} = 0 \tag{7}
\]

By substituting in (4) and (5),

\[
\frac{d\pi_{I,S}}{dr} = v'(r) + (\mu^S(r) + r\mu^S'(r))\left[\frac{P(x_{I,S})}{2} + \frac{2}{r\mu^S(r)}\frac{c'(x_{I,S})^2}{c''(x_{I,S})} - \frac{r\mu^S(r)}{4}P''(x_{I,S})\right] \tag{8}
\]

Suppose $\mu^S(r_{I,S}) + r_{I,S}\mu^S'(r_{I,S}) \leq 0$. The term in the last brackets is positive. Then, (A.11) implies that $\frac{d\pi_{I,S}}{dr}(r_{I,S}) < 0$ leading to contradiction. This concludes the proof. ■

The next result implies that firms with collective bargaining procedure have less incentives to empower workers.

Proposition 5 Suppose $P(x) = 1 - e^{-x}$. Collective bargaining induces less decision rights to be allocated to the workers in both organizations.

$r_{I,S} > r_{C,S}, r_{I,M} > r_{C,M}$

Proof: See the Appendix. ■

The intuition of this result is as follows. Under collective bargaining, the workers skill level is lower (Proposition 2), so that the additional delegation generates less value. Also note that, in the $M$-organization, the owner-manager’s share of the rent is lower under the collective bargaining (Proposition 1), so that the efficiency created by additional delegation gives lower rent to the owner-manager. These observations imply $\frac{\partial \pi_{C,k}}{\partial r} < \frac{\partial \pi_{I,k}}{\partial r}$ for $\forall r \in (0,1)$.

Furthermore, because of the free-rider problem, a marginal increase in decision authority does
not increase the workers’ incentives under collective bargaining as much as under individual bargaining, leading to 
\[ \frac{\partial \pi^{C,k}}{\partial x} \frac{dC,k}{da} < \frac{\partial \pi^{I,k}}{\partial x} \frac{dI,k}{da}. \]

Next, we compare the owner-manager’s optimal choice under individual bargaining with the efficient allocation \( I^{I,k} \) that maximizes the total value created in the firm, \( Y^k(r, x^{I,k}(r)) - 2c(x^{I,k}(r)) \). Note that the efficient allocation discussed here does not assume the efficient investment in skills. Thus, its efficiency is constrained by the workers’ self-interested choice of skill investment.

**Proposition 6** The owner-manager always underdelegate decision rights to the workers in the S-organization. It is also true in the M-organization if the cost function is well behaved.

\[ I^{I,S} > I^{I,M} \]

When \( c(X) = \frac{1}{2}cx^2 \), \( I^{I,M} > I^{I,M} \).

**Proof:** See the Appendix.

A problem that the manager may delegate less responsibilities than would be efficient has been discussed in Prendergast [30] and Freeman and Lazear [9]. In Prendergast, the underdelegation arises because the principal cannot capture all intrinsic benefit of implementing tasks (e.g., acquisition of skills by “learning-by-doing”) in the face of liquidity constraint imposed on workers. In the framework presented here, the cause is the increased bargaining power generated by delegation.

Recall that \( I^{I,k} \) solves \( \frac{dI^{I,k}}{dx} = 0 \). By plugging in the equations: \( \pi^{I,k} = Y^k - w^{I,k,i} - w^{I,k,j} \)

\[ ^{11} \text{Freeman and Lazear derive a similar result in a different context where the firm decides whether it should create a works council to empower workers or not. They argue that, even if setting up a works council is efficient, the employer may not be better off by doing so because the empowered workers will likely capture a significant part of the efficiency gain.} \]
and \( \frac{\partial w_I^{I,k,i}}{\partial x_i} (x^{I,k}) = c'(x^{I,k}) \), we obtain

\[
\frac{d x_I^{I,k}}{d r} = \frac{d}{d r} (Y_k - 2c(x^{I,k})) - 2 \frac{\partial w_I^{I,k,i}}{\partial r} \frac{\partial x_i}{\partial x_j} \frac{d x_I^{I,k}}{d r} = 0
\]

where \( j \neq i \). The owner-manager tend to underdelegate because the workers also capture some of the rent directly created by delegation \((-2 \frac{\partial w_I^{I,k,i}}{\partial r} < 0)\). Let us call it the **hold-up effect**.

In the M-organization, there is an offsetting effect: an increase in a worker’s skills in response to larger responsibilities weakens his co-worker’s bargaining power \((-2 \frac{\partial w_I^{I,k,i}}{\partial x_j} \frac{dx_I^{I,k}}{dr} > 0)\). We call it the **substitution effect** again. There is no substitution effect in the S-organization because \( \frac{\partial w_I^{I,k,i}}{\partial x_j} = 0 \). This implies that the distortion in the allocation of decision rights will be smaller in the M-organization unless the substitution effect is too large.\(^{12}\)

We will demonstrate that the optimal set of decision rights delegated to the workers tend to be larger in the M-organization.

**Proposition 7** When the two organizations have the identical production frontier for the symmetric investment, the M-organization induces the owner-manager to delegate more decision rights to the workers.

Suppose \( P(x) = 1 - e^{-x} \) and \( \mu^S = \mu^M \). Then \( r^{I,S} < r^{I,M} \)

**Proof:** See the Appendix. \(\blacksquare\)

The role of *ex post* bargaining in getting this result is essential because of the following two reasons. \(^{12}\) First, because *ex post* bargaining gives higher incentives to the workers with

\(^{12}\) There may be some pairs of production functions and cost functions that induce overdelegation in the M-organization although we haven’t found any such simple functions. It is possible if an increase in the allocation of decision rights increases the substitutability of the workers’ skills significantly around the optimal level, so that the further delegation weaken the workers’ relative bargaining power.
substitutable human capital stocks, the efficient allocation of decision rights is typically more decentralized in the M-organization than in the S-organization. Second, the owner-manager usually distorts the allocation because he cannot capture all the rents created by the efficient allocation. The under-delegation problem is more severe in the S-organization because the owner-manager receives a smaller share of the efficiency gain due to the weaker bargaining power.

It will be easily understood that choosing the M-organization tends to give a higher ex post profit to the owner-manager. This difference in profits is created by two factors: (1) the owner-manager has stronger bargaining power in the M-organization (Proposition 1); and (2) the workers are better motivated to acquire skills in the M-organization (Proposition 3). More formally,

Corollary 2 Suppose \( P(x) = 1 - e^{-x} \) and \( \mu^S = \mu^M \), the M-organization always give the asset owner a higher profit ex post than in the S-organization.

Proof:

\[
\pi^{I,M}(r^{I,M}, x^{I,M}(r^{I,M})) > \pi^{I,M}(r^{I,S}, x^{I,M}(r^{I,S})) > \pi^{I,S}(r^{I,S}, x^{I,M}(r^{I,S})) > \pi^{I,S}(r^{I,S}, x^{I,S}(r^{I,S}))
\]

where the first inequality is derived by the fact that \( r^{I,M} \) is the optimal choice in the M-organization, the second is immediate from Proposition 1 and the third from Proposition 3.

It is not determinate whether the workers’ wage will be higher or lower in the M-organization even with the same assumptions in Proposition 7. Although the workers are given more responsibilities and are more motivated to invest in firm-specific human capital, which strengthens
their bargaining power, they may not receive a higher wage simply because their share of the rent is smaller in the M-organization (Proposition 1).

### 3.4 Market Equilibrium

Throughout the paper, we have focused on the *ex post* wage bargaining and its equilibrium allocation of the rent. However, suppose firms compete for workers. Firms would be willing to pay to young unskilled workers up to the profit they can earn *ex post*. Then, the owner-manager in the more efficient organization should be able to offer the better wage profile and, thus, would prevail in the market.

In general, the M-organization will be adopted when: (1) tasks are complementary, so that multiskilled workers can come up with better solutions or better implementation ($\mu^M > \mu^S$); (2) learning single skill has substantial decreasing returns or different skills are complements in learning ($P(\frac{x_1}{x_2})/P(X)$ is high or $c_{x_1,x_2} \leq 0$); (3) cost of communication is low (assumed to be zero in our model); and/or (4) skills are highly firm-specific, so that underinvestment in firm-specific human capital is more costly. We demonstrate the relative efficiency of the M-organization when the production frontiers of both organizations are identical.

**Corollary 3** Suppose $P(x) = 1 - e^{-x}$, $\mu^S = \mu^M$ and $c(X) = \frac{1}{2}cx^2$. There exists a cost parameter $c > 0$ such that, for any $c \geq c$, the M-organization is more efficient than the S-organization and, thus, would be chosen in the equilibrium.

**Proof:**

$$Y(r^{I,M},x^{I,M}(r^{I,M})) - 2c(x^{I,M}(r^{I,M})) > Y(r^{I,S},x^{I,M}(r^{I,S})) - 2c(x^{I,M}(r^{I,S}))$$

where the inequality is derived by $r^{I,M} > r^{I,M} > r^{I,S}$. 27
Then, Proposition 2 implies that there exists a cost parameter $c > 0$ such that, for any $c \geq \underline{c}$, the workers underinvest in skills in the M-organization. Then, from Proposition 3, $\underline{x}^{S} = \underline{x}^{M} > x^{I,M} > x^{I,S}$. This implies

$$Y (r^{I,S}, x^{I,M} (r^{I,S})) - 2c (x^{I,M} (r^{I,S})) > Y (r^{I,S}, x^{I,S} (r^{I,S})) - 2c (x^{I,S} (r^{I,S}))$$

This concludes the proof.

Different skills tend to be more complementary when: (a) the production process is complex and flexible and, thus, the coordination among workers is essential to improve the productivity; and/or (b) the firm’s strategy requires that the production should be carefully coordinated with its customers and/or suppliers. Some empirical analyses are consistent with the above implication. Osterman [27] finds that firms which have a high-skill technology and/or “high-road” strategy are likely to transform work systems. Pil and Macduffies [29] show that flexible work practices increase the likelihood that a plant will increase its reliance on flexible automation. If flexible work practices induce more investment in firm-specific skills, firms with such practices are more likely to choose technology which relies more on those skills. Boning et al. [6] find that the new work system is more effective in plants that have more complex production processes.

Finally, the difference between the two forms of organization becomes considerable when the workers wages reflect their individual bargaining power regardless of whether there actually is an explicit or implicit individual bargaining process or not. Therefore, the M-organization will be favored in the workplaces that is not unionized and/or has more promotion prospects.

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13 “high-road” strategy means that firms compete on the basis of quality, variety or service rather than cost.
(so that there is more differentiation in lifetime income).

3.5 Applicability

The theory developed here crucially depends on the two assumptions: individual outputs are not verifiable; and each worker’s firm-specific skills are observable to the other worker of the firm as well as to the owner-manager. When individual outputs are verifiable, the owner-manager in the S-organization can design a contingent contract that induces a more efficient outcome than he can achieve by ex post bargaining. But such assumption would not be proper in many modern workplaces where production processes are complex and the quality aspect is getting more important. Team incentives may be more feasible, but they will never outperform ex post individual bargaining because of free-riding problem.

The role of observable skills in our model implies that the introduction of formal and intensive evaluation procedure which relies on subjective evaluation by the managers, peers and/or customers may be key to the relative efficiency of the M-organization discussed later. One supportive example is the typical Japanese automobile plant. Koike [22] explains that payment-for-skill in Japanese plants is implemented by the payment by job grade with a range of rates which reflect individual differences in skill development. He also argues that job matrices\textsuperscript{14} commonly observed in Japanese automobile plants allow everyone to observe and examine the level of skills acquired by the others as well as help to avoid favoritism.

One possible critique to our theory may be that, in manufacturing plants, wage bargaining

\textsuperscript{14}A “job matrix” is the table which describes the breadth and depth of each worker’s experience. It indicates who can work in which positions with what level of skill. It is often posted on the bulletin board at the shopfloor and revised by the subforeman.
is highly centralized and wage formula is typically standardized, so that individual bargaining
or the Shapley value as the wage bargaining outcome is not realistic. First, however, wages in
this model should be interpreted as lifetime wage income of skilled labor rather than short-term
wage. Even if workers cannot directly bargain over wages in the short run, those with better
skills can typically influence the managers’ decisions which affect their income in the long run
(e.g., promotion, job assignment, training, etc.). Therefore, bargaining process formalized in
our model captures a worker’s communication with his supervisors to make their decisions
reflect his voice over the long period of time. Second, most of our results hold as long as the
workers’ investments in skills constitute strategic substitutes in the M-organization and the
size of delegated decision rights and the worker’s skills are Edgeworth complements in the wage
function. So, the adoption of the Shapley value is not so essential.

4 Conclusion

This work makes several important contributions. First of all, we have demonstrated another
form of inefficiency created by incomplete contracts. Namely, the firm typically underdelegate
decision rights to the workers from the fear of giving away too much bargaining power to them.

Second, it explains one benefit of flexible work systems. Multiskilling practices can reduce
the distortion on investment and delegation created by the hold-up problem and tend to be
more efficient unless specialization offers a substantial technological advantage.

Third, it sheds a light on the complementarity among the practices found in the past liter-
ature. The theory implies that, when a firm chooses the M-organization, it should adopt work
teams to facilitate communication among workers, increase training programs to help workers
acquire broad skills, delegate more responsibilities to workers and introduce job rotation both for the training purpose and for the incentive purpose (i.e. to increase “competition”). Pay for skills is also consistent with this theory.

Finally, this work offers a possible link between a firm’s choice of organization and its technology and strategy. As has been discussed in the Section 3.4, a firm’s technology and strategy affect the complementarity among tasks, the degree of decreasing returns to learning, and the value of firm-specific human capital, which all affect the relative efficiency of the M-organization over the S-organization.
Appendix

A Assumptions (A.6), (A.7) and (A.8)

Lemma 3 When (A.6), (A.7) and (A.8) are satisfied, there exists \( r \in [0, 1] \) such that \( A_r \) is an optimal set of delegated decision rights.

Proof: Let \( A \) be the optimal set of delegated decision rights for the S-organization under individual bargaining. (A.7) gives us \( r_1 \) and \( r_2 \) such that
\[
\frac{\mu(A_r \cap S_1)}{2} \geq \lambda(A \cap S_1) \mu(A \cap S_1), \quad \frac{\mu(A_r \cap S_2)}{2} \geq \lambda(A) \mu(A \cap S_2),
\]
and \( V(((A_r \cap S_1) \cup (A_r \cap S_2))^c) \geq V(A^c) \). Therefore, assigning \( (A_r \cap S_1) \cup (A_r \cap S_2) \) to the workers should give both the owner-manager and the workers at least as much incentive and productivity as delegating \( A \) does. So, this new set should be optimal.

Now suppose \( r_1 \neq r_2 \) and let \( x_i(r_j) \) be the worker \( i \)'s choice of investment when he is assigned \( A_{r_j} \cap S_i \):
\[
\pi^{I \cdot S}((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2), x_1(r_1), x_2(r_2)) \geq \pi^{I \cdot S}(A_{r_1}, x_1(r_1), x_2(r_1)) \text{ leads to }
\]
\[
V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) - V(A_{r_1}^c) \geq \frac{\mu(A_{r_1} \cap S_2)}{4} P(x_2(r_1)) - \frac{\mu(A_{r_2} \cap S_2)}{4} P(x_2(r_2)).
\]
\[
\pi^{I \cdot S}((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2), x_1(r_1), x_2(r_2)) \geq \pi^{I \cdot S}(A_{r_2}, x_1(r_2), x_2(r_2)) \text{ leads to }
\]
\[
V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) - V(A_{r_2}^c) \geq \frac{\mu(A_{r_2} \cap S_1)}{4} P(x_1(r_2)) - \frac{\mu(A_{r_1} \cap S_1)}{4} P(x_1(r_1)).
\]
From (A.6) and the homogeneity of the workers, the sum of the right-hand sides of the two inequalities is zero. Therefore,
\[
2V(((A_{r_1} \cap S_1) \cup (A_{r_2} \cap S_2))^c) - V(A_{r_1}^c) - V(A_{r_2}^c) \geq 0. \text{ But this contradicts (A.9).}
\]

The proofs for collective bargaining and for the M-organization are more straight-forward and omitted.
Consider the case of individual bargaining for the M-organization.

\[
\frac{\partial w^{I,M,i}}{\partial x_{i,1}} = \frac{\lambda(A_W)\mu(A_W)}{4} P'(x_{i,1})(1 - \frac{2}{3} P(x_{j,1})) = c'(x_{i,1} + x_{i,2})
\]

\[
\frac{\partial w^{I,M,i}}{\partial x_{i,2}} = \frac{\lambda(A_W)\mu(A_W)}{4} P'(x_{i,2})(1 - \frac{2}{3} P(x_{j,2})) = c'(x_{i,1} + x_{i,2})
\]

If \(x_{j,1} \geq x_{j,2}, x_{i,1} \leq x_{i,2}\). But SNE indicates \(x_{i,1} = x_{j,1}\) and \(x_{i,2} = x_{j,2}\). The only possible case is \(x_{i,1} = x_{i,2} = x_{j,1} = x_{j,2} \equiv \frac{x}{2}\). \(x\) is the solution of

\[
\frac{\partial w^{I,M,i}}{\partial x_{i}} = \frac{\lambda(A_W)\mu(A_W)}{4} P'(\frac{x_i}{2})(1 - \frac{2}{3} P(\frac{x_i}{2})) = c'(x_i)
\]

(A.5) implies that \(x\) is uniquely determined. The proof for collective bargaining is almost identical.

Next, compare the first-order conditions for \(x^{I,M}, \tilde{x}^{I,M}, x^{C,M}\) and \(\tilde{x}^{C,M}\). 

This concludes the proof of the first half.
Choose $\lambda$ such that $P\left(\frac{x^I.M}{2}\right) = \frac{3}{5}$, then the second part of the proposition holds.

### D Proof of Proposition 5

For $P(x) = 1 - e^{-x}$, $P(x)'' = -P'(x)$ and $P(x) = 1 - P'(x)$.

By substituting (4), (5) and these equations into (7), we get

$$\frac{d\pi^t.S}{dr} = \frac{\partial w^t,M,i}{\partial x_i} - c'(x_i) = \frac{\lambda(AW)\mu(AW)}{4}P\left(\frac{x}{2}\right)\left(1 - \frac{2}{3}P\left(\frac{x}{2}\right)\right) - c'(x_i)$$

$$\frac{\partial (w^t,M,i + w^t,M,j)}{\partial x_i} - c'(x_i) = \frac{\lambda(AW)\mu(AW)}{4}P\left(\frac{x}{2}\right)\left(1 - \frac{4}{3}P\left(\frac{x}{2}\right)\right) - c'(x_i)$$

$$\frac{\partial w^C,M,i}{\partial x_i} - c'(x_i) = \frac{\lambda(AW)\mu(AW)}{8}P\left(\frac{x}{2}\right)\left(1 - P\left(\frac{x}{2}\right)\right) - c'(x_i)$$

$$\frac{\partial (w^C,M,i + w^C,M,j)}{\partial x_i} - c'(x_i) = \frac{\lambda(AW)\mu(AW)}{4}P\left(\frac{x}{2}\right)\left(1 - P\left(\frac{x}{2}\right)\right) - c'(x_i)$$

By comparing the slopes, we get $x^I.M > x^{C,M} > \hat{x}^I.M > x^{C,M}$ or $x^I.M > \hat{x}^C,M > x^{C,M} > \hat{x}^I.M$. Furthermore, $\frac{\partial (w^t,M,i + w^t,M,j)}{\partial x_i}|_{x_1 = x_2 = \hat{x}^I.M} \leq \frac{\partial w^C,M,i}{\partial x_i}|_{x_1 = x_2 = \hat{x}^I.M}$ at $\hat{x}^I.M \implies \hat{x}^I.M \leq x^{C,M}$

$$\frac{\partial (w^t,M,i + w^t,M,j)}{\partial x_i}|_{x = \hat{x}^I.M} \leq \frac{\partial w^C,M,i}{\partial x_i}|_{x = \hat{x}^I.M} \iff P\left(\frac{\hat{x}^I.M}{2}\right) \geq \frac{3}{5}$$

Choose $\lambda$ such that $P\left(\frac{\hat{x}^I.M}{2}\right) = \frac{3}{5}$, then the second part of the proposition holds.
\[
\frac{d\pi^{C,S}}{dr} = v'(r) + (\mu^S(r) + r\mu^{S'}(r)) \left[ \frac{1}{2} - \frac{P'(x^{C,S})}{2} \frac{c''(x^{C,S})/c'(x^{C,S})}{c'(x^{C,S})/c'(x^{C,S}) + 1} \right]
\]

(A.5) indicates that \(P_0'(x) = \frac{c'(x)}{c'(x) + 1} \) is decreasing in \(x\). Then, \(x^{I,S} > x^{C,S}\) implies that \(d\pi^{I,S} dr > d\pi^{C,S} dr\) for all \(r\) such that \(\mu^S(r) + r\mu^{S'}(r) > 0\). This leads to our result for the S-organization. The proof for the M-organization is similar and omitted.

**E Proof of Proposition 6**

Let \(r^k\) be the number such that \(\mu_k(r^k) + r^k\mu^{k'}(r^k) = 0\). Then, \(\mu^k(r) + r\mu^{k'}(r) > 0\) if and only if \(0 < r < r^k\).

Let \(x_1 = x_2 = x\).

\[\tau^{I,k}\] solves \(\frac{dY^k}{dr} = \frac{d\pi^{I,k}}{dr} + 2 \frac{\partial u^{I,k,i}}{\partial r} + \frac{\partial \partial w^{I,k,i}}{\partial x} dx^{I,k} = 0\).

For the S-organization, we use the fact that \(\frac{\partial \partial u^{I,S,i}}{\partial x} > 0\), which is verified easily. It is straightforward to show that, for \(0 \leq \forall r < \tau^S\), \(\frac{\partial u^{I,S,i}}{\partial r} > 0\) and \(\frac{d\pi^{I,S}}{dr} > 0\). Therefore, with \(\frac{\partial \partial u^{I,S,i}}{\partial x} > 0\), \(\frac{dY^S}{dr} > \frac{d\pi^{I,S}}{dr}\) for \(0 \leq \forall r < \tau^S\). This implies that \(\frac{dY^S}{dr} > 0\) for \(0 \leq \forall r < r^{I,S}\) leading to \(\tau^{I,S} > r^{I,S}\).

For the M-organization, \(\frac{\partial \partial u^{I,S,i}}{\partial r} > 0\) and \(\frac{d\pi^{I,S}}{dr} > 0\) are still true, but

\[
\frac{\partial w^{I,M,i}}{\partial x} = \frac{1}{4} r\mu^M(r) P'(\frac{x^{I,M}}{2}) - \frac{1}{3} r\mu^M(r) P'(\frac{x^{I,M}}{2}) P(\frac{x^{I,M}}{2})
\]

and it is non-negative if and only if \(P(\frac{x^{I,M}}{2}) \leq \frac{3}{4}\). Thus, it suffices to show that \(\frac{\partial \partial u^{I,k,i}}{\partial r} + \frac{\partial w^{I,k,i}}{\partial x} \frac{dx^{I,k}}{dr} > 0\) even when \(P(\frac{x^{I,M}}{2}) > \frac{3}{4}\). We use the following relations.

(a) \(\frac{r\mu^M(r)}{4} P'(\frac{x^{I,M}}{2}) (1 - \frac{2}{3} P(\frac{x^{I,M}}{2})) = c'(x^{I,M})\): obtained from the first-order condition, \(\frac{\partial \partial w^{I,M,i}}{\partial x} = c'(x^{I,M})\).
(b) \( P''(x) = \frac{1}{2} P'\left(\frac{x}{2}\right) - P\left(\frac{x}{2}\right) < 0 \): immediate from \( P'' < 0 \).

(c) \( P(x) > xP'(x) \): obtained from the concavity of \( P \).

Now suppose \( P\left(\frac{x}{2}\right) > \frac{3}{4} \). Given \( c(x) = \frac{1}{2}cx^2 \),

\[
\frac{\partial w^{I,M,i}}{\partial x} \frac{dx^{I,M}}{dr} = \frac{\mu^M + r\mu^M '(r)}{2} P\left(\frac{x^{I,M}}{2}\right) \left(1 - \frac{2}{3} P\left(\frac{x^{I,M}}{2}\right)\right)
\]

\[
\frac{\partial w^{I,M,i}}{\partial r} \frac{dx^{I,M}}{dr} = \frac{r\mu^M(r)}{4} P\left(\mu^M\right) \left(1 - \frac{4}{3} P\left(\frac{x^{I,M}}{2}\right)\right)
\]

We used (a) and (b) to derive the first inequality and (c) and \( x' = x \) for the second one. By summing the two results, \( \frac{\partial w^{I,M,i}}{\partial r} + \frac{\partial w^{I,M,i}}{\partial x} \frac{dx^{I,M}}{dr} > (\mu^M + r\mu^M '(r)) P\left(\frac{x^{I,M}}{2}\right) \left(1 - \frac{2}{3} P\left(\frac{x^{I,M}}{2}\right)\right) > 0 \)

for \( r \) such that \( \mu^M(r) + r\mu^M '(r) > 0 \). This leads to \( \frac{dy^{I,M}}{dr} > \frac{dx^{I,M}}{dr} \) for \( 0 < \forall r < \mu^M \) implying that \( \frac{dy^{I,M}}{dr} > 0 \) for \( 0 \leq \forall r \leq x^{I,S} \). Therefore, \( \tilde{r}^{I,M} > r^{I,M} \).

\[ F \quad \text{Proof of Proposition 7} \]

By substituting \( P(x) = 1 - e^{-x} \) and \( \mu^S = \mu^M = \mu \) into (8), we get

\[
\frac{d\pi^{I,S}}{dr} = v'(r) + (\mu(r) + r\mu'(r)) \left[\frac{1}{2} P\left(\frac{x^{I,S}}{2}\right) + \frac{2}{\mu(r)} \frac{c'(x^{I,S})^2}{4} + \frac{\mu(r)}{4} e^{-x^{I,S}}\right]
\]

\[
= v'(r) + (\mu(r) + r\mu'(r)) \left[\frac{1}{2} P\left(\frac{x^{I,S}}{2}\right) + \frac{2c'(x^{I,S})}{\mu(r)} + \frac{1}{c'(x^{I,S})} \frac{e^{-x^{I,S}}}{c'(x^{I,S}) + 1}\right]
\]

where the second line is derived by using the first-order condition \( \frac{\mu(r)}{4} \frac{P'(x^{I,S})}{P'(x^{I,S})} = \frac{\mu(r)}{4} e^{-x^{I,S}} = c'(x^{I,S}) \).
Similarly,

\[
\frac{d\pi^{\text{I,M}}}{dr} = v'(r) + (\mu'(r) + r\mu''(r))\left[ P\left(\frac{x^{\text{I,M}}}{2}\right) - \frac{1}{3} P\left(\frac{x^{\text{I,M}}}{2}\right)^2 \right]
\]

\[
+ \frac{2}{r\mu(r)} \frac{c''(x^{\text{I,M}})}{c''(x^{\text{I,M}})/c'(x^{\text{I,M}}) + 1}
\]

\[
\geq v'(r) + (\mu(r) + r\mu'(r))\left[ P\left(\frac{x^{\text{I,M}}}{2}\right) + \frac{1}{3} P(x^{\text{I,M}}) \right]
\]

\[
+ \frac{2C'(x^{\text{I,M}})}{r\mu(r)} \frac{1}{c''(x^{\text{I,M}})/c'(x^{\text{I,M}}) + 1}
\]

We used the first-order condition \( \frac{r\mu(r)}{4} P\left(\frac{x^{\text{I,M}}}{2}\right)(1 - \frac{2}{3} P\left(\frac{x^{\text{I,M}}}{2}\right)) = \frac{r\mu(r)}{4} \left( \frac{1}{3} e^{-x^{\text{I,M}}} + \frac{2}{3} e^{-x^{\text{I,M}}} \right) = c'(x^{\text{I,M}}) \) to derive the last inequality.

Compare the above two conditions term by term.

\[
\frac{1}{2} P(x^{\text{I,S}}) \leq \frac{1}{2} P(x^{\text{I,M}}) = \frac{1}{6} P(x^{\text{I,M}}) + \frac{1}{3} P(x^{\text{I,M}}) < \frac{1}{3} P\left(\frac{x^{\text{I,M}}}{2}\right) + \frac{1}{3} P(x^{\text{I,M}})
\]

The last inequality is derived by the concavity of \( P \). The next two inequalities are straightforward from \( x^{\text{I,S}} < x^{\text{I,M}} \) and \( \text{(A.5)} \).

\[
c'(x^{\text{I,S}}) \leq c'(x^{\text{I,M}})
\]

\[
\frac{1}{c''(x^{\text{I,S}})/c'(x^{\text{I,S}}) + 1} < \frac{1}{c''(x^{\text{I,M}})/c'(x^{\text{I,M}}) + 1}
\]

Hence, \( \frac{d\pi^{\text{I,S}}}{dr} < \frac{d\pi^{\text{I,M}}}{dr} \) for all \( r \) such that \( \mu(r) + r\mu'(r) > 0 \). This concludes the proof.
References


