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Work and Organization Practices and QCD Manufacturing Performance

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Abstract

I explored the relationships between work and organization practices and the quality, cost, and delivery-time of manufacturing performance, based on evidence gathered from assembly lines and cells at Japanese electronics plants. The relationships were complicated and elusive, regardless of those practices' closer vicinity to the direct corresponding effects compared with their more distant relations to the firm's performance. The results indicated the limits of HR's strategic impact. Nevertheless, work and organization practices had some bearing on manufacturing performance, and they still mattered, especially for managers at manufacturing companies. Furthermore, I found two HR systems that were embedded in a manufacturing setting.

Keywords:
Strategic human resource management; work and organization practices; QCD manufacturing performance; manufacturing configurations

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Strategic human resource management (SHRM) scholars have conducted and generated a large body of empirical survey-based research on the relationships between HRM and performance over more than a decade. In conducting this research, they typically ask an HRM manager or executive for information or data on the prevalence of specific HRM practices among all employees or on the portion of the firm's employees covered by particular HRM practices regardless of the fact that most or even all of the employees at a certain workplace might not ever affected by these HRM practices (Arthur, 1994; Guest, Michie, Conway, & Sheehan, 2003; Huselid, 1995; MacDuffie, 1995; Osterman, 1994). Then the scholars examine whether and how the prevalence of these HRM practices is associated with corporate performance, e.g., net profit, ROE (return on equity), ROA (rerun on assets), and Tobin's *q*. Here, let's assume that HRM activities and system components involve HRM philosophy, HRM policy, HRM programs, HRM practices, and HRM climate (Arthur & Boyles, 2007; Becker & Huselid, 1998; Colbert, 2004). Although many SHRM scholars have aimed to study the relationships between HRM "practices" and corporate performance, most of the previous work actually focused on HRM program as "the set of formal HR activities used in the organization" (Arthur & Boyles, 2007: 80).

HRM practices involve "the implementation and experience of an organization's HR programs by lower-level managers and employees" (Arthur & Boyles, 2007: 80). Scholars would not be able to comprehend the relationship between HRM and performance and HRM's strategic significance for several reasons if they neglected the HRM practices occurring at front-line or work organizations. First, what has generally been considered "best practices" (Pfeffer, 1998) might not be in fact so. Second, scholars might be unable to make accurate measurements of whether or how much HRM is associated with performance if they focus on the abstract level of HRM system components, i.e., HRM policy and programs. Third, the HRM-performance link is not direct but instead mediated by the implementations of HRM strategy (Becker & Huselid, 2006). Fourth, the questions, such as what are HRM practices, specifically the work and organization practices experienced and used by rank-and-file workers, and whether and how these practices are associated with their direct effects, such as quality, cost, and delivery-time manufacturing performance, would literally represent "strategic significance" (Becker & Huselid, 2006) for manufacturing companies. Even though much of the previous SHRM literature attempted to examine "HRM practices" (although these studies actually examined HRM programs and policy), the performance measure adopted was firm performance, not a direct effect such as operating or manufacturing performance. The linkage between HRM practices and firm performance is distal (Becker & Huselid, 2006), and thus it might seem that some hypotheses formed in the previous work were not supported by the generated results or, moreover, that the estimated effects of HRM practices on firm performance were not so strong even though the hypotheses were shown to have some validity. The obtained results might have caused some scholars to become skeptical about the impact of HRM practices on firm performance (Cappelli & Neumark, 2001).

Although some previous studies explored HRM practices, they were interested in how the use of HRM practices related to worker outcomes such as commitment and labor turnover, rather than operating or manufacturing performance (e.g., Dore, 1973; Lincoln & Kelleberg, 1996). One exception is the research conducted by Appelbaum, Bailey, Berg, and Kalleberg (2000), especially their research on work and organization practices on steel-making lines and their relations to uptime as a quality indicator. They collected data from operators on both the formal and informal practices that were actually implemented. As stated later, however, the components of the high performance work system presented by Appelbaum et al. were not always identical to the work and organization practices that I found were necessary and effective in Japanese cell production.

The purpose of this research was to explore the relationships between work and organization practices and the corresponding QCD (quality, cost, and delivery-time) manufacturing performance measures, based on evidence from assembly lines and cells at Japanese electronics plants. This research would make theoretical and practical contributions by addressing one of the unresolved questions in SHRM research: whether HRM practices have anything to do with the relevant direct effects. Such a finding would be strategically significant for executives as well as line mangers at manufacturing companies. To conduct this research, I collected evidence from assembly cells at Japanese electronics plants since cell production is highly related to HRM practices. Cell production is a rather new production method that was adopted by some Japanese manufacturers, especially electronics makers around the mid to late 1990's. It is "a manufacturing configuration dependent on people" (Isa & Tsuru, 2002), where success hinges on how skills and capabilities are elicited from operators and how those people are managed. I gathered evidence from traditional assembly lines as well to examine not only the additive effect of work and organization practices on manufacturing performance along with manufacturing configurations, i.e., cells or lines, but also the interactive or synergistic effect of the two variables. This research, on the whole, is composed of two stages. The first involves inductive or qualitative research, based on case study, to explore what work and organization practices were used in cell production and whether they had anything to do with manufacturing performance. The second stage is deductive or quantitative research, conducted by using statistical analysis to test the hypotheses built on the findings of case study research.

OVERVIEW OF CASE STUDY RESEARCH ON JAPANESE CELL PRODUCTION

Background

Cell production is a replacement method for mass production. A conventional mass production line is called an assembly line while what is dubbed a cell or cell line is similarly called an assembly cell (Johnson, 2005). Assembly lines are usually operated with automated conveyor belts which are sometimes thought of as the symbol of assembly lines, and relatively many people work on them. Meanwhile, assembly cells are run on a setup of machines and equipment arranged in various forms, such as U-shaped, T-shaped, straight line, and circle. Assembly cells typically use a smaller number of “cell operators” than that of workers on assembly lines. Cell production has been employed with the aim of not just high-variety and small-lot manufacturing but also “agile manufacturing”, that is, the capability to quickly change both product quantities and mixes. On the other hand, mass production lines have been transferred to manufacturing facilities overseas, in particular to those in China and Southeastern Asian countries.

It is said that since cell production is a manufacturing configuration dependent on people, the role people play is more important in cell production than in conventional mass production systems (Isa & Tsuru, 2002). Several anecdotal example of the human and HRM aspects of cell production have been noted by Japanese journalists and academics (Isa & Tsuru 2002; Iwamuro, 2004; Sakazume, 2004; Shinobu, 2003; Shirai, 2001). Workers are expected to become multi-skilled, since they need to handle multiple work processes in order to produce various types of products in response to market fluctuations. Cell operators are permitted to make supervisory decisions since cells are regarded as autonomous units held accountable for the consequences. Workers are expected to be highly committed to tasks, since they have to broaden the range of their skills, and achieve the performance goals given to each cell. Therefore, they must be assessed and motivated not just by the conventional seniority-based evaluation system — deeply entrenched in Japanese companies — but also by an innovative pay-for-performance policy. These anecdotes inspired me to conduct research on cell production in terms of HRM practices; such a study would not only provide production managers with prescriptions for success in cell production, but would also contribute to the field of SHRM by exploring HRM practices that are actually utilized and effective in a human-centered manufacturing system, cell production. Therefore, I addressed HRM issues in cell production, focusing on work and organization practices.

I used insights and perspectives gained from SHRM research when examining work and organization practices for cell production. This was because the literature of SHRM presents “high performance work practices” that support team activities, skills, knowledge, and commitment, which are posited to boost performance. From among the several studies in SHRM research, I chose the work done by Appelbaum et al. (2000) as a starting point. This was because their work focused on high performance work systems used by U.S. manufactures of steel, apparel goods, and medical electronic instruments, thus providing a strong theoretical and methodological foundation for my work addressing HRM issues relevant to cell production.

As a research methodology, I chose s case study approach because there existed no rigorous theoretical or empirical research on the comprehensive HRM aspects of cell production (Eisenhardt, 1989; Yin, 2003). Over the three years from 2002 through 2005, I visited 20 plants in Japan that employed cell production, including factories manufacturing PCs, copy machines, printers, air conditioners, lighting products, electrical appliances, electronic components, game consoles, machine tools, large-scale machines, and automotive components. From the 20 plants, I selected 16 plants where sufficient evidence was gathered to permit case study research. I selected multiple cases in order to generalize the findings from case study research (Eisenhardt, 1989). In this case study research, I used direct observation, interviews, archival records, and public documents as sources of evidence. In addition to these sources, I used questionnaires that I handed out at a few plants. Among these sources, interviews were particularly important because respondents provided deep insights into and intriguing views of many aspects of cell production including technological characteristics, organizations, and cell operator management. Respondents included plant managers, personnel managers, production managers, and other personnel in charge of cell production.

Research Findings

Through case study research I found work and organization practices typically used in implementing cell production. First of all, cell production, whatever configurations, was not characterized by an autonomous work environment where an operator had enough discretional ability to make managerial decisions, which Appelbaum et al. (2000) stressed above all among the components of the high performance work system since it could make people intrinsically motivated. Second, cell operators were required to expand the range of their skills so that they could handle multiple work processes and assemble various product items in small lot sizes with a few other cell operators or in some cases alone. Consequently, they were trained to be multi-skilled workers. Third, cell operators were motivated in several ways, not just by monetary but also non-monetary rewards, to become highly committed to their work. Fourth, cell operators were assumed to work interdependently with each other so that they could avoid wasted time and inventory buffer in assembly cells and thus reduce lead-time and work-in-process inventory. Interdependence was not one of the components proposed by Appelbaum et al. for a high performance work system. Fifth and finally, cell operators were required to participate in off-the-line continuous improvement activities, since assembly cells were mutable and thus not as fixed as traditional assembly lines: accordingly, suggestions and opinions provided by operators were needed to make cells more efficient. Another reason was that cell production was employed in tandem with the introduction of the Toyota, or lean, production system in the Japanese electronics industry; continuous improvement activities are an important aspect of that production system. Continuous improvement was also not one of the components Appelbaum et al. considered valid for a high performance work system.

As a result, through the case study research I found individual work and organization practices typically used in implementing cell production, in relation to behavioral requirements: skills, interdependence, motivation, and continuous improvement activities. Consequently, I advocated a set of those practices from the configurational perspective in SHRM literature that requires individual HRM practices to be consistent with each other in order to maximize a *horizontal fit*（Dreher & Dougherty, 2002）. I called this set of practices *the perfectly potentiality-tapping HR system*. It was named for cases where those practices were intended to elicit potential capabilities and skills from operators and tap them to ensure the success of cell production. Meanwhile, I designated an HR system that was not aimed at fostering these desired behaviors or rather that was intended to suppress them, as *the imperfectly potentiality-tapping HR system*. Table 1 presents sample work and organization practices of the two HR systems, categorized according to the domains of education and staffing, work design and interdependence, off-the-line improvement activities, and motivation.

TABLE 1
Sample Work and Organization Practices of Two HR Systems for Cell Production

Imperfectly Potentiality-Tapping HR System	**HRM Domains**	**Perfectly Potentiality-Tapping HR System**
Deploy contingent and unskilled workers outsourced from personnel agencies	Education and staffing	Develop multi-skilled workers who have long service with the company
Task are designed to be individual-based	Work design and interdependence	Workers are required to harmonize with each other in performing tasks
Limited opportunities to participate in improvement activities	Off-the-line improvement activities	Suggestion system, direct contact with technical staff, etc.
Motivated with only monetary incentives	Motivation	Motivated in several ways, e.g., by recognizing that workers made a good attempt even if they failed

Furthermore, I considered some cases that demonstrated clear relationships between the two HR systems and manufacturing performance. The perfectly potentiality-tapping HR system generated fewer defective products, lessened work-in-process inventory, and shortened manufacturing lead-time. That HR system, if implemented on "real cells" that is, assembly cells operated by a small number of operators with the aim of agile manufacturing, seemed more likely to achieve those superior performance measures (see Hyer and Brown [1999] for a review of real cells). On the other hand, the imperfectly potentiality-tapping HR system was associated with productivity, or product quantities assembled per operator. That HR system, when adopted on "quasi-cells" that is, cells operated with a relatively large number of unskilled workers with the aim of large-lot manufacturing — something like assembly lines — seemed more likely to generate high productivity. Thus, the relationships between manufacturing performance and the HR systems seemed to vary depending on the two types of cells; this corroborates the contingency perspective in SHRM that stresses the alignment of an HR system with the organizational context in order to maximize a *vertical fit* (Dreher & Dougherty, 2002).

In the case study research, I answered "what" work and organization practices were important to cell production and "whether" these work and organization practices affected manufacturing performance. However, I could not examine "how much" these work and organization practices affected manufacturing performance. This would require a survey-type research and, subsequently, quantitative and statistical analyses using hard evidence (Yin, 2003). Furthermore, I needed to advance my research by including assembly lines as well as assembly cells, since assembly lines were still used along with assembly cells in most of the plants I visited for my case study research. Furthermore, I intended to examine not only the additive effect of work and organization practices on manufacturing performance along with type of manufacturing configuration — assembly cells or lines — but also the interactive or synergistic effect between the two constructs or conceptual variables. Therefore, I continued my research by statistically testing the relationships between work and organization practices and manufacturing performance, specifically QCD, based on evidence from assembly lines as well as assembly cells.

HYPOTHETICAL RELATIONSHIPS BETWEEN QCD AND WORK AND ORGANIZATION PRACTICES

Based on the findings from the case study research, I built the hypotheses to be tested by statistical analysis.

First, I established a hypothesis on a relationship between work and organization practices and productivity, which I used as a gauge for the cost of manufacturing performance. Productivity, or the ratio of output to input, is defined in several ways; for instance, it is sometimes calculated by dividing all products assembled by the time taken for assembly. In this research, productivity represents how many products are assembled per worker, and I attempted to establish productivity for each cell or line. I adopted this definition of productivity because it was one of the primary performance measures used in the plants I visited for my case study. The case study research indicated that the imperfectly potentiality-tapping HR system was associated with productivity. To form the productivity hypotheses and other hypotheses related to manufacturing performance consistently, I created a construct or conceptual variable called, *the system of work and organization practices*. This is intended to captures a set of those practices experienced and implemented by assembly workers. Here, the perfectly potentiality-tapping HR system is at end of a continuum presenting great value (for statistical convenience) while the imperfectly potentiality-tapping HR system is at the opposite end representing low value. I hypothesized the relation as follows:

> *Hypothesis 1a. The system of work and organization practices has a negative effect on productivity. That is, the imperfectly potentiality-tapping HR system generates a higher level of productivity.*

The case study research not only associated the imperfectly potentiality-tapping HR system with productivity, but also revealed that these relations were obvious on quasi-cells rather than on real cells. These findings led me to reason that the imperfectly potentiality-tapping HR system can be expected to generate a higher level of productivity when implemented on assembly lines than when implemented on assembly cells, since quasi-cells resemble assembly lines in terms of not only form but also aim. Statistically speaking, the system of work and organization practices and manufacturing configurations have a positive interactive effect on productivity. In building these moderation hypotheses, I made a construct called *manufacturing configurations*. Assembly lines stand at one end of this dimension while assembly cells are at the other end, since cell production is a replacement for mass production methods and assembly cells evolved from assembly lines. Here, the greater value of this variable represents a manufacturing configuration more characteristic of assembly cells, while the lower value indicates a manufacturing configuration more characteristic of assembly lines. Testing Hypothesis 1a involves investigating the additive effect of the system of work and organization practices on productivity in conjunction with manufacturing configurations while testing the moderation relationship involves exploring the two constructs'synergistic effect on productivity.

> *Hypothesis 1b. The system of work and organization practices and manufacturing configurations have a positive interactive effect on productivity. Specifically, the imperfectly potentiality-tapping HR system generates a higher level of productivity when implemented on assembly lines than when implemented on assembly cells.*

Next, I set forth a hypothesis on the relationship between work and organization practices and delivery-time. I adopted work-in-process inventory as an indicator for delivery-time manufacturing performance since it is expected to be reduced as a result of shortened delivery-time or vice versa. I used manufacturing lead-time as another indicator for delivery-time and provided the lead-time hypotheses, to be developed later. The case study research found that the perfectly potentiality-tapping HR system had something to do with the lower level of work-in-process inventory. As described in methods, I created a variable of work-in-process inventory in such a way that the greater value of this variable represents a smaller level of work-in-process inventory, and thus a lower value means a larger level. Accordingly, I hypothesized the relation as follows:

Hypothesis 2a. The system of work and organization practices has a positive effect on work-in-process inventory. That is, the perfectly potentiality-tapping HR system reduces the level of work-in-process inventory.

The case study research not only associated the perfectly potentiality-tapping HR system with reduced work-in-process inventory, but also showed that the relation was likely to be stronger when the perfectly potentiality-tapping HR system was implemented on real cells rather than on quasi-cells. Indeed, reducing work-in-process inventory is one of the primary reasons to introduce cell production or assembly cells in place of mass production or assembly lines. This finding from the case study research indicated that the perfectly potentiality-tapping HR system is likely to generate a smaller level of work-in-process inventory when implemented on assembly cells than on assembly lines. In other words, the perfectly potentiality-tapping HR system might increase the level of work-in-process inventory if used on assembly lines. Statistically speaking, the system of work and organization practices and manufacturing configurations have a positive interactive effect on work-in-process inventory, beyond their additive effects, as seen with Hypothesis 2a.

Hypothesis 2b. The system of work and organization practices and manufacturing configurations have a positive effect on work-in-process inventory. Specifically, the perfectly potentiality-tapping HR system generates a smaller level of work-in-process inventory when used on assembly cells than when implemented on assembly lines.

In addition to work-in-process inventory, I adopted manufacturing lead-time as another indicator of delivery-time as mentioned earlier. Manufacturing lead-time or throughput time means how much time it takes for a team of operators to complete all of the assembly operations on cells or lines. The case study showed that the perfectly potentiality-tapping HR system was associated with shortened manufacturing lead-time. As explained in methods, I created the variable of manufacturing lead-time in such a way that the higher value in that variable represents a shorter manufacturing lead-time. This relation can be hypothesized as follows:

Hypothesis 3a. The system of work and organization practices has a positive effect on manufacturing lead-time. That is, the perfectly potentiality-tapping HR system shortens manufacturing lead-time.

Not only did the case study research associate the perfectly potentiality-tapping HR system with shortened manufacturing lead-time, but also showed that the relation was likely to be stronger when the perfectly potentiality-tapping HR system was implemented on real cells rather than on quasi-cells. Consequently, the perfectly potentiality-tapping HR system is expected to generate shorter manufacturing lead-time when implemented on assembly cells than on assembly lines. In other words, the perfectly potentiality-tapping HR system might lengthen manufacturing lead-time if used on assembly lines.

Hypothesis 3b. The system of work and organization practices and manufacturing configurations have a positive effect on manufacturing lead-time. Specifically, the perfectly potentiality-tapping HR system generates shorter manufacturing lead-time when used on assembly cells than when used on assembly lines.

Finally, I established a hypothesis on the relationship between work and organization practices and quality. I employed product defects (caused by a particular cell or line) as a measure for calibrating quality performance. Product defects caused by a team of operators on a particular cell or line represent manufacturing process quality rather than the quality of products themselves. As stated later, I created the variable of product defects in such a way that a greater value represents fewer product defects. The case study research indicated that the perfectly potentiality-tapping HR system had something to do with decreased product defects. Consequently, I hypothesized this relationship as follows:

Hypothesis 4a. The system of work and organization practices has a positive effect on product defects. That is, the perfectly potentiality-tapping HR system reduces the likelihood of product defects.

Not only did the case study research find that the perfectly potentiality-tapping HR system improved product-defect levels, but it also revealed that the relation was likely to be stronger when that HR system was implemented on real cells than on quasi-cells. Consequently, it can be expected that the perfectly potentiality-tapping HR system is likely to generate fewer product defects when implemented on assembly cells than on assembly lines. Naturally, there exists the probability that the perfectly potentiality-tapping HR system would decrease product defects if used on assembly lines, but it is important to stress that this relation is likely to be “stronger” when the perfectly potentiality-tapping HR system is used on assembly cells.

Hypothesis 4b. The system of work and organization practices and manufacturing *configurations have a positive interactive effect on product defects. Specifically, the perfectly potentiality-tapping HR system generates a lower likelihood of product defects when used on assembly cells than when used on assembly lines.*

METHODS: QUANTITATIVE ANALYSES

Research Design and Sample

The hypotheses were tested by running quantitative analyses. For these analyses, survey research was conducted using questionnaires, and hard evidence was collected. In conducting research on HRM-performance, a methodological issue arises when the same respondent answers questions on both HRM practices and performance (Becker & Gerhart, 1996). In this case, the respondent is apt to positively answer the questions on HRM practices if performance at his or her company is superior, while he or she is apt to negatively answer HRM questions if performance is not so high. Therefore, I designed two different types of questionnaires (written in Japanese) for managers and team or group leaders who are responsible for cells or lines, sometimes called a cell leader or a line leader. Managers — who are in charge of the assembly section(s) and to whom cell or line leaders report — were to answer a questionnaire focusing on QCD performance, manufacturing configurations, and control variables (i.e., production volume, *mizu-sumashi*, and *poka-yoke*, to be explained in detail later). Team leaders were to answer another questionnaire focusing mainly on work and organization practices. Dyads of managers and leaders answered their respective questionnaires, giving attention to the cells or lines for which they were responsible. Therefore, in survey research and quantitative analyses, the unit of analysis was an assembly cell or line.

Data were collected from the autumn of 2006 through the beginning of 2007. Table 2 provides information on the survey participants. I contacted managers at the plants I had visited before for the case study research and asked them to participate in the survey research. This was important because I needed much cooperation from the survey participants as well as their deep understanding of the survey research to successfully carry it out. Therefore, ten of the twenty participating companies were ones I had previously visited to conduct the case study. All of the participating companies can be generally categorized as “electronics makers” according to the classifications of the Tokyo Stock Exchange or other criteria, such as the industrial associations in which they hold membership (e.g., the Japan Electrical Manufacturers’ Association). However, these companies or their plants made a wide variety of products: PCs, printers, copier machines, air conditioners, lighting products, wireless communications equipment, heating appliances, refrigerators, automated teller machines (ATMs), electrical components for digital cameras, PCs, etc., and industrial equipment including motors, breakers, and transformers.

Many of the participating companies have transferred production facilities to overseas sites in such regions as China and Southeastern Asian countries and own their overseas plants; however, I focused on plants based in Japan to remove or control for cultural factors that could affect the results.

TABLE 2
Information of Survey Participants

Company Codes	Plants	Lines or Cells	Managers	Leaders
company 1	1	22	11	22
company 2	1	4	2	4
company 3	1	1	1	1
company 4	1	3	2	3
company 5	1	3	1	3
company 6	1	4	1	4[a]
company 7	1	4	1	4
company 8	1	1	1	1
company 9	1	1	1	1
company 10	1	1	1	1
company 11	1	1	1	1
company 12	1	1	1	1
company 13	1	2	2	2
company 14	2	5	5	5
company 15	1	4	1	4
company 16	1	2	1	2[b]
company 17	1	2	2	2
company 18	3	6	5	6
company 19	1	1	1	1
company 20	1	9	2	9
Total Number	23	77	43	77[c]

[a] In company 6, a manager was responsible for a cell or line as a leader at the same time. Therefore, at that company one manager and three leaders actually participated.
[b] In company 16, a leader was in charge of two different cells or lines at the same time. Therefore, at that company one leader actually participated.
[c] For the reasons given just above, a total of 75 leaders actually particpated.

Seventy-seven dyads of managers and leaders answered the two types of questionnaires; accordingly, 77 cells or lines constituted the cases or observations used for subsequent statistical analyses. The number of participating leaders, 77, was larger than that of their manager counterparts, 43, because managers were usually responsible for more than one line or cell, or thus one leader. Although 77 leader responses were gathered, 75 actual leaders participated in the survey research for two reasons: 1) a manger in company 6 was in a position to oversee a cell or line as a leader at the same time, and 2) a leader in company 16 was in charge of two different cells or lines at the same time. Those two cases were not excluded from the sample because 1) these cases reflect a reality for manufacturing work organizations, and 2) 77 cases or observations is not so many as samples. Of the 77 cases, 22 were from company 1. It might be assumed that the results of the data analyses were disproportionately affected by those 22 cases. However, I used the data from all 77 cases for several reasons. First, I found through the case study that there were various types of cells, such as real cells and quasi-cells, as well as even assembly lines in a single plant. Moreover, some teams of assembly operators generated superior performance while other teams did not do well, depending on how they were managed. I also conducted multi-level regression analyses with random coefficient regression in which individual cells or lines (level 1) were nested within or clustered around the companies (level 2) under which they operated. The results indicated that the second level or group-level predictor, i.e., companies, did not affect manufacturing performance. Therefore, I conducted statistical analyses with the data from all 77 cases.

The sample size of 77 might seem small for performing statistical analyses and estimating parameters. However, it is currently difficult to conduct this type of survey research in Japan and thus to collect data, especially hard evidence, from Japanese electronics makers. They are reluctant to disclose data because they face much severer competition with rivals from around the world than before and they are concerned that competitors might exploit released data. Actually, when I contacted some of the companies I had visited for the case study, they rejected my request for their participation in the survey research. That is why I had to approach managers at plants to which I had not contacted before and request those plants to participate in the survey research. Furthermore, the cases included some companies well known for transforming manufacturing systems that were no longer competitive, thus regaining competitiveness. For all of these various reasons, I decided to base the statistical analyses on all 77 cases.

Variables

Criterion variables. I used productivity, work-in-process inventory, manufacturing lead-time, and product defects as the criterion variables, as stated earlier. To measure those performance indicators — as well as the predictors and controls — I adopted the 5-point Likert scale for several reasons. One reason was that even though this study focuses on electronics makers, they manufacture many different categories of products (e.g., PCs, copier machines, components), making it difficult to apply the same benchmarking criteria to all of the cells or lines surveyed. Another reason was that due to the extremely severe competition in the electronics sector, managers I contacted were concerned that their performance data might be exploited by competitors, so some of them were reluctant to provide specific performance data. Therefore, I asked managers to evaluate performance on their cells or lines by using questions designed with the 5-point Likert scale. Managers were asked to evaluate current performance on cells or lines through various comparisons: with other cells or lines at the same plant, with the past (around five years ago) level of the same performance indicator for a typical team of assembly workers making the same type of product at the same plant, with the "average" level of the corresponding performance indicator in the same industry, and so forth. Each of the performance measures was given an aggregated and averaged score of several question items. Internal consistency reliabilities (Cronbach's α) of all performance measurements were high — .80 for productivity, .83 for work-in-process inventory, .83 for manufacturing lead-time, and .75 for product defects — so these indicators were used as the criterion variables. The higher value in each of the performance measurements represents superior performance: the higher value in the variable of productivity represents a higher level of that performance measurement; of work-in-process inventory a smaller level; of manufacturing lead-time a shorter level; and of product defects a lower level.

Predictor variables. I created 24 question items on work and organization practices while considering those practices found to be generally used and effective in implementing cell production in the case study research. Work and organization practices were assessed on the 5-point Likert scale by leaders using all 24 question items. Responses ranged from 1 ("strongly disagree") to 5 ("strong agree"). The question items included 6 items on education, 5 items on interdependence, 7 items on improvement activities, and 6 items on motivation. To grasp the dimension(s) of work and organization practices, I performed a common or exploratory factor analysis with the principal component method using the 24 indicators. Table 3 shows the results of exploratory factor analysis of work and organization practices. All but two of the indicators loaded at .30 or greater on a single factor; besides, around 35 percent of the total variance was accounted for by the single factor. As for the 24 indicators, Cronbach's α was high at .91. Therefore, although two of the indicators' loadings were less than .30, I followed the procedures SHRM scholars have proposed to capture the system of HRM practices, rather than single and isolated practices, and aggregated and averaged the values for all 24 question items the leaders answered (Huselid, 1995; MacDuffie, 1995). The proposed approach assumes that a construct is captured by the average of the twenty-four question items on work and organization practices when conducting statistical analysis. Accordingly, the system of work and organization practices was adopted as the predictor variable in testing hypotheses. A higher value in the system of work and organization practices represents a situation more proximal to the perfectly potentiality-tapping HR system, while a lower value indicates a situation more similar to the imperfectly potentiality-tapping HR system.

TABLE 3
Results of Exploratory Factor Analysis of Work and Organizations Practices

Questionnaire Items	Factor 1
Training for workers on your cell or line	
Operators deal with multiple work processes.	.57
Most of the workers are "experienced" employees who have long careers in assembly work.	.42
Workers acquire new skills and broaden the range of their skills while doing their jobs.	.74
Operators get more skillful bosses or colleagues to instruct them in new tasks at the workplace, i.e., on the cell or line, whenever they need to do so.	.72
Through training off the cell or line (OffJT), workers learn and upgrade the skills required of them as a "multi-skilled worker" who can handle multiple work processes.	.69
Operators are trained to become a multi-skilled workers, using a skill map that demonstrates the skill levels targeted for each operator.	.54
Interdependence among workers on your cell or line	
Workers not only focus on their own work but also keep a balance with the pace of their co-workers work so that they do not disturb it.	.66
Workers are assumed to help co-workers adjacent on the cell or line if they have trouble with their work.	.59
Workers bear responsibility for the consequences of the cell or line, e.g., quantity, cost, and quality, together with co-workers.	.62
Workers increase understanding of each other's work while working on the line or cell.	.77
The cell or line under your supervision competes against other cells or lines at the plant over performance, e.g., quality and lead-time.	.27
Improvement activities for workers assigned to your cell or line	
Workers are instructed to present solutions through suggestion systems.	.47
The solutions workers presented through suggestion systems are useful for making the cell or line more efficient.	.59
Workers regularly (e.g., once a week) hold and participate in a QC circle or other off-the-line improvement activities.	.59
Everyone working on the cell or line, whether regular or non-regular workers, takes part in off-the-line improvement activities.	.64
Solutions that operators find through improvement activities are employed as standardized procedures to prevent the same major or minor trouble with the cell or line from occurring again.	.71
Workers exchange know-how and solutions with people on other cells or lines.	.79
Workers are allowed to directly provide opinions and solutions with technical staff members (such as manufacturing engineers).	.55
Motivating workers on your cell or line	
Promotion of workers to a higher position is closely linked to their skill levels.	.35
As a cell or line leader, you make a point of recognizing the efforts and attempts at improvement workers make, even if they fail.	.10
Within-plant-certifications, intended to promote skill levels, are useful for motivating workers.	.34
Workers find their own assembly work "challenging" or "creative."	.69
Workers feel a "sense of achievement" through performing their assembly jobs.	.59
Workers have chances to meet corporate executives who are on a plant tour.	.49
Eigenvalue	8.36
Proportion of variance accounted for	34.83

Meanwhile, using the SAS CALIS procedure, I performed a confirmatory factor analysis to test the four-factor model incorporating the four domains in work and organization practices, i.e., education, interdependence, improvement activities, and motivation. Although overall fit statistics for the four-factor model were not favorable（*df*=246; chi-square=471; GFI=.65; RMSEA =.11）, all but one of the factors' loadings were found to have t values greater than 2.0 and thus significant. Therefore, to assess the predictive utility of each model, I established a 6-item-averaged education variable（Cronbach's α=.77）, a 5-item-averaged interdependence variable（Cronbach's α=.74）, a 7-item-averaged improvement activity variable（Cronbach's α=.84）, and a 6-item-averaged motivation variable（Cronbach's α=.81）.

Furthermore, in conducting statistical analyses, the construct of manufacturing configurations was used as another predictor variable. I asked managers to assess the technological aspects of cells or lines under their supervision in terms of not only the forms of lines or cells but also lot size, product variety, and frequency of change in production volume and product items. This assessment was made with the five question items on the 5-point Likert scale. I averaged the values of those five question items（Cronbach's α=.61）and used this average as a variable to capture manufacturing configurations. A greater value in this variable means that the manufacturing system surveyed is closer to assembly cells, while a lower value means it is more similar to assembly lines. To explore an interactive or synergistic effect between the system of work and organization practices and manufacturing configurations, the product term of those two variables was also used as a predictor or independent variable.

Control variables. To test Hypotheses 1a and 1b, production volume was set as the control variable. Here, the current level of production volume is compared with past average weekly production volumes. A higher value in production volume means that the current weekly-based production volume is larger than that of past weeks. The term *mizu-sumashi*（meaning "whirligig beetles" in Japanese）was selected as the control variable to test Hypotheses 2a, 2b, 3a, and 3b. This is because *mizu-sumashi* replenishment workers are expected to be a key enabler in achieving shortened manufacturing lead-time leading to reduced work-in-process inventory, or vice versa. *Mizu-sumashi* workers are expected to correctly and promptly pick up a variety of components and supply them to assembly cells and lines on time. They typically belong to the replenishment section, not the assembly section. A higher value of *mizu-sumashi* means that participating managers felt greater satisfaction with the timely and appropriate supply of components to cells or lines by *mizu-sumashi* replenishment workers. The term *poka-yoke*（meaning "mistake-proof" in Japanese）was selected as the control variable for the product defect models. *Poka-yoke* involves using tools or equipment to prevent defects in products manufactured on cells or lines by taking such measures as stopping operations or sounding alarms for errors. Therefore, it is a critical enabler to boost manufacturing process quality. Assembly operators could conceivably design and prepare *poka-yoke* tools on their own. In the case study, however, *poka-yoke* tools were designed and set up by production engineers, not assembly workers, in most of the plants visited. Therefore, in this research it is assumed that production engineers, not assembly workers, are responsible for providing *poka-yoke*. A greater value of *poka-yoke* means that participating managers felt greater satisfaction with *poka-yoke* mistake-proofing equipment or tools.

Model Specifications

The hypotheses were tested by formulating the following general mathematical equations:

(1-1) Manufacturing performance measure$_i = \alpha + \beta_1$ control variable$_i + \mu_i$

(1-2) Manufacturing performance measure$_i = \alpha + \beta_1$ control variable$_i + \beta_2$ manufacturing configurations$_i + \mu_i$

(1-3) Manufacturing performance measure$_i = \alpha + \beta_1$ control variable$_i + \beta_2$ manufacturing configurations$_i + \beta_3$ education$_i + \beta_4$ interdependence$_i + \beta_5$ improvement activities$_i + \beta_6$ motivation$_i + \mu_i$

(1-4) Manufacturing performance measure$_i = \alpha + \beta_1$ control variable$_i + \beta_2$ manufacturing configurations$_i + \beta_3$ the system of work and organization practices$_i + \mu_i$

(1-5) Manufacturing performance measure$_i = \alpha + \beta_1$ control variable$_i + \beta_2$ manufacturing configurations$_i + \beta_3$ the system of work and organization practices$_i + \beta_4$ manufacturing configurations$_i$ ＊the system of work and organization practices$_i + \mu_i$

where the subscript $_i$ represents a case or observation for each of the cells or lines. If hypothesis 1a is tested, equation (1-4), specifically, productivity$_i = \alpha + \beta_1$ production volume$_i + \beta_2$ manufacturing configurations$_i + \beta_3$ the system of work and organization practices$_i + \mu_i$, is used. If hypothesis 1b is tested, equation (1-5), specifically, productivity$_i = \alpha + \beta_1$ production volume$_i + \beta_2$ manufacturing configurations$_i + \beta_3$ the system of work and organization practices$_i + \beta_4$ manufacturing configurations$_i$ ＊the system of work and organization practices$_i + \mu_i$, is used.

In addition to equations (1-4) and (1-5), equations (1-1), (1-2), and (1-3) were formulated to examine the "utility" of the models, that is, how much improvement in prediction of a criterion variable, Y_i (in this case manufacturing performance measure$_i$), is associated with the addition of X_i or a set X_{i1}, X_{i2}, $X_{i3}, \cdots$, X_{ik} to other predictor variable or a set of other predictors (Cohen, Cohen, West, & Aiken, 2003). The predictive utility of models is examined by observing increments in multivariate squared correlation (ΔR^2) that are attributed to the addition of X_i or a set X_{i1}, X_{i2}, X_{i3}, $\cdots$, X_{ik} to other predictor variable(s) already entered. Such an analysis is conducted with hierarchical multiple regressions. Equation (1-1) is the baseline model for subsequent hierarchical multiple regression analyses. Then the predictive utility of models （1-4） and （1-5） can be assessed, compared with that of the model （1-2）, including manufacturing configurations in addition to a control variable, and of the model（1-3）where the four domains of work and organization practices are added to the model （1-2）.

RESULTS

Table 4 represents descriptive statistics including means, standard deviations, correlations, and reliabilities. Given that the sample size 77 was not large, I considered regression coefficients in a probability level of less than .1 significant.

TABLE 4
Means, Standard Deviations, Correlations, and Reliabilities[a]

Variables	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Production volume	2.96	1.07													
2. *Mizu-sumashi*	2.79	0.71	.14												
3. *Poka-yoke*	2.92	0.68	-.04	.59**											
4. Manufacturing configurations	3.30	0.67	-.18	-.14	-.10	(.61)									
5. Productivity	3.35	0.68	.27*	.40**	.46**	-.31**	(.80)								
6. Work-in-process inventory	3.22	0.91	-.02	-.20^{+}	-.23*	.32**	.11	(.83)							
7. Manufacturing lead-time	3.44	0.64	.34**	.33**	.29*	-.26*	.70**	.25*	(.83)						
8. Product defects	3.34	0.68	.28*	.50**	.28*	-.14	.37**	.07	.52**	(.75)					
9. Education	3.00	0.70	.07	.13	-.14	.22^{+}	-.02	.12	-.09	0	(.77)				
10. Interdependence	3.45	0.63	.19^{+}	.29*	0	.03	.04	-.07	-.04	.11	.62**	(.74)			
11. Improvement activities	2.98	0.67	.24*	.23*	.01	-.01	.14	.13	-.06	.05	.66**	.59**	(.84)		
12. Motivation	3.00	0.47	-.03	.24*	.00	.18	.12	.11	.12	.14	.66**	.44**	.50**	(.61)	
13. System of work and organization practices	3.13	0.55	.12	.22^{+}	-.09	.13	-.01	.06	-.13	.03	.89**	.79**	.85**	.73**	(.91)

[a] n=77. Internal consistency reliability coefficients（Cronbach's alphas）appear on the diagonal.
$^{+}$ p<.10
* p<.05
** p<.01

Table 5 shows the regression results for testing Hypotheses 1a and 1b. As shown in model 4 in Table 5, as opposed to Hypothesis 1a, the system of work and organization practices did not have a negative effect on productivity （β=0, p>.10）. As shown for model 3, the predictive utility was not significant: the increment （ΔR^2） was negligible in the criterion variable's variance attributable to the set of four components of the work and organization practice system entered in addition to the control variable and manufacturing configurations; moreover, the unique portion of the total variance in the criterion variable accounted for by the four variables （ΔR^2=.06, p>.10） was insignificant. On the other hand, motivation as one component of the system had a positive effect on productivity （β=0.41, p<.10）.

TABLE 5
Results of Regression Analysis for Productivity[a]

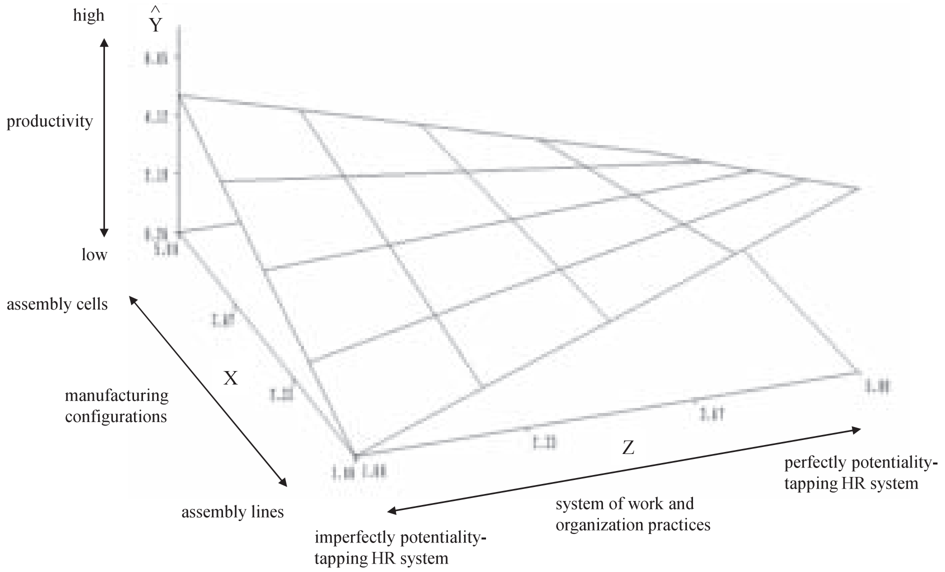
Predictors	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	2.85**	3.86**	3.10**	3.84**	-2.94
Production volume	0.17*	0.14*	0.14^{+}	0.14^{+}	0.19**
Manufacturing configurations		-0.28*	-0.28*	-0.28*	1.76**
Education			-0.20		
Interdependence			-0.07		
Improvement activities			0.11		
Motivation			0.41^{+}		
System of work and organization practices				0	2.08**
System of work and organization practices × manufacturing configurations					-0.63**
ΔR^2		.07	.06	0	.11
F for ΔR^2		6.17**	1.21	0	10.43**
R^2	.07	.14	.20	.14	.26
Overall model F	5.82*	6.20**	2.90*	4.08**	6.06*

[a] $n=77$.
[+] $p<.10$
* $p<.05$
** $p<.01$

As shown in model 5 in Table 5, the system of work and organization practices and manufacturing configurations had a statistically significant interactive effect on productivity, but the regression coefficient of the product term had a negative sign, as opposed to a positive sign as predicted by Hypothesis 1b ($\beta=-0.63$, $p<.01$). Figure 1 shows the relations using a three-dimensional plot. Figure 1 indicates that when assembly lines are used, the perfectly potentiality-tapping HR system generates higher productivity. Meanwhile, when assembly cells are employed, the imperfectly potentiality-tapping HR system generates higher productivity, while the perfectly potentiality-tapping HR system lowers the level of productivity. According to this result of regression analysis, the capabilities and skills of operators can be better utilized on assembly lines than on assembly cells. In this sense, and contrary to popular wisdom, the “manufacturing configuration dependent on people” is not the assembly cell but in fact the assembly line. The perfectly potentiality-tapping HR system becomes a way to elicit capabilities and skills from operators working on assembly lines, that is, it literally taps the potential of these workers and consequently boosts productivity.

FIGURE 1

Three-Dimensional Representation of the Relationships among the System of Work and Organization Practices, Manufacturing Configurations, and Productivity[a]



[a] The regression lines are drawn based on the equation $\hat{Y}=-2.94+1.76X+2.08Z-0.63XZ$ from model 5.

Table 6 shows the regression results for testing Hypotheses 2a and 2b. As shown in model 4, the system of work and organization practices was not related to work-in-process inventory（$\beta=0.09$, $p>.10$）. Consequently, Hypothesis 1a was not supported. As seen in model 3, even if the increment in the criterion variable's variance attributable to the set of four components of the system was not significant（$\Delta R^2=.06$, $p>.10$）, the regression coefficient of improvement activities had a positive effect on work-in-process inventory（$\beta=0.38$, $p<.10$）. As shown in model 5, as opposed to Hypothesis 2b, the system of work and organization practices and manufacturing configurations did not have a positive interactive effect on the work-in-process inventory. Therefore, for work-in-process inventory, there was no synergistic effect between the two variables but only an additive effect of the improvement activities along with manufacturing configurations.

TABLE 6
Results of Regression Analysis for Work-In-Process Inventory[a]

Predictors	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	3.94**	2.45**	2.09**	2.45**	-1.64
Mizu-sumashi	-0.26⁺	-0.20	-0.22	-0.22	-0.22
Manufacturing configurations		0.41**	0.41*	0.39*	1.53⁺
Education			-0.04		
Interdependence			-0.29		
Improvement activities			0.38⁺		
Motivation			0.14		
System of work and organization practices				0.09	1.32
System of work and organization practices × manufacturing configurations					-0.37
ΔR^2		.09	.06	0	.02
F for ΔR^2		7.39**	1.26	0.24	1.87
R^2	.04	.13	.19	.13	.15
Overall model F	3.16⁺	5.41**	2.67*	3.65*	3.24*

[a] $n=77$.
⁺ $p<.10$
* $p<.05$
** $p<.01$

Table 7 shows the regression results for testing Hypotheses 3a and 3b. As shown in model 4, as opposed to Hypothesis 3a, the system of work and organization practices did not have a positive effect on manufacturing lead-time ($\beta=-0.21$, $p>.10$). However, model 3 indicates that motivation, one of the four components of the system of work and organization practices, was positively associated with manufacturing lead-time ($\beta=0.37$, $p<.10$), even though the unique portion of the total variance in the criterion variable accounted for by the set of four components was not significant ($\Delta R^2=.06$, $p>.10$). Model 5 indicates that there is no presence of an interactive effect between the system of work and organization practices and manufacturing configurations, which means that there was only an additive effect of motivation along with manufacturing configuration. Accordingly, Hypothesis 3b was not supported.

TABLE 7
Results of Regression Analysis for Manufacturing Lead-Time[a]

Predictors	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	2.61**	3.39**	3.35**	3.83**	2.9
Mizu-sumashi	0.30**	0.30**	0.27*	0.31**	0.31**
Manufacturing configurations		-0.21*	-0.24*	-0.18+	0.10
Education			-0.09		
Interdependence			-0.09		
Improvement activities			-0.14		
Motivation			0.37+		
System of work and organization practices				-0.21	0.09
System of work and organization practices × manufacturing configurations					-0.09
ΔR^2		.05	.06	.03	0
F for ΔR^2		4.14**	1.35	2.58	0.24
R^2	.11	.15	.22	.18	.19
Overall model F	9.05**	6.78**	3.20**	5.48*	4.12*

[a] $n = 77$.
+ $p < .10$
* $p < .05$
** $p < .01$

Table 8 shows the regression results for testing Hypotheses 4a and 4b. As shown in model 4, as opposed to Hypothesis 4a, the system of work and organization practices did not have a positive effect on product defects ($\beta = 0.09$, $p > .10$). Moreover, none of the regression coefficients of the four components comprising the system was significant in model 3. Therefore, the increment in the power of prediction due to the four components was not significant ($\Delta R^2 = .04$, $p > .10$). Model 5 shows that, as opposed to Hypothesis 4b, there is no presence of a joint effect between the system of work and organization practices and manufacturing configurations. The control variable *poke-yoke* alone was consistently significant over all of the models for product defects.

TABLE 8

Results of Regression Analysis for Product Defects[a]

Predictors	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	2.53**	2.96**	2.17**	2.69**	1.61
Poka-yoke	0.28*	0.26*	0.24*	0.27*	0.26*
Manufacturing configurations		-0.12	-0.14	-0.13	0.21
Education			-0.12		
Interdependence			0.14		
Improvement activities			-0.07		
Motivation			0.33		
System of work and organization practices				0.09	0.44
System of work and organization practices × manufacturing configurations					-0.11
ΔR^2		.01	.04	0	0
F for ΔR^2		1.06	0.82	0.42	0.24
R^2	.08	.09	.13	.09	.10
Overall model *F*	6.15*	3.61*	1.43	2.52^{+}	1.93

[a] $n=77$.
$^{+}$ $p<.10$
* $p<.05$
** $p<.01$

DISCUSSIONS

None of the hypotheses were supported, and thus the results were somewhat discouraging. Nevertheless, by carefully interpreting the results of the regression analyses, we can notice many important facts beyond what was hypothesized. In the following, I interpret the results based not only on my insights but also on my follow-up research comprising direct observation at the field sites and interviews with managers at participating companies. Then, I explain the implications of this research.

Interpretations of the Results

First, let's interpret the results of the productivity models. The interactive term between the system of work and organization practices and manufacturing configurations was statistically significant; however, it had a negative sign, as opposed to Hypothesis 1b. The manufacturing configuration actually dependent on people was not assembly cells but rather assembly lines, as long as the performance indicator is productivity. This result could be interpreted in different ways. First, a greater number of unskilled and contingent workers were assigned to cells at the time I collected the data used for the quantitative research than when I had conducted the case study research from 2002 through 2005. Currently, production engineers and line managers may be designing assembly cells in such a way that even those unskilled and contingent workers could work with them. Perhaps those unskilled, contingent workers are being deployed to a de-skilled cell and then redeployed to another in response to fluctuations in production volume; as a result, assembly cells would eventually be able to sustain a certain level of productivity and even enhance productivity. Second, assembly line operators were not as unskillful as I had supposed; indeed, at a PC plant I visited in autumn 2007 for follow-up research, assembly cells — which were the dominant manufacturing configuration when I visited there for the case study research in 2004 — were replaced by assembly lines, which had become standard again at that plant. However, the remade assembly lines were not just long lines using conveyor belts; they were operated under the principles of a lean production system, and the workers, especially the line leaders, were required to attain higher problem-solving skills and be more committed to the work than when the assembly cells were dominant at the plant. The level of productivity improved after employing assembly lines in tandem with the introduction of a lean production system.

Second, let’s interpret the results for the work-in-process inventory models. There was no interactive effect on work-in-process inventory between the system of work and organization practices and manufacturing configurations. However, because Table 4 shows that manufacturing configurations are positively correlated with education ($r=.22$, $p<.10$), I conducted additional exploratory analyses to understand how manufacturing configuration mediated the effect of education. In other words, I investigated whether there was an indirect effect of education on work-in-process inventory, although no such direct effect occurred ($\beta=-0.04$, $p>.10$, see model 3 in Table 5), that takes place entirely via manufacturing configurations. First, I regressed manufacturing configurations on all of the components of the system of work and organization practices simultaneously. The result of the multiple regression analysis showed that only the regression coefficient of education was significant ($\beta=0.38$, $p<.05$). Second, to recheck the results, I obtained the partial correlation coefficients of those predictor variables with manufacturing configurations. Again, the partial correlation coefficient of education alone was significant ($pr=.25$, $p<.05$). Using not just the statistical results but also my experience at the field sites, I would say that manufacturing configurations work not as a moderator but rather as a “mediator” linking education as an antecedent variable and work-in-process inventory as a consequent variable.

Third, let’s interpret the results for the lead-time models. Through statistical analyses, I was unable to prove that the system of work and organization practices interacts with manufacturing configurations; instead, I found only an additive effect of motivation on manufacturing lead-time in conjunction with manufacturing configurations. It is noted that manufacturing configurations had a negative effect in the lead-time model, that is, assembly lines had something to do with lead-time. This result counters the understanding shared by Japanese scholars and journalists that assembly cells have replaced assembly lines because the latter cause long manufacturing lead-time. This can be explained as follows. Assembly lines would be better off shortening the time needed to complete a single type product, not various products, by enhancing the division of labor and managing operators according to cycle or tact time, i.e., the time needed for each worker to complete a work process assigned to him or her. This assumption would explain why assembly lines are more productive than assembly cells, as shown in the results of the productivity models.

Finally, let's interpret the results for the product defect models. None of the predictor variables, except the *poka-yoke* control variable, was associated with product defects. Even the effect of manufacturing configurations was not consistently related to it across all of the models. This suggests that because *poka-yoke* mistake-proofing tools are typically set up by production engineers, as explained earlier, control of product defects, or manufacturing process quality, is maintained and improved by these production engineers and staff, not by front-line workers like cell or line operators. Furthermore, this result again suggests a conclusion going against the common wisdom on Japanese manufacturers, that is, that a high standard of quality is generated on the shop floor or, as Abo (1994: 90) stated that "quality is built-in as the manufacturing process proceeds." Instead, the level of manufacturing process quality might actually be largely determined at the stage of product or process design, prior to assembly operations. Indeed, when visiting an electronics device maker for follow-up research, I asked a production manager about manufacturing process quality, and he explained, "It does not matter to quality whether cells or lines are adopted. In the stage of designing products, we devise products that are easy for operators to assemble [to improve manufacturing process quality]."

Implications

First, the results of the regression analyses imply that the relationships between work and organization practices and QCD are complicated and even elusive. This conclusion stands regardless of those practices' closer vicinity to the direct relevant effect, i.e., QCD manufacturing performance, compared with the distant relations between the practices and the firm's performance, since those relations varied with the performance criterion variable used. It is said that the linkage between HRM — composed of HRM philosophy, policy, program, practices, and climate—and a firm's performance is still a "black box," even though many SHRM scholars have endeavored to explore these relations (e.g., Becker & Huselid, 2006). To open the black box and see the mechanism, it would be crucial to examine the relationship between HRM practices and operating performance, since HRM practices are actually implemented and experienced by front-line workers, and the corresponding and relevant operating performance (e.g., productivity) will in turn translate to firm-level performance (e.g., net profit, ROE). The results of regression analyses suggest that even the linkage between work and organization practices and QCD — which may be considered easy to unravel at first glance — is actually more complicated than expected and quite difficult to explore. Consequently, although some SHRM scholars stress that focus should be placed on HRM practices and implementations and that their linkage to the relevant performance measures should be examined (Arthur & Boyles, 2007; Becker & Huselid, 2006; Gerhart, 2005), it will actually be difficult to examine the relationships between HRM practices and the direct effects.

Second, the results imply the limits of HR's strategic impact (Becker & Huselid, 2006). The system of work and organization practices was not associated with QCD manufacturing performance, although the components making up the system were related to productivity, work-in-process inventory, and manufacturing lead-time, and, moreover, the system of work and organization practices together with manufacturing configurations had a positive interactive effect on productivity. As for product defects, only the control variable, *poka-yoke*, had a positive effect, which suggests that manufacturing process quality might be largely determined by production engineers and staff, not assembly operators. Therefore, the results imply that the impact of work and organization practices might be not as strong as I—and other SHRM scholars — had expected. These results might encourage some scholars who question the impact of HRM practices on performance to be even more skeptical of it (Cappelli & Neumark, 2001). The results notwithstanding, work and organizations had something to do with manufacturing performance, and they still matter, especially for manufacturing companies and their managers, as discussed later.

Third, although the results indicated that work and organization practices did not necessarily have a strong impact on QCD, this research found that these work and organization practices did converge toward one dimension or factor. The set of these practices that I found to be prevalent and effective in the case study of cell production is deeply embedded in the shop-floor organizations of electronics-assembly plants, at least Japanese ones, regardless of the manufacturing configuration adopted. Furthermore, it might be possible to analyze work and organization practices at most manufacturing plants — despite whether they make electronics products or other products such as machine tools, apparel goods, and automobiles — in terms of the work and organization practice indicators presented in this research. Then, such practices could be categorized as either the perfectly potentiality-tapping HR system or the imperfectly potentiality-tapping HR system.

Finally, managers at manufacturing companies, especially those in charge of manufacturing operations, sometimes overstress technological aspects in manufacturing systems, overlooking the human and HRM aspects. The results suggest that those managers should pay more attention to HRM issues if they hope to boost QCD manufacturing performance. For instance, this research found that the system of work and organization practices and manufacturing configurations combined to provide a synergistic effect on productivity. Many manufacturers, including both U.S. and Japanese makers, have transferred the manufacturing function to overseas facilities located in low-labor-cost countries (O'Toole & Lawler, 2007), where in general they engage in mass-production operations. If managers at those manufacturers hope to continue production in Japan and the U.S., they will need to develop their sophistication in HRM as well as manufacturing techniques. This research can help those managers who are struggling with maintaining and further improving manufacturing competitiveness.

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