Multiskilling, Delegation, and Continuous Process Improvement: A Comparative Analysis of U.S.-Japanese Work Organizations

by

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Abstract

This paper focuses on the following U.S.-Japanese differences in work organizations and labor market practices: in Japanese firms, (i) real decision-making authority is delegated more to lower hierarchical levels, (ii) employees are multiple-skilled, (iii) human capital accumulation is more firm-specific, (iv) labor turnover rate is lower, and (v) continuous process improvement is more prevalent. I present a model that addresses interconnections among three key features of work organizations (multiskilling, delegation, and continuous process improvement), and analyses ways in which they are related to labor market practices. It analyses strategic interactions among firms concerning their choices of the nature of work organizations, and shows that strategic complementarity due to labor market externality can yield the multiplicity of equilibria, which provides a systematic explanation for the U.S.-Japanese differences.

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1. INTRODUCTION

Nature of work organizations and labor market practices differ between the United States and Japan in a variety of ways. This paper focuses on the following differences. First, real decision-making authority is delegated more to lower hierarchical levels in Japanese firms than in U.S. firms. Aoki (1986, 1988) argues that typical Japanese firms employ horizontal information structure, in which workers have substantial decision-making power and determine how to cope with irregular events and exceptional operations through horizontal information exchange and coordination. Whereas typical U.S. firms employ vertical information structure, in which such decision is made at higher hierarchical levels. Second, Japanese firms tend to provide their employees with multiple skills for different jobs through on-the-job training and rotation, whereas such multiskilling practice is less common in U.S. firms. Third, human capital accumulation in Japanese firms is more firm-specific than in U.S. firms. Fourth, Japanese firms conduct continuous process improvement more than U.S. firms do. In particular, workers in Japanese firms are strongly encouraged to improve their work methods through actively participating in quality control (QC) circle activities.[1] Finally, the labor turnover rate is higher in the United States than in Japan. Hashimoto and Raisian (1985) showed that fifteen-year job retention rates were much higher in Japan than in the United States across all age groups.[2]

Several authors previously pointed out interconnections among some of these differences. Aoki (1986) analysed trade-offs between the two information structures, where delegated workers make quicker but sub-optimal decisions under horizontal information structure. He argued that horizontal information structure tends to be more efficient than vertical information

[1] Quality control circles in firms are small groups of workers meeting routinely to discuss ways to improve the efficiency and quality of their work performances (see, e.g., Hart and Kawasaki, 1999).

[2] See Section 2 for details on empirical evidences and case studies corresponding to the five differences described in this paragraph.

structure if workers have broad knowledge on the whole work process of the firm through multiskilling, because such broad knowledge enables workers to make better decisions concerning how to cope with irregular and emergent events. Koike (1988) pointed out that the provision of multiple skills through rotation is indispensable for inducing workers to improve their work methods through quality control (QC) circles activities, because such improvement requires that workers have a good understanding of the entire production process.

This paper provides a theoretical explanation for the five U.S.-Japanese differences based on the multiplicity of equilibria. It presents a model that incorporates the previous insights described above, and analyses ways in which several key features of work organizations are related to labor market practices. In my model, the difference in labor turnover rate endogenously arises due to labor market externality and provides a systematic explanation for the U.S.-Japanese differences. The explanation can be viewed as a formalization of the conjecture by Aoki (1986), who suggested that the different nature of labor mobility between the United States and Japan, interfirm mobility and intrafirm mobility (i.e. rotation) respectively, could be closely related to the difference in information structure of the firms between the two countries.

The logic of my argument goes as follows. A firm can provide its early-career employees with multiple skills for different jobs by incurring extra costs for their human capital accumulation. The employees then obtain a good understanding of the firm's entire work process through acquiring multiple skills. This enables the firm to conduct continuous process improvement by inducing its employees to actively participate in quality control (QC) circles activities. The firm can also take advantage of its employees' multiple skills by employing horizontal information structure in which real decision-making authority is delegated to lower hierarchical levels, because employees with multiple skills can cope with irregular and emergent events quickly and effectively.

Continuous process improvement involves a number of small changes and modifications, which are mostly unobservable from outside the firm.[3] Therefore, if a firm conducts continuous process improvement, a degree of specificity is introduced into the firm's technology.[4] An improved technology yields higher productivity only if it is operated by an employee who has been trained in the technology and so is familiar with its firm-specificity. Hence, the more employees remain in the firm, the higher the benefit of continuous process improvement. When other firms also conduct continuous process improvement, the firm's turnover rate becomes lower (and so its retention rate becomes higher) because its employees are less productive in other firms. Hence, the benefit of continuous process improvement increases when other firms also conduct continuous process improvement. On the other hand, the cost for providing its employees with multiple skills, the prerequisite for continuous process improvement, is not affected by other firms' behavior. If the net benefit is positive only if other firms also conduct continuous process improvement, two equilibria can exist; all firms conduct continuous process improvement in one equilibrium, whereas no firms conduct it in the other equilibrium. The former is interpreted as the Japanese equilibrium, and the latter the U.S. equilibrium.

In the Japanese equilibrium, each firm provides its employees with multiple skills, which enables continuous process improvement. Also, each firm employs horizontal information structure, because it is more efficient than vertical information structure if employees have multiple skills. Since continuous process improvement leads to a degree of specificity in a firm's

[3] In their survey of 650 U.S. executives, Levin *et al.* (1987) found that secrecy is perceived to be much more effective than patents for preventing duplication of new and improved processes.

[4] This has been pointed out by several authors. See Section 3 for details.

technology, skills acquired by its employees become less effective in other firms. This lowers the turnover rate in the Japanese equilibrium, which, in turn, implies that Japanese firms' extra human capital investments in multiple skills pay off later. In contrast, no firms provide their employees with multiple skills in the U.S. equilibrium. This induces each firm to employ vertical information structure and adopt the general technology without conducting continuous process improvement. Employees accumulate general human capital under the general technology, and this raises the turnover rate in the U.S. equilibrium. Concerning equilibrium selection, historical events can provide an explanation for why different equilibria have been selected in the United States and Japan. I will discuss this point in detail in Section 4.

This paper is related to Morita (2001), which focused on U.S.-Japanese differences concerning continuous process improvement, turnover rate, and the level and firm-specificity of human capital accumulation. The paper showed that connection between continuous process improvement and the firm-specificity of training causes multiplicity of equilibria, and explored its labor market consequences. One equilibrium is interpreted as the Japanese equilibrium, in which all firms conduct continuous process improvement, and as a consequence training provided by such a firm becomes less effective in other firms. This lowers the turnover rate, which, in turn, increases firms' incentives to train employees. In the other equilibrium (interpreted as the U.S. equilibrium), training is general, which raises the turnover rate and decreases incentives to train.

Several other authors have also presented theoretical analyses related to the present paper. Carmichael and MacLeod (1993) considered a model in which workers have good ideas for technological progress. They showed that employees could induce workers to actively participate in technological progress by providing them with multiple skills. By multiskilling, employers can credibly commit to retain workers after technological progress is completed, because it is the employers' own interests *ex post* to transfer these workers to other jobs. Under principal-multi agents frameworks, Itoh (1991, 1992, 1994) and Owan (2001) analyzed agents' incentive issues, which are not addressed in the present paper. Itoh identified, in a variety of settings, conditions in which a principal prefers broad task assignments to specialized task assignments. Itoh (1994) showed that broad task assignment can be desirable from the incentive viewpoint even without technological complementarity among tasks. Owan (2001) showed that a principal can benefit from delegating a substantial level of decision-making authority to agents and assigning multiple and overlapping tasks to them, because this induces agents to acquire higher levels of human capital in order to enhance their bargaining power for their *ex post* wage negotiations.

Concerning explanations for cross country differences based on multiple equilibria, several authors recently proposed models that provide explanations for the lower turnover rate and higher human capital accumulation in Japan (or Germany) than in the United States (see, for example, Prendergast, 1989; Chang and Wang, 1995; Acemoglu and Pischke, 1998). These are adverse selection models, where informational asymmetry on workers' abilities plays a central role in explaining the differences.

The present paper is complementary to these earlier papers. The main contribution of the present paper is that it addresses interconnections among three key features of work organizations (multiskilling, delegation, and continuous process improvement), and analyses ways in which they are related to labor market practices. It analyses strategic interactions among firms concerning their choices of the nature of work organizations, and shows that strategic complementarity due to labor market externality can yield the multiplicity of equilibria, which provides a systematic explanation for the U.S.-Japanese differences in work organizations and labor market practices. Furthermore, the explanation is consistent with historical events during the Second World War, where government labor regulations for enhancing labor productivity during the war were substantially different between the United States and Japan in many aspects.

The rest of the paper is organized as follows. Section 2 presents empirical evidence and case studies concerning the five U.S.-Japanese differences which this paper focuses on. Section 3 presents a two-period model, where firms simultaneously make decisions concerning the nature of their work organizations in period 1 and employees accumulate human capital. Employees can switch their employers between period 1 and 2. Section 4 first derives the Subgame Perfect Nash Equilibria of the model, and shows that the result provides an explanation for the five U.S.-Japanese differences in work organizations and labor market practices. Section 5 summarizes and concludes.

2. EVIDENCE

In this section, I present empirical evidence and case studies concerning the five U.S.-Japanese differences this paper focuses on. First, real decision-making authority is delegated more to lower hierarchical levels in Japanese firms than in U.S. firms. Lincoln *et al.* (1986) identified this phenomenon through a careful comparative survey of 55 American and 51 Japanese manufacturing plants. They investigated hierarchical levels to which real decision-making authority for 37 decision items is assigned, and found that the average level of decision-making authority was substantially lower in Japanese plants than in American plants. Similarly, Kagono *et al.* (1985) found, through their large-scale questionnaire survey of U.S. and Japanese firms, that strategic corporate decisions are made at or near the top in U.S. firms, whereas the decision making process involves employees at lower hierarchical levels in Japanese firms. See also, e.g., Clark (1979) and Cole (1979).

Second and third differences, multiskilling and firm-specificity of human capital accumulation, concern the nature of human capital accumulation within firms. Koike (1977) observed, in his comparative study of Japanese and U.S. manufacturing plants, that workers in Japanese plants acquire much wider range of different skills through on-the-job training and rotation than workers in U.S. plants do (see also Koike, 1988). Such multiskilling is not limited to factory workers but is also prevalent among so called white-collar employees in Japanese firms (see, e.g., Kono, 1984; Dertouzos *et al.*, 1989). According to Ito (1992), “In order to have workers who possess many different skills, a Japanese company has them invest in various skills early in their careers at the company’s expense. These human-capital investments pay off later in the worker’s careers” (p. 215).

Concerning firm-specificity of human capital accumulation, Koike (1977) observed that Japanese firms provide their employees with more firm-specific skills by rotating them among related jobs (see also Dertouzos *et al.*, 1989; Ito, 1992). Aoki and Okuno-Fujiwara (1996) pointed out that, in Japanese factories, operators handle machine troubles and unusual operations through their firm-specific skills, whereas in U.S. factories it is usually engineers who handle them through general skills. Also, a recent survey of large Japanese firms, conducted by Daiichi Insurance Company in 1996, showed that only 34 per cent of employees felt they had transferable skills.

Fourth, Japanese firms conduct continuous process improvement more than U.S. firms do. According to Koike (1988), workers in Japanese firms are encouraged to improve their work methods through actively participating in quality control (QC) circle activities, whereas workers in U.S. firms are expected to perform just routine work without making such improvement. The M.I.T. commission on Industrial Productivity found, through a number of case studies conducted in the late 1980s, that continuous process improvement is a key factor behind Japanese firms' productive edge. For example, the Commission found that, in Japanese steel manufacturing companies, engineers were located at each plant to continuously improve manufacturing processes through quickly addressing day-to-day operational problems; whereas, in the U.S. counterparts, engineers were deployed at a central location and conducted trouble shooting only when they were called for (Dertouzos *et al.*, 1989, p. 75-6).

Finally, the labor turnover rate is higher in the United States than in Japan (see, e.g., Hashimoto and Raisian, 1985; Mincer and Higuchi, 1988; Blinder and Krueger, 1996). Hashimoto and Raisian (1985) analyzed data from the *Basic Survey of Employment* for Japan and data from the *Special Labor Force Report* for the United States, and found that the fifteen-year job retention rates of the male population between the early 1960s and the late 1970s were much higher in Japan than in the United States across all age groups. They also found that average job tenure of employed males as of 1979 was longer in Japan than in the United States not only for large firms but also for small firms.[5]

3. THE MODEL

Consider a two-period economy. Only one good is produced in the economy, and its price is normalized to one. There is free entry and firms are risk neutral, and therefore in equilibrium all firms earn zero profits. To keep the analysis simple, firms and individuals do not discount the future. Labor is the only input, and the production requires two jobs (call them job A and job B).

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[5] The labor turnover rate in Japan continued to be substantially lower than that in the United States in the 1990s. See, e.g., Genda and Rebick (2000).

An employee can be assigned to only one of these two jobs in each period. There is a continuum of individuals, indexed by $j \in [0, N]$ ($N > 0$). In each period, labor supply is perfectly inelastic and fixed at one unit for each individual. Individuals display no disutility of effort. Also, assume that individuals are either risk neutral or averse.

Output is realized at the end of each period. Firm i's output in period t is given by

$$Y_{it} = \mathrm{Min}[P_{it}^{A}, P_{it}^{B}].$$

$P_{it}^{A} \equiv \int_{A_{it}} \rho_{it}^{A}(j)\,d\mu$ and $P_{it}^{B} \equiv \int_{B_{it}} \rho_{it}^{B}(j)\,d\mu$, where A_{it} (B_{it}) denotes the set of j such that $j \in A_{it}$ (B_{it}) means individual j is employed by firm i and assigned to job A (B) in period t, μ denotes Lebesgue Measure, and $\rho_{it}^{A}(j)(\rho_{it}^{B}(j))$ denotes individual j's productivity when she is employed by firm i and assigned to job A (B) in period t. The specification of $\rho_{it}^{A}(j)(\rho_{it}^{B}(j))$ will be given below.

At the beginning of period 1, each individual has the same general human capital and looks identical to the firms. Firms simultaneously make first period wage offers ($\hat{w}_i > 0$, i = 1, 2, …) to the individuals. Each individual offers herself for employment to the firm that offers the highest wage. If several firms offer the same wage, individuals split themselves equally among the firms.[6]

In period 1, after having hired individuals but prior to producing any output, all the firms that have hired individuals simultaneously make the following three decisions. Once the decisions are made, they become public knowledge. First, the firms decide whether they provide their employees with a single skill (denoted S) or multiple skills (denoted M). Let k_i (= S or M) denote firm i's choice. If k_i = S, a half of firm i's employees acquire a skill for Job A, and the

[6] To ensure that at least three firms operate in equilibrium, I assume that the maximum number of employees a single firm can hire is $D < N/2$. See the Appendix for details.

other half acquire a skill for job B. If k_i = M, all the employees acquire both skills. Let c_S (> 0) denote a cost (per employee) for a firm to provide a single skill, and c_M (>c_S) for multiple skills. Let $c \equiv c_M - c_S$ (> 0), which is the extra cost for providing multiple skills. Second, they choose either vertical information structure (denoted V) or horizontal information structure (denoted H). Let r_i (= V or H) denote firm i's choice. Third, they decide whether or not to conduct continuous process improvement; each firm chooses either general technology (denoted G) or improved technology (denoted I). Let t_i (= G or I) denote firm i's choice.

In the first period of a firm's operation, each employee's productivity is fixed at d (> 0). While productivity in the second period is affected by choices made in the first period by firms that hired individuals.[7] Recall that each firm i's choices are denoted by (k_i, r_i, t_i), where k_i = S (provision of a single skill) or M (multiple skills), r_i = V (vertical information structure) or H (horizontal information structure), and t_i = G (general technology) or I (improved technology). In the second period of firm u's operation, individual j's productivity in job A (B) is given by $\rho_{ut}^{A}(j)(\rho_{ut}^{B}(j))$ = d if individual j did not acquire a skill for job A (B) in the previous period and $\rho_{ut}^{A}(j)(\rho_{ut}^{B}(j)) = y_{uj}^{i}$ otherwise, where superscript i and subscript u mean that individual j was hired by firm i in the first period and is in firm u in the second period. y_{uj}^{i} is given by

$$y_{uj}^{i}(a_{uj}, k_i, r_u, t_i, t_u) = \begin{cases} a_{uj}x(t_i, t_u, z)H(k_i) + d & \text{if } r_u = H \\ a_{uj}x(t_i, t_u, z)V(k_i) + d & \text{if } r_u = V \end{cases},$$

where a_{uj} is individual j's match quality with firm u. Here, x(t_i, t_u, z) (z = 0 or 1) captures the productivity of an individual who acquired skills in firm i and is in firm u in period 2, where z =

[7] In this specification, a firm that enters in period 2 has a fixed productivity per employee of d even if it employs workers who have already acquired skills in other firms. Implicitly, I am assuming that the higher productivity in a firm's second period of operation is partly due to knowledge acquired by a firm during its first period of operation.

0 means that she has stayed with the same employer, and z = 1 means that she has changed her employer. Namely, i = u if z = 0 and i ≠ u if z = 1.

Assume H(M) > V(M) > V(S) > H(S) > 0. That is, if an employee has multiple skills, her productivity is higher under horizontal information structure than vertical information structure, whereas her productivity is higher under vertical information structure if she has just a single skill. This assumption reflects the point made by Aoki (1986), who argued that horizontal information structure tends to be more efficient than vertical information structure if workers have broad knowledge on the whole work process of the firm through multiskilling, because such broad knowledge enables workers to make better decisions concerning how to cope with irregular and emergent events. Also assume that each firm i can choose t_i = I (improved technology) only if it chooses k_i = M (multiple skills). This assumption reflects Koike (1988)'s observation that the provision of multiple skills is indispensable for inducing workers to improve their work methods through quality control (QC) circles activities, because such improvement requires that workers have a good understanding of the entire production process.[8]

If a firm conducts continuous process improvement, the technology is improved but a degree of specificity is introduced. This is because, in general, continuous process improvement involves a number of small changes and modifications, which lead to highly firm-specific technologies. Doeringer and Piore (1971) made exactly this point. 'Line supervision, and sometimes operatives and maintenance crews as well, are forever modifying equipment in order

[8] To illustrate the importance of understanding the entire production process, Koike described an example from an automated workshop for wrapping sausages. The workers in the workshop found that, in order to reduce the defect rate for wrapping, the heating treatment of the sausages should be adjusted at the earlier processing stages.

to improve its efficiency. Such changes accumulate quickly and can produce considerable movement toward specificity' (p. 17).[9]

Technology and skill acquisition are closely related. I assume that, if an individual acquires a skill under the general technology, her skill is equally valuable at any firm that employs the general technology; while, if an individual acquires a skill under an improved technology, her skill is specific to this firm to a certain degree. I assume that, holding everything else constant, an improved technology yields higher second period productivity than the general technology only if it is operated by an individual who is familiar with its firm-specificity. Otherwise, it yields less productivity than the general technology.[10]

The two assumptions above imply the following properties for $x(\cdot, \cdot, \cdot)$. First, $x(I, I, 0)$ takes the highest value among all combinations of $x(t_i, t_u, z)$. Namely, holding everything else constant, an individual's second period productivity is the highest if she acquired skills under a firm's improved technology and operates it in period 2. Second, $x(t_i, t_u, 1) \leq x(G, G, 0)$ for all combinations of t_i and t_u, where the weak inequality holds with equality if and only if $t_i = t_u = G$. This says two things. First, suppose that an individual operates the general technology in period 2. If an individual acquired a skill under the general technology in period 1, her productivity is unaffected whether or not she changed her employers. On the other hand, if she acquired a skill under an improved technology, holding everything else constant, her period 2 productivity becomes lower due to firm-specificity of her skill. Second, if a firm's improved technology is

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[9] Also, Hayes and Wheelwright (1984) pointed out, 'Most world class Germany and Japanese manufacturing companies have large, well-staffed, very active machine shops. Much of the success of these companies is a result of the proprietary production processes that are incubated in these shops and therefore unavailable to their competitors' (p. 381).

[10] In other words, through continuous process improvement, changes and modifications are made to machines in the production process such that, if the machines are operated optimally then productivity increases, but if the machines are operated as if they were general technology machines then productivity falls.

operated by an individual who has not acquired skills under the technology and hence is not familiar with its firm-specificity, holding everything else constant, the improved technology yields less productivity than the general technology.

Individual j has match qualities $\mathbf{a}_j \equiv (a_{1j}, a_{2j}, \ldots, a_{\gamma j})$ with firm 1, 2, ..., γ respectively, where γ denotes the number of firms that offer second period wages and $0 \le a_{ij} \le 1$. The match qualities are independently and identically distributed across firms and individuals according to a uniform distribution between 0 and 1. This is common knowledge. At the beginning of period 1, $\mathbf{a}_j$ is unknown to individual j and the firms. If an individual is employed by firm i in period 1, the match quality a_{ij} becomes known to the individual and firm i at the end of period 1.[11] Match quality in my model is an experience good as in Jovanovic (1979).

At the beginning of period 2, firms simultaneously make second period wage offers. All firms that operated in period 1 make wage offers to all individuals. Firms that did not operate in period 1 can also make wage offers. Firm i's wage offer to another firm's period 1 employees is denoted w^{iu} ($i \neq u$). Note that, when a firm makes wage offers to its own period 1 employees, it knows their match qualities with itself. Hence, the wage offers can be different across individuals. w_j^{ii} denotes firm i's wage offer to its own period 1 employee, individual j. I assume that wage offers are public knowledge. Given the wage offers, each individual takes the highest one. If more than one firm offers the highest wage, the employee stays with her current employer if it offered the highest wage, and randomly chooses one of the highest offers otherwise.

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[11] One way to justify the learning of match qualities is by assuming that the match qualities affect first period productivities, and each employer learns her first period employees' match qualities by observing their productivities. All the results of the paper follow under this assumption if each individual's expected first period productivity is d.

Whether or not other firms learn the match quality a_{ij} does not affect the results, because an individual's match qualities are independently distributed across firms. If the match qualities were correlated across firms and the realization of match quality were known only to the individual and her current employer, adverse selection would occur as in Greenwald (1986). Since the focus of this paper is on interconnections among the three key features of work organizations and its labor market consequences, I do not incorporate adverse selection into my model.

I summarize the interaction among the firms and the individuals as follows.

(Stage 1) Firms simultaneously make first period wage offers ($\hat{w}_i > 0$, i = 1, 2, …) to the individuals. Each individual offers herself for employment to the firm that offers her the highest wage. If several firms offer the same wage, individuals split themselves equally among the firms. The maximum number of employees a single firm can hire is D.

(Stage 2) Firms that hired a strictly positive number of individuals simultaneously make the following three decisions: each firm i chooses (k_i, r_i, t_i), where k_i = S (provision of a single skill) or M (multiple skills), r_i = V (vertical information structure) or H (horizontal information structure), and t_i = G (general technology) or I (improved technology).

(Stage 3) The match quality a_{ij} becomes known to individual j and her period 1 employer firm i. Then, each firm makes its second period wage offers to other firms' period 1 employees; firm i chooses w^{iu} (> 0, i ≠ u). At the same time, each firm makes its second period wage offers to its own period 1 employees (if any); firm i chooses w_j^{ii} (> 0) for all j employed by firm i in period 1. Firms that did not operate in period 1 can also make second period wage offers.

(Stage 4) Given the second period wage offers, each individual takes the highest one. If more than one firm offers the highest wage, the employee stays with her current employer if it offered the highest wage, and randomly chooses one of the highest offers otherwise.

4. ANALYSIS

In this section, I consider Subgame Perfect Nash Equilibria (SPNE) in pure strategies of the model described above. I define MHI-equilibrium to be an SPNE outcome where each firm provides its employees with multiple skills (M), chooses horizontal information structure (H), and employs an improved technology (I). Whereas in SVG-equilibrium each firm provides its employees with a single skill (S), chooses vertical information structure (V), and adopts the general technology (G). The central result is presented in Proposition 1, which states that there exist parameterizations under which the game has both an MHI-equilibrium and an SVG-equilibrium and there are no other symmetric equilibrium outcomes. Note, all proofs except Lemma 1 are in the Appendix.

For the MHI-equilibrium to exist, each firm i's optimal choice concerning skill provision, information structure and technology must be $(k_i, r_i, t_i) = (M, H, I)$ given all other firms choose (M, H, I). Similarly, each firm i's optimal choice must be $(k_i, r_i, t_i) = (S, V, G)$ given all other firms choose (S, V, G) for the SVG-equilibrium to exist. Lemma 1 analyses stage 3 subgames in which all firms except firm i have made the same choice denoted (K, R, T) where K = S or M, R = V or H, and T = G or I, and identifies equilibrium second-period wage offers to firm i's first period employees.

Lemma 1: Suppose that at least three firms operate in period 1, and that firm i chose (k_i, r_i, t_i) and all other firms chose $(k_u, r_u, t_u) = (K, R, T)$ at stage 2. The SPNE outcome of the subsequent subgame is characterized by the following.

$$w^{ui} \leq (1/2)[(1/2)x(t_i, T, 1)R(k_i) + d] \equiv w^* \text{ for all } u \neq i, \quad (1)$$

where the weak inequality holds with equality for at least two firms.

$$w_j^{ii} = \begin{cases} w^* \; if \;\; a_{ij} \geq x(t_i, T, 1)R(k_i)/(2x(t_i, t_i, 0)r_i(k_i)) \equiv \tilde{a} \\ \eta \;\; otherwise \end{cases}, \quad (2)$$

for all j employed by firm i in period 1, where $0 \leq \eta < w^*$.

Suppose individual j was employed by firm i in period 1. Since her match quality with other firms is unknown, her period 2 expected productivity in firm u (≠ i) (provided that she is assigned to a job for which she has acquired a skill) is $E(a_{uj})x(t_i, t_u, 1)r_u(k_i) + d = (1/2)x(t_i, T, 1)R(k_i) + d$ if firm u operated in period 1. Note that the expected productivity is the same value across all other firms that operated in period 1 and less than that value in firms that did not operate in period 1, and that firm u's output in period t is given by $Y_{ut} = Min[P_{ut}^A, P_{ut}^B]$. Then, Bertrand wage competition bids up the wage until it equals $(1/2)[(1/2)x(t_i, T, 1)R(k_i) + d] \equiv w^*$. This establishes (1). Firm i can retain individual j by offering $w_j^{ii} = w^*$. Since firm i knows its employees' match qualities with itself when it makes period 2 wage offers, it retains individual j if $(1/2)[a_{ij}x(t_i, t_i, 0)r_i(k_i)+d] - w^* \geq 0 \Leftrightarrow a_{ij} \geq x(t_i, T, 1)R(k_i)/(2x(t_i, t_i, 0)r_i(k_i)) \equiv \tilde{a}$.[12] This establishes (2). Note that the turnover rate of firm i's first period employees is determined by the cut-off match quality ã. The second period wage offers and the turnover rate are determined by choices made by firms at stage 2 concerning skill provision, information structure and technology. I will now present the central result in Proposition 1.

Proposition 1: For any given parameter values, there exist values c' (> 0) and c" (> 0) such that, if c' < c < c", the game has both an MHI-equilibrium and an SVG-equilibrium and no other symmetric equilibria. The MHI-equilibrium Pareto dominates the SVG-equilibrium if c' < c < c". Also, the MHI-equilibrium exhibits a lower turnover rate than the SVG-equilibrium. There exist parameterizations for which c' < c".[13]

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[12] This property holds whether k_i is S or M, because, if k_i = S, a half of firm i's period 1 employees acquire a skill for job A and the other half acquire a skill for job B.

[13] There do not exist asymmetric equilibria in which at least two firms choose the same combination of skill provision (S or M), information structure (V or H), and technology (G or I). However, I was unable to rule out the possibility of asymmetric equilibria in which one firm chooses a different combination from all other firms.

It is well known that strategic complementarity can cause multiple equilibria.[14] Cooper and John (1988) showed that strategic complementarity is necessary for multiple symmetric Nash equilibria. The logic is as follows.[15] Consider a game where n agents choose actions, either the low action (L) or the high action (H), simultaneously and non-cooperatively to maximize their payoffs. Suppose there exist two symmetric equilibria, the low action equilibrium and the high action equilibrium. Then an agent's optimal strategy is L when all other agents choose L. Namely the agent's incremental payoff from choosing H over L is negative when all other agents choose L. On the other hand, if all other agents choose H, the agent will increase her payoff by choosing H over L. Namely the incremental payoff is positive in this case. This is a strategic complementarity; an agent's marginal (incremental) return increases when all other agents increase their actions (choose H over L).

In my model, strategic complementarity arises endogenously due to labor market externality. Suppose that firm i provides its employees with multiple skills in period 1. The firm must incur an extra cost, c (> 0) per employee, for providing multiple skills. In return, since multiskilling enables continuous process improvement, firm i can choose an improved technology (I), which enhances period 2 productivity of its retained employees. Firm i can further increase their productivity by choosing horizontal information structure (H). These are the benefits of multiskilling. Since a degree of specificity is introduced into a firm's technology if an improved technology is chosen, firm i's period 1 employees become less productive in other firms if other firms also choose improved technologies. This lowers firm i's turnover rate, and so enhances its marginal (incremental) benefit from choosing multiskilling because it can

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[14] A game exhibits strategic complementarity if the marginal returns to increasing one's strategy rise with increase in the competitors' strategies (see Bulow *et al.* ,1985; Milgrom and Roberts, 1990).

[15] Cooper and John considered the case where action is a continuous variable, whereas action is a discrete variable in the following argument.

retain more employees who are familiar with its own improved technology. That is, firm i's marginal benefit of choosing (M, H, I) strategy over (S, V, G) strategy increases, due to labor market externality, if all other firms also choose (M, H, I) strategy. This is the strategic complementarity in my model.

On the other hand, the extra cost for providing multiple skills is not affected by other firms' choices. Hence, if the extra cost for multiskilling is in an intermediate range, the net benefit of choosing (M, H, I) strategy can be positive only if other firms also choose the same strategy. Then the game has both an MHI-equilibrium and an SVG-equilibrium, where the former Pareto dominates the latter. To understand the welfare comparison result, consider firm i in the SVG-equilibrium. Firm i's second-period profit increases if all other firms choose (M, H, I) strategy over (S, V, G) strategy. This is because firm i's first-period employees become less effective in other firms in the second period if all other firms choose (M, H, I) strategy, which in turn means that firm i can retain its employees at a lower second-period wage. But, if all other firms choose (M, H, I) strategy, firm i can further increase its second-period profit by choosing (M, H, I) strategy because the game has the MHI-equilibrium as well. Noting that in equilibrium all firms earn zero profit due to free entry, this implies that total wages are higher in the MHI-equilibrium than in the SVG-equilibrium, and so the former Pareto dominates the latter.

By interpreting the MHI-equilibrium to be Japanese equilibrium and the SVG-equilibrium to be U.S. equilibrium, the model provides an explanation for the five U.S.-Japanese differences in work organizations and labor market practices. In the Japanese equilibrium, all firms provide their employees with multiple skills, and take advantage of the multiple skills by conducting continuous process improvement and employing horizontal information structure. A degree of specificity is introduced into each firm's improved technology, which results in firm-specificity in human capital and thus lowers the turnover rate. Due to the low turnover rate, each firm's extra investment in multiskilling pays off later. In contrast, in the U.S. equilibrium all firms provide their employees with a single skill. This induces each firm to employ vertical information structure and adopt the general technology, which results in general human capital and higher turnover rate. The extra investment in multiple skills does not pay off due to the high turnover rate.

This explanation can be viewed as a formalization of the conjecture by Aoki (1986), who suggested that the different nature of labor mobility between the United States and Japan, interfirm mobility and intrafirm mobility (i.e. rotation) respectively, could be closely related to the difference in information structure of the firms between the two countries. He wrote, “I simply suggest that there may be a close connection between labor market characteristics and information systematic characteristics of the firm from a comparative perspective” (Aoki, 1986, p. 981). In my model, the difference in labor turnover rate endogenously arises due to labor market externality and provides a systematic explanation for U.S.-Japanese differences in several key features of work organizations.

Concerning equilibrium selection, historical events during the Second World War can provide an explanation for why different equilibria have been selected in the United States and Japan. Moriguchi (2000) points out that government labor regulations for enhancing labor productivity during the war were substantially different between the United States and Japan in many aspects. The U.S. government promoted job simplification and standardization, and created industry-wide training programs such as the Training Within Industry program. In contrast, the Japanese government encouraged corporate training programs and the development of workers with multiple and firm-specific skills. The Skilled Employee Training Ordinance of

1939 required employers to provide three-year training programs within a company in order to foster “skilled mainstay workers (*chuken jukuren-ko*), which were defined as those who were multi-skilled and possessed a considerable technical ability to judge and perform tasks on the shop floor without consulting an instructor.[16]

In my framework, one can interpret that this difference in governmental policies during the war led the United States to choose the SVG-equilibrium while Japan to choose the MHI-equilibrium in the postwar period. This interpretation is consistent with the fact that the average turnover rate of manufacturing workers in the U.S. was comparable to that in Japan before the Second World War, in contrast to the postwar period during which the two numbers exhibited a significant difference (Moriguchi, 2000).

In the next proposition, I consider parameterizations for which c' < c", but where the extra cost for providing multiple skills is not in the intermediate range (namely c' < c < c" does not hold).

Proposition 2: Let c' and c" be as in Proposition 1. (i) The MHI-equilibrium is the unique symmetric SPNE outcome if c < c'. (ii) The SVG-equilibrium is the unique symmetric SPNE outcome if c > c".

If the extra cost for multiskilling is low, the net benefit of choosing (M, H, I) strategy becomes positive even if other firms choose the general technology (G) over an improved technology (I). The game does not have the SVG-equilibrium in this case. If the extra cost is

[16] Moriguchi (2000) argues that wartime labor regulation in the U.S. and Japan tended to reinforce the employment practices that had been gradually developed in large private firms throughout the 1930s, and diffuse these practices to the rest of the economy.

high, the net benefit of choosing (M, H, I) strategy becomes negative even if other firms choose the same strategy. The game does not have the MHI-equilibrium in this case.

5. SUMMARY AND CONCLUSION

This paper has focused on the five U.S.-Japanese differences in work organizations and labor market practices; namely, real decision-making authority is delegated more to lower hierarchical levels in Japanese firms, Japanese firms tend to provide their employees with multiple skills, human capital accumulation is more firm-specific in Japanese firms, Japanese labor turnover rate is lower, and Japanese firms conduct continuous process improvement more than U.S. firms do.

I have presented a model that provides an explanation for these differences based on the multiplicity of equilibria, where strategic complementarity concerning choice of work organizations arises endogenously due to labor market externality. In the Japanese equilibrium, each firm provides its employees with multiple skills. This enables continuous process improvement, because employees obtain a good understanding of the firm's entire work process through acquiring multiple skills. Also, each firm employs horizontal information structure, in which multiple-skilled employees have substantial decision-making authority and determine how to cope with irregular and emergent events. Since continuous process improvement leads to a degree of specificity in a firm's technology, skills acquired by its employees become less effective in other firms. This lowers the turnover rate in the Japanese equilibrium, which, in turn, implies that Japanese firms' extra human capital investments for providing multiple skills pay off later. In contrast, no firms provide their employees with multiple skills in the U.S. equilibrium. This induces each firm to employ vertical information structure and adopt the general technology. Employees accumulate general human capital under the general technology, and this raises the turnover rate in the U.S. equilibrium.

This paper is related to Morita (2001), which showed that connection between continuous process improvement and the firm-specificity of training causes multiplicity of equilibria, and explored its labor market consequences. Carmichael and MacLeod (1993) presented a model in which multiskilling serves as employers' commitment device for inducing their employees to actively participate in technological progress. Under principal-multi agents frameworks, Itoh (1991, 1992, 1994) and Owan (2001) analyzed agents' incentive issues, which have not been addressed in the present paper. Concerning explanations for cross country differences based on multiple equilibria, several authors recently proposed models that provide explanations for the lower turnover rate and higher human capital accumulation in Japan (or Germany) than in the United States (see, for example, Prendergast, 1989; Chang and Wang, 1995; Acemoglu and Pischke, 1998), where informational asymmetry on workers' abilities causes multiple equilibria.

This paper makes a contribution complementary to them. The main contribution of the present paper is that it addresses interconnections among three key features of work organizations (multiskilling, delegation, and continuous process improvement), and analyses ways in which they are related to labor market practices. It analyses strategic interactions among firms concerning their choices of the nature of work organizations, and shows that strategic complementarity due to labor market externality can yield the multiplicity of equilibria, which provides a systematic explanation for the U.S.-Japanese differences in work organizations and labor market practices. Furthermore, concerning equilibrium selection, historical events during the Second World War can provide an explanation for why different equilibria have been selected in the United States and Japan in the post war period.

Although this paper focused on an explanation for U.S.-Japanese differences based on multiplicity of equilibria, my model can be extended so that it yields explanations based on exogenous factors such as differences in the effectiveness of research and development (R&D). Mansfield (1988) found, in his comparative study of industrial R&D in Japan and the United States, that the rate of return from industrial basic research was higher in the United States than in Japan. This difference implies that U.S. firms tend to invest in basic research more than Japanese firms do, where basic research aims at inventing entirely new products and processes. This in turn implies that the return of continuous process improvement in U.S. firms tends to be lower than in Japanese firms, because such an improvement is built upon currently available technology and production processes which could become obsolete if entirely new technology and production processes are invented. My theoretical framework would then suggest that, if the extra cost for providing multiple skills is in an intermediate range, multiskilling is beneficial only for Japanese firms, and this would result in the set of U.S.-Japanese differences that this paper focused on. In a future research, I plan to extend the model in such directions.[17]

[17] I would like to thank Bill Schworm for suggesting this idea.

APPENDIX

The process in which firms employ individuals in period 1 is as follows. Suppose n' firms offer the highest wage. Since individuals split themselves equally among the firms, N/n' individuals offer themselves for employment to each firm. If N/n' ≤ D, each firm employs N/n' individuals and the process ends. If N/n' > D, each firm employs D individuals, and the remaining (N-n'D) individuals offer themselves to the firm(s) that offer the second highest wage. The process continues until all the individuals are employed. In any equilibrium where each firm makes the same choice at stage 2, all firms that hire some individuals offer the same first period wage due to symmetry and zero profit condition.

Note that all individuals are employed in any Subgame Perfect Nash Equilibria (SPNE). To see this, suppose some individuals are not employed. Then, a firm has an incentive to offer a wage w ($\in (0, d)$), employ them, and earn a strictly positive profit. Therefore, D < N/2 ensures that at least three firms operate in any equilibrium.

Proof of Proposition 1:

I will first establish two more lemmas.

Lemma 2: Suppose that, at stage 1, firm i offered $\hat{w}_i$ (> 0) and hired n (> 0) individuals and at least two other firms hired a positive measure of individuals. Suppose also that firm i chose (k_i, r_i, t_i) and all other firms chose (k_u, r_u, t_u) = (K, R, T) (where K = S or M, R = V or H, T = G or I) at stage 2. Firm i's profit in the SPNE of the subsequent stage 3 subgame, denoted $\pi_i[(k_i, r_i, t_i), (K, R, T)]$, is as follows.

$\pi_i[(k_i, r_i, t_i), (K, R, T)] = n\{(1/2)[\phi(k_i, r_i, t_i, R, T) + d + ((N – n)/n)\lambda(r_i, t_i, K, R, T)] – \chi – \hat{w}_i \}$,

where

(i) $\phi(k_i, r_i, t_i, R, T) \equiv \{1/[2x(t_i, t_i, 0)r_i(k_i)]\}[x(t_i, t_i, 0)r_i(k_i) – (1/2)x(t_i, T, 1)R(k_i)]^2$ if $\tilde{a} \le 1$ ($\tilde{a} \equiv x(t_i, T, 1)R(k_i)/(2x(t_i, t_i, 0)r_i(k_i))$) and 0 otherwise,

where $r_i(k_i) \equiv \begin{cases} V(k_i)\ if\ r_i = V \\ H(k_i)\ if\ r_i = H \end{cases}$, and $R(k_i)$ is defined analogously.

(ii) $\lambda(r_i, t_i, K, R, T) \equiv \begin{cases} \varphi\ if\ x(T,t_i,1)r_i(K) > 2x(T,T,1)R(K) \\ \theta\ if\ 2x(T,T,1)R(K) > x(T,t_i,1)r_i(K) > x(T,T,1)R(K) \\ 0\ otherwise \end{cases}$, where $\varphi \equiv (1/16)[x(T, t_i, 1)r_i(K)]^2/[x(T, T, 0)R(K)]$,

$\theta \equiv (1/4)[x(T, t_i, 1)r_i(K) - x(T, T, 1)R(K)][x(T, T, 1)/x(T, T, 0)]$,

(iii) $\chi \equiv \begin{cases} c^S \ \text{if} \ k_i = S \\ c^M \ \text{if} \ k_i = M \end{cases}.$

Proof of Lemma 2:

First I will show that firm i's period 2 profit from retained employees is $(n/2)\phi(k_i, r_i, t_i, R, T)$. By Lemma 1, firm i retains individual j if $a_{ij} \geq x(t_i, T, 1)R(k_i)/(2x(t_i, t_i, 0)r_i(k_i)) \equiv \tilde{a}$ by offering $w_j^{ii} = w^*$. Then, firm i's period 2 profit from retained employees is 0 if $\tilde{a} > 1$. Otherwise, applying the law of large numbers, the profit is given by

$$n(1 - \tilde{a})\{(1/2)[E[a_{ij}| \ a_{ij} \geq \tilde{a}]x(t_i, t_i, 0)r_i(k_i)+d] - w^*\}$$
$$= (n/2)\{1/[2x(t_i, t_i, 0)r_i(k_i)]\}[x(t_i, t_i, 0)r_i(k_i) - (1/2)x(t_i, T, 1)R(k_i)]^2. \quad \text{(A1)}$$

Next I will show that firm i's period 2 profit from employees trained by other firms, denoted π_{i2}^O, is $(1/2)(N- n)\lambda(r_i, t_i, K, R, T)$. First note that all N individuals are employed in period 1. Without loss of generality, let i = 1 and assume that two other firms (call them firm 2 and 3) employed a positive measure of individuals in period 1. If individual j accumulated her skill in firm 2, her period 2 expected productivity in firm 1 (provided that she is assigned to a job for which she has acquired a skill) in period 1 is $(1/2)x(T, t_1, 1)r_1(K) + d$ and that in firm 3 is $(1/2)x(T, T, 1)R(K) + d$. Hence, $\pi_{12}^O = 0$ if $x(T, t_1, 1)r_1(K) < x(T, T, 1)R(K)$. Assume $x(T, t_1, 1)r_1(K) > x(T, T, 1)R(K)$ in what follows, and ignore firm 3 for now. Suppose firm 1 offers $w^{12}(\geq 0)$ to firm 2 trained individuals. Then, noting that firm 2's output in period t is given by $Y_{2t} = \text{Min}[P_{2t}^A, P_{2t}^B]$, firm 2 retains individual j if and only if

$$(1/2)[a_{2j}x(T, T, 0)R(K) + d] \geq w^{12} \Leftrightarrow a_{2j} \geq (2w^{12} - d)/(x(T, T, 0)R(K)).$$

Then, the measure of firm 2 trained individuals who move to firm 1 is $n_2(2w^{12} - d)/(x(T, T, 0)R(K))$, where n_2 denotes the measure of firm 2's period 1 employees. Then firm 1's period 2 profit from firm 2 trained individuals is

$$n_2[(2w^{12}-d)/(x(T, T, 0)R(K))](1/2)[(1/2)x(T, t_1, 1)r_1(K) - (2w^{12}-d)]. \quad \text{(A2)}$$

The optimal choice of w^{12} is $w^* = (1/2)[(1/4)x(T, t_1, 1)r_1(K) + d]$.

Now, take the existence of firm 3 into account. Individual j's period 2 expected productivity in firm 3 is $(1/2)x(T, T, 1)R(K) + d$. Hence, for firm 1 to hire her, $w^{12} \geq (1/2)[(1/2)x(T, T, 1)R(K) + d]$ must hold. Note that $w^* \geq (1/2)[(1/2)x(T, T, 1)R(K) + d] \Leftrightarrow x(T,$

t_1, 1)r_1(K) ≥ 2x(T, T, 1)R(K). If x(T, t_1, 1)r_1(K) ≥ 2x(T, T, 1)R(K), the optimal wage offer (denoted w^{12}*) is w*. Plug this in (A2) and obtain (n_2/2)(1/16)[x(T, t_1, 1)r_1(K)]^2/[x(T, T, 0)R(K)], as firm 1's period 2 profit from firm 2 trained individuals. The same argument for individuals trained by firm 3. Hence,

$$\pi_{12}^O = (1/2)(N\text{-}n)\varphi, \qquad (A3)$$

where $\varphi \equiv (1/16)[x(T, t_i, 1)r_i(K)]^2/[x(T, T, 0)R(K)]$. Similarly, if 2x(T, T, 1)R(K) > x(T, t_1, 1)r_1(K) > x(T, T, 1)R(K), then w^{12}* = (1/2)[(1/2)x(T, T, 1)R(K) + d], and

$$\pi_{12}^O = (1/2)(N\text{-}n)\theta, \qquad (A4)$$

where $\theta \equiv (1/4)[x(T, t_i, 1)r_i(K) - x(T, T, 1)R(K)][x(T, T, 1)/x(T, T, 0)]$. Then, (A1), (A3) and (A4) imply the result. *Q.E.D.*

Lemma 3: The MHI-equilibrium and the SVG-equilibrium are only candidates for symmetric SPNE outcome.

Proof of Lemma 3: Given after the proof of Proposition 1.

Let $\underline{m}$ be the minimum integer which satisfies N/($\underline{m}$ -1) < D. I will first identify a necessary condition for the game to have both an MHI-equilibrium and an SGV-equilibrium where m (∈ [$\underline{m}$, $\overline{m}$]) firms operate in period 1, and then show that the condition is also sufficient. In what follows, define π_i[(k_i, r_i, t_i), (K, R, T)] as in Lemma 2.

Suppose that, at stage 1, firm i offered $\hat{w}_i$ (> 0) and hired n (> 0) individuals and at least two other firms hired a positive measure of individuals. Since V(S) > H(S), we have

$$\begin{aligned}
&\phi(S, V, G, V, G)\\
&= (1/2)[1 - x(G, G, 1)V(S)/(2x(G, G, 0)V(S))][x(G, G, 0)V(S) - (1/2)x(G, G, 1)V(S)]\\
&> (1/2)[1 - x(G, G, 1)V(S)/(2x(G, G, 0)H(S))][x(G, G, 0)H(S) - (1/2)x(G, G, 1)V(S)]\\
&= \phi(S, H, G, V, G).
\end{aligned}$$

This implies π_i[(S, H, G), (S, V, G)] < π_i[(S, V, G), (S, V, G)], and so firm i's optimal strategy cannot be (k_i, r_i, t_i) = (S, H, G) given all other firms choose (k_u, r_u, t_u) = (S, V, G). Suppose firm i chooses k_i = M given all other firms choose (k_u, r_u, t_u) = (S, V, G), and let r_M (= V or H) and t_M (= G or I) denote firm i's corresponding optimal choice for r_i and t_i respectively. Then, if the

SVG-equilibrium exists, π_i[(S, V, G), (S, V, G)] > π_i[(M, r_M, t_M), (S, V, G)] holds. This is equivalent to

$$c > c', \text{ where } c' \equiv (1/2)[\phi(M, r_M, t_M, V, G) - \phi(S, V, G, V, G)].$$

Next consider a necessary condition for the MHI-equilibrium to exist. Suppose that, at stage 1, firm i offered $\hat{w}_i$ (> 0) and hired n (> 0) individuals and at least two other firms hired a positive measure of individuals. I establish the following claim:

Claim 1: (i) Given all other firms choose (k_u, r_u, t_u) = (M, H, I), firm i's optimal choice cannot be (k_i, r_i, t_i) = (M, V, I). (ii) π_i[(M, V, G), (M, H, I)] < π_i[(M, H, G), (M, H, I)].

Proof of Claim 1:

(i) Since H(M) > V(M), we have

$$(2/n)\{\pi_i[(M, H, I), (M, H, I)] - \pi_i[(M, V, I), (M, H, I)]\}$$
$$\geq (1/2)[1 - x(I, I, 1)H(M)/(2x(I, I, 0)H(M))][x(I, I, 0)H(M) - (1/2)x(I, I, 1)H(M)]$$
$$- (1/2)[1 - x(I, I, 1)H(M)/(2x(I, I, 0)V(M))][x(I, I, 0)V(M) - (1/2)x(I, I, 1)H(M)]$$
$$> 0.$$

Hence π_i[(M, V, I), (M, H, I)] < π_i[(M, H, I), (M, H, I)], which implies the result.

(ii) $$(2/n)\{\pi_i[(M, H, G), (M, H, I)] - \pi_i[(M, V, G), (M, H, I)]\}$$
$$> \phi(M, H, G, H, I) - \phi(M, V, G, H, I)$$

(Note, H(M) > V(M) implies λ(H, G, M, H, I) > λ(V, G, M, H, I).)

$$\geq (1/2)[1 - x(G, I, 1)H(M)/(2x(G, G, 0)H(M))][x(G, G, 0)H(M) - (1/2)x(G, I, 1)H(M)]$$
$$- (1/2)[1 - x(G, I, 1)H(M)/(2x(G, G, 0)V(M))][x(G, G, 0)V(M) - (1/2)x(G, I, 1)H(M)]$$

> 0. This implies the result.

Q.E.D.

Suppose that an MHI-equilibrium exists where m ($\in [\underline{m}, \overline{m}]$) firms operate in period 1. In the equilibrium, all m firms offer the same period 1 wage at stage 1 and choose (M, H, I). There is no incentive for each of the m firms to choose a set of strategies different from (M, H, I) at stage 2. Also, there is no incentive for another firm to offer the same period 1 wage and choose a set of strategies different from (M, H, I) at stage 2. This and Claim 1 together imply that the following two conditions hold (let r_S denote firm i's optimal choice for r_i when firm i chooses k_i = S (and so t_i = G) and all other firms choose (k_u, r_u, t_u) = (M, H, I)):

First, "$\pi_i[(S, r_S, G), (M, H, I)] < \pi_i[(M, H, I), (M, H, I)]$ when n = N/(m + 1)". This condition is equivalent to

$$c < \tilde{c}''(m+1),$$

$$\text{where } \tilde{c}''(\gamma) \equiv (1/2)[\phi(M, H, I, H, I) - \phi(S, r_S, G, H, I) - (\gamma - 1)\lambda(r_S, G, M, H, I)].$$

Second, "$\pi_i[(M, H, G), (M, H, I)] < \pi_i[(M, H, I), (M, H, I)]$ when n = N/(m + 1)". This condition is equivalent to

$$m < M, \text{ where } M \equiv \{\phi(M, H, I, H, I) - \phi(M, H, G, H, I)\}/\lambda(H, G, M, H, I).$$

Then, "$c' < c < \tilde{c}''(\underline{m}+1)$ and $\underline{m} < M$" is a necessary condition for the game to have both an MHI-equilibrium and an SVG-equilibrium where m ($\in [\underline{m}, \overline{m}]$) firms operate. The necessary condition is equivalent to

$$c' < c < c'', \text{ where } c'' \equiv \begin{cases} \tilde{c}''(\underline{m}+1) & \text{if } \underline{m} < M \\ c' & \text{otherwise} \end{cases}. \qquad \text{(A5)}$$

Next, I will show that (A5) is also sufficient. Suppose (A5) holds. Pick any c that satisfies (A5) and define $\overline{m}$ to be the maximum integer such that "$c' < c < \tilde{c}''(\overline{m}+1)$ and $\overline{m} < M$" holds. Define w_M and w_S as follows.

$$w_M \equiv (1/2)[\phi(M, H, I, H, I) + d] - c_M,$$

$$w_S \equiv (1/2)[\phi(S, G, V, G, V) + d] - c_S.$$

Note, $\pi_i[(S, r_S, G), (M, H, I)] \le \pi_i[(M, H, I), (M, H, I)]$

$$\Leftrightarrow (N - n)/n \le [\phi(M, H, I, H, I) - \phi(S, r_S, G, H, I) - 2c]/\lambda(r_S, G, M, H, I), \qquad \text{(A6)}$$

and $\pi_i[(M, H, G), (M, H, I)] \le \pi_i[(M, H, I), (M, H, I)]$

$$\Leftrightarrow (N - n)/n \le [\phi(M, H, I, H, I) - \phi(M, H, G, H, I)]/\lambda(H, G, M, H, I). \qquad \text{(A7)}$$

Let n* be the maximum real number such that both (A6) and (A7) hold. We have $\pi_i[(M, H, G), (M, H, I)] \le \pi_i[(M, H, I), (M, H, I)]$ and $\pi_i[(S, r_S, G), (M, H, I)] \le \pi_i[(M, H, I), (M, H, I)]$ for all n ≥ n* because (N – n)/n is decreasing in n. Note that $N/(\overline{m}+1) \ge n^*$ by the definition of $\overline{m}$. Let $\underline{n}$ denote the minimum measure of individuals that a firm hired at stage 1. Consider Strategy M and Strategy S defined as follows.

Strategy M: At stage 1, m ($\in [\underline{m}, \overline{m}]$) firms make the maximum wage offer $\hat{w}_i = w_M$. At stage 2, all firms choose (M, H, I) if $\underline{n} \geq n^*$ and choose (S, V, G) otherwise.

Strategy S: At stage 1, m ($\in [\underline{m}, \overline{m}]$) firms make the maximum wage offer $\hat{w}_i = w_S$. At stage 2, all firms choose (S, V, G).

Under Strategy M, each of the m firms hires N/m individuals in period 1, because $m \geq \underline{m}$ implies N/m < D. Since $N/m \geq n^*$ for all m ($\in [\underline{m}, \overline{m}]$), the outcome of Strategy M is the MHI-equilibrium. Clearly, the outcome of Strategy S is the SVG-equilibrium.

In what follows, I will show that both Strategy M and Strategy S are SPNE strategies. Consider stage 2 subgames. c' < c implies that (S, V, G) is each firm's optimal choice given other firms choose this. By the definition of n*, if $\underline{n} \geq n^*$, then (M, H, I) is each firm's optimal choice given other firms choose this. Hence, both Strategy M and Strategy S constitute SPNE strategies of the stage 2 subgames.

Next, consider firm i's optimal wage offer at stage 1 given other (m-1) firms follow Strategy M where m ($\in [\underline{m}, \overline{m}]$). Suppose that firm i chooses $\hat{w}_i = w_M$. Noting that $c < \tilde{c}''(\overline{m}+1)$ implies "π_i[(S, r_S, G), (M, H, I)] < π_i[(M, H, I), (M, H, I)] when n = N/(m + 1)", firm i's profit is zero since π_i[(M, H, I), (M, H, I)] = 0 when $\hat{w}_i = w_M$. Suppose firm i chooses $\hat{w}_i < w_M$. Then each of other firms hires min[N/(m-1), D] individuals. N/(m-1) < D holds for all m ($\in [\underline{m}, \overline{m}]$) because $N/(\underline{m}-1) < D$. Then, other firms together hire all the N individuals. Hence firm i employs no individuals in period 1 and so its profit is zero. Suppose firm i chooses $\hat{w}_i > w_M$. Then firm i hires D individuals, and each of other firms hires (N-D)/(m-1)(> 0) individuals. If $(N-D)/(m-1) \geq n^*$, then all firms choose (M, H, I), and firm i's profit is negative because $\hat{w}_i > w_M$. Suppose (N-D)/(m-1) < n*, then all firms choose (S, V, G). Note that the following holds for firm i.

$$\pi_i[(M, H, I), (M, H, I)] > \pi_i[(S, V, G), (M, H, I)] > \pi_i[(S, V, G), (S, V, G)],$$

where the first inequality is implied by D > n*. The second inequality holds because,

$$(2/n)\{\pi_i[(S, V, G), (M, H, I)] - \pi_i[(S, V, G), (S, V, G)]\}$$
$$\geq \phi(S, V, G, H, I) - \phi(S, V, G, V, G)$$
$$= \{1/[2x(G, G, 0)V(S)]\}[x(G, G, 0)V(S) - (1/2)x(G, I, 1)H(S)]^2$$

$- \{1/[2x(G, G, 0)V(S)]\}[x(G, G, 0)V(S) - (1/2)x(G, G, 1)V(S)]^2$

> 0 (Note: $x(G, G, 1) > x(G, I, 1)$ and $V(S) > H(S)$).

Hence, firm i's profit cannot exceed $D\{(1/2)[\phi(M, H, I, H, I) + d] - c_M - \hat{w}_i\}$, which takes a negative value because $\hat{w}_i > w_M$. Then, firm i has no incentive to choose $\hat{w}_i > w_M$. Hence, $\hat{w}_i = w_M$ is its optimal wage offer. Through a similar logic, it can be shown that, given m ($\in [\underline{m}, \overline{m}]$) firms follow Strategy M, it is impossible for another firm to earn a positive profit. Therefore, Strategy M is an SPNE strategy of the entire game. Through a similar logic, it can be shown that Strategy S is also an SPNE strategy.

To show the existence of parameterizations for which c' < c", I will show an example. Let x(I, I, 0) = 2.0, x(G, G, 1) = x(G, G, 0) = 1.5, x(I, G, 1) = 1.1, x(G, I, 1) = 0.8, x(I, I, 1) = 0.25, H(M) = 2.0, V(M) = 1.8, V(S) = 1.2, H(S) = 1.0, $\underline{m} = 4$, D > N/3. Then c' ≈ 0.454 < c" ≈ 0.484.

Now turn to welfare comparison. Suppose c' < c < c" holds. Let W_{MHI} (W_{SVG}) denote total surplus in the MHI-equilibrium (SVG-equilibrium). Lemma 2 implies

$$W_{MHI} = N(1/2)[\phi(M, H, I, H, I) + d - c^M],$$

$$W_{SVG} = N(1/2)[\phi(S, V, G, V, G) + d - c^S].$$

Note that c < c" implies

$$(1/2)\phi(M, H, I, H, I) - c$$

$$> (1/2)[\phi(S, V, G, H, I) + \underline{m}\,\lambda(V, G, M, H, I)]$$

$$\geq (1/2)\phi(S, V, G, H, I).$$

Then, since $\phi(S, V, G, H, I) > \phi(S, V, G, V, G)$ holds, we have

$$(1/2)\phi(M, H, I, H, I) - c > (1/2)\phi(S, V, G, V, G),$$

which implies $W_{MHI} > W_{SVG}$.

Finally, the labor turnover rate in the SVG-equilibrium is $\tilde{a} = x(G, G, 1)V(S)/(2x(G, G, 0)V(S)) = 1/2$, while the labor turnover rate in the MHI-equilibrium is $\tilde{a} = x(I, I, 1)H(M)/(2x(I, I, 0)H(M)) < 1/2$ (because $x(I, I, 0) > x(I, I, 1)$). Q.E.D.

Proof of Lemma 3:

Define $\pi_i[(k_i, r_i, t_i), (K, R, T)]$ as in Lemma 2. It suffices to show (i) – (iv) below.

(i) $\pi_i[(S, V, G)), (S, H, G)] > \pi_i[(S, H, G), (S, H, G)]$

(ii) $\pi_i[(M, H, G), (M, V, G)] > \pi_i[(M, V, G), (M, V, G)]$

(iii) $\pi_i[(M, H, I), (M, V, I)] > \pi_i[(M, V, I), (M, V, I)]$

(iv) $\pi_i[(M, H, I), (M, H, G)] > \pi_i[(M, H, G), (M, H, G)]$

(i) Since V(S) > H(S), we have,

$$(2/n)\{\pi_i[(S, V, G), (S, H, G)] - \pi_i[(S, H, G), (S, H, G)]\}$$
$$\geq \phi(S, V, G, H, G) - \phi(S, H, G, H, G)$$
$$> \{1/[2x(G, G, 0)V(S)]\}[x(G, G, 0)V(S) - (1/2)x(G, G, 1)V(S)]^2$$
$$- \{1/[2x(G, G, 0)H(S)]\}[x(G, G, 0)H(S) - (1/2)x(G, G, 1)H(S)]^2$$
$$= [1/(2x(G, G, 0))][x(G, G, 0) - (1/2)x(G, G, 1)]^2(V(S) - H(S)) > 0.$$

Hence, $\pi_i[(S, V, G)), (S, H, G)] > \pi_i[(S, H, G), (S, H, G)]$.

(ii) Since H(M) > V(M), we have

$$(2/n)\{\pi_i[(M, H, G), (M, V, G)] - \pi_i[(M, V, G), (M, V, G)]\}$$
$$\geq \phi(M, H, G, V, G) - \phi(M, V, G, V, G)$$
$$> \{1/[2x(G, G, 0)H(M)]\}[x(G, G, 0)H(M) - (1/2)x(G, G, 1)H(M)]^2$$
$$- \{1/[2x(G, G, 0)V(M)]\}[x(G, G, 0)V(M) - (1/2)x(G, G, 1)V(M)]^2$$
$$= [1/(2x(G, G, 0))][x(G, G, 0) - (1/2)x(G, G, 1)]^2(H(M) - V(M)) > 0.$$

Hence, $\pi_i[(M, H, G), (M, V, G)] > \pi_i[(M, V, G), (M, V, G)]$.

(iii) Since H(M) > V(M), we have

$$(2/n)\{\pi_i[(M, H, I), (M, V, I)] - \pi_i[(M, V, I), (M, V, I)]\}$$
$$\geq \phi(M, H, I, V, I) - \phi(M, V, I, V, I)$$
$$> \{1/[2x(I, I, 0)H(M)]\}[x(I, I, 0)H(M) - (1/2)x(I, I, 1)H(M)]^2$$
$$- \{1/[2x(I, I, 0)V(M)]\}[x(I, I, 0)V(M) - (1/2)x(I, I, 1)V(M)]^2$$
$$= [1/(2x(I, I, 0))][x(I, I, 0) - (1/2)x(I, I, 1)]^2(H(M) - V(M)) > 0.$$

Hence, $\pi_i[(M, H, I), (M, V, I)] > \pi_i[(M, V, I), (M, V, I)]$.

(iv) Since x(I, I, 0) > x(I, G, 1) and x(I, I, 0) > x(G, G, 0) = x(G, G, 1), we have

$$(2/n)\{\pi_i[(M, H, I), (M, H, G)] - \pi_i[(M, H, G), (M, H, G)]\}$$
$$\geq \phi(M, H, I, H, G) - \phi(M, H, G, H, G)$$

$= \{1/[2x(I, I, 0)H(M)]\}[x(I, I, 0)H(M) - (1/2)x(I, G, 1)H(M)]^2$

$\quad - \{1/[2x(G, G, 0)H(M)]\}[x(G, G, 0)H(M) - (1/2)x(G, G, 1)H(M)]^2$

$> \{1/[2x(I, I, 0)H(M)]\}[x(I, I, 0)H(M) - (1/2)x(I, I, 0)H(M)]^2 - (1/8)x(G, G, 0)H(M)$

$= (1/8)(x(I, I, 0) - x(G, G, 0))H(M) > 0.$

Hence, $\pi_i[(M, H, I), (M, H, G)] > \pi_i[(M, H, G), (M, H, G)]$.

Q.E.D.

Proof of Proposition 2:

(i) Suppose c < c'. Then we have $\pi_i[(M, r_M, t_M), (S, V, G)] > \pi_i[(S, V, G), (S, V, G)]$, which implies that the SVG-equilibrium does not exist. Since c < c'' holds, Strategy M is an SPNE strategy as in the proof of Proposition 1.

(ii) Suppose c > c''. Since c > c' holds, Strategy S is an SPNE strategy. c > c'' implies that the game does not have an MHI-equilibrium in which m ($\geq \underline{m}$) firms operate in period 1. Suppose that the game has an MHI-equilibrium in which $\hat{m}$ firms operate in period 1. Then $\hat{m} < \underline{m}$ must hold, which implies $N/(\hat{m}-1) > D$. A strategy that supports the MHI-equilibrium must include '$\hat{m}$ firms make the highest period 1 wage offer w_M and hire $N/\hat{m}$ individuals at stage 1, and choose (M, H, I) at stage 2.' Suppose all firms except firm 1 follow the strategy. Since $N/(\hat{m}-1) > D$ holds, firm 1 can earn positive profit by offering a first period wage less than w_M and hiring a positive measure of individuals. Hence, the MHI-equilibrium cannot exist. *Q.E.D.*

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