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CHANGING NATURE OF JAPANESE FIRM?: TECHNOLOGY ADOPTION, ORGANIZATIONAL STRUCTURE AND HUMAN RESOURCE STRATEGY

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1 Introduction

It is perceived that adoption of new technology (particularly information technology) causes significant changes in firm's organization structure and human resource strategy. A considerable number of case studies address this point, and a general conclusion of IT's impact on its organizational characteristics has been drawn, such as IT's essential role in "business process re-engineering" (Hammer and Champy (1993)) and IT's enhancement of flexible adjustment to dynamic business environments (Davidow and Malone (1993)). A recent study in the U.S. shows that only IT investments do not provide a whole solution of firm's productivity growth, but that it is also needed an appropriate human resource strategy, such as commitment to skill development of its workers, decentralized decision making mechanism and performance base incentive system (Brynjolfsson and Hitt (1996)).

In a broader context, innovative work practices can enhance firm's adaptive capability of new technology (Vickery and Wurzburg (1996)). Innovative work practices refers to worker involvement systems, such as work team (e.g. QC circle), employee stock ownership program and flexible and broader job assignment (Ichniowski et. al. (1996)). Theoretical support to the complementarity of technology, firm's business strategy and its organization is presented in Milgrom and Roberts (1990) and Milgrom and Roberts (1995). They stress the importance of coordination among various functions inside a firm, such as engineering, production, shipping and marketing to achieve efficient and flexible "modern manufacturing" operation.

This paper provides some empirical evidence on the complementarity of technology adoption, organizational characteristics and human resource strategy of Japanese firms. After the burst of "economic bubbles" in the early 1990's, Japanese firms faced a strong pressure for rationalization of their business activities, number of them have gone through significant restructuring processes.

In this sense, a major motivation of organizational changes in this period is improving efficiency by suppression of workforce. In this paper, how such effort is related to technology use and its consequences to human resource strategy is investigated.

In addition to this adverse economic environment, there are also some structural factors, such as technological development and globalization of firm's activities, which may affect "Japanese human resource management system", i.e., long-term employer employee relationship, seniority payment and promotion, firm specific skill development, etc. These elements are in the relationship of strategic complementarity (Aoki and Okuno (1996)), while this system was challenged by firm's efforts of workforce rationalization. In addition, an advance of information and knowledge based economy may require a firm to re-allocate its resources quickly, which cannot be achieved by consensus based decision making system inside Japanese firms (Motohashi and Nezu (1997)). How Japanese firms coped with such difficulty, as well as opportunity, is also addressed in this paper.

2 Data and issues for measuring organizational characteristics

This study is based on the survey data designed by MITI and the Ministry of Labor (MOL), and conducted by the Japan Productivity Center for Socio-Economic Development in 1995. This survey (MITI-MOL survey, hereafter) covers a broad range of questionnaire, including technology adoption, organizational structure change, human capital development and incentive system for workers, during the period from 1991 to 1994.[1] The survey was conducted to 6,622 firms, publicly traded in Japanese stock markets or by over the counter market, and 1206 firms responded.

There are some points to be noted for this survey. First, the unit of observation of MITI-MOL survey is firm, instead of establishment, which is often taken by this type of survey, such as Brynjolfsson and Hitt (1996), NUTEK (1996) and Osterman (1994). The main advantage of establishment over firm is that a respondent is more likely to know details of work practices, as compared to that of firm (Osterman (1994)). This is true for surveying detail work practices, which apply individual workers of each organization, such as TQC and team base management. In contrast, MITI-MOL survey concentrates on firm wide human resource strategy and organizational change, such as wage policy and changing organizational hierarchy.

[1] List of variables and summary statistics is available in the Government of Japan (1996).

The second issue is measurement error. Non-response biases might exist, because the response rate of very low (18.2%).[2] One way to correct such bias is to conduct a follow up survey to sampling of non respondees, as is shown in NUTEK (1996), while such kind of survey has not been conducted in this case. In addition, another type of error is rooted in questionnaire itself, because substantial number of questions require qualitative and subjective responses. Although there is no clear and agreed definition of "organizational structure", one have to ask a question like "has your organization been flattered?" to capture such important organizational aspect. In this sense, it is important to come up with coordinated conceptual framework and survey methodology for further development of this area (Vickery and Wurzburg (1996)).

3 Building blocks

3.1 Basic settings; technology adoption and organizational change

In this section, statistical analysis on technology adoption, organizational changes and human resource strategy is provided. The relationship between technology adoption and organizational changes is investigated first, then bundles of work practices, i.e., skill development, incentive system and job security, are interacted with technology and organizational variables.

Core variables of this study are technology adoption and organizational changes. As regards technology adoption, MITI-MOL survey asked whether a firm introduced the following three kinds of IT related technology in 1991 and 1994.

- Intra-firm network system : Information network system inside a firm, such as LAN (local area network), POS (point of sales system) and information system to control production and distribution
- Inter-firm network system : Information network system between firms, such as distribution network between suppliers and customers
- Office automation system : Information system to improve efficiency either of production sites or of back offices, such as CAD/CAM, flexible manufacturing system and accounting management system

As is seen from Table 1, the penetration rate of all three kinds of technology increased significantly from 1991 to 1994.

[2] It is also noted that there might be selection biases, because samples are drawn from the list of publicly traded firms, instead of entire population. This can be treated econometrically, such as by Heckman's two step method. (Heckman (1979)).

MITI-MOL survey also asked whether a firm conducted the following seven kinds of organizational change from 1991 to 1994.

- flattering the structure of firm (FLAT)
- integrating divisions or departments of firm (INT-D)
- suppression of back office staffs (CUT)
- diversification of office location (DIV)
- integrating office location (INT-O)
- enhancing flexible work time system (FLEX)
- active use of outsourcing (OUT)

Table 2 provides a first cut information on this organizational variable in relation to technology adoption. Technology variable is presented by the number of technology introduced in 1991 and 1994, respectively.

A positive association between technology and organizational change can be shown both in technology level (the number of technology adopted in 1991 or 1994) and in changes in the level (the number of technology introduced between 1991 and 1994). Information technology use may be a precondition for organizational transformation of firm, or a firm's managerial decision for IT investment and organizational change may be done simultaneously. To see which factor is dominant, the following descriptive regression is conducted.

$$\Pr(org\_change) = \alpha + \beta_1 tech91 + \beta_2 tech\_change + \beta_3 ind + \beta_4 size + \varepsilon$$

Tech91 and Tech_change is a set of dummy variables for the number of technologies in 1991 and the number of technology introduced from 1991 to 1994. It is also controlled for industry and size effects.[3] Table 3 shows coefficients of technology variables for each 7 organization variable.

In general, regression results suggest that technology level in 1991 has more explanatory power. Specifically, a firm with all three technologies in 1991 is more likely to go through organizational change in all types, while a statistical significant coefficient can be found in only two types of organizational change for variables of technology adoption from 1991 to 1994. These two types of organizational change ("suppression of back office staffs" and "enhancing of flexible work time") are not really organizational transformation, but rather changes in work practices. Therefore, a firm with IT adoption is likely to go through major organizational transformation, such as changes of the firm structure, while chances of an opposite causality are small.

In the following sections, human resource variables (human capital development, incentive system and job security) are interacted with firm's characteristics of technology adoption and organizational changes. To keep simplicity of analysis, each type of human resource strategy is regressed by both technology and organizational variables. As regards technology adoption, the following 4 categories of firms are created to capture the difference in human resource practices both by the number of technologies adopted in 1991 and by the number of technologies adopted during the period from 1991 to 1994.

- High-tech firm : a firm with all three technologies in both 1991 and 1994
- Low-tech firm : a firm with 1 or 2 technologies in both 1991 and 1994
- Change-tech firm : a firm which introduced one or more technology during the period from 1991 to 1994
- No-tech firm : a firm with no technology in either 1991 or 1994

As regards organizational variable, the first principal component of seven organizational variable is used. Because its eigenvectors are all positive, ranging from 0.359 to 0.395, and its eigenvalue is 3.04, as compared to 0.93 for the second principal one, the transformed variable by the first principal component works very well as a proxy of the degree of overall organizational change. In contrast, the ratio of noise to information is quite high for the second or lower components.

3.2 Human capital development

Human capital development is an important factor to make most of new technology adoption, and a positive link between technology and worker's skill have been supported by "skill biased technical progress " literature. (Doms et al. (1997), Krueger (1993), etc.) At the micro level, computers are supposed to substitute for "routine jobs", and workers can concentrate on more difficult jobs requiring higher skills. However, this does not work well without a proper system of worker's motivation for skill development (Levy and Murnane (1996)). The relationship between organizational change and human capital development is more complicated, because workforce rationalization may do harm to worker's incentive for long term skill development.

MITI-MOL survey has qualitative questions on changes in the need for skill level by five occupation categories, managers, administrative, R&D, sales and production workers. It should be noted that skill level here is measured by respondee's perception (upskill, no change or downskill) on each type of jobs, instead of objective scales such as educational attainments and years of work experience. Four kinds of skill type in an original questionnaire are aggregated into two, IT related skill and non-IT related skill, then the following regression is conducted by occupation and by skill type.[4]

$$\Pr(skill\_change) = \alpha + \beta_1 tech + \beta_2 org + \beta_3 ind + \beta_4 size + \varepsilon$$

[3] There are 16 industry types (roughly 2 digit level JSIC) and 4 size classes by the number of employees. The same control variables are applied to the following regressions as well.

[4] Regressions are done by ordered probit model.

Regression is conducted for two kinds of samples, all firms (upper panel of Table 4) and only firms with technology in either 1991 or 1994 (lower panel of Table 4). The first result shows a general association of skill, technology and organizational change, while the second one shows the effect of technology adoption when restricting samples to only technology firms. The first panel suggests positive link of upskilling with both technology and organizational change. According to the manager's perception, coping with new IT system needs higher skill level not only in IT related skill, but also non IT related one, such as general planning and coordination ability. In addition, a positive link between the need for high skills and organizational change is found. Due to the long economic depression in Japan in the early 1990's, Japanese firms faced a strong pressure for downsizing. In fact, a firm with organizational change shows relatively larger employment loss, as is shown later. It is interesting to see that managers which have gone through such tough restructuring process perceive the necessity to skill upgrading more than the others.

According to the lower panel of Table 4, positive and significant coefficients with organization variable are found, even for only technology firms. As regards technology variables, it is found that skill upgrading for tech-change firms is perceived as much as that for high-tech firms, but more than that of low-tech firm, particularly for managers. In addition, in high tech firms, non IT related skills for sales and production workers are perceived to be more upgraded, as compared to those in tech change firms.

The MITI-MOL survey asked respondee's opinion on obstacles for human capital development and desirable measures to help firms to conduct training. Table 5 and 6 are regression results of each choice of questionnaire as a dependent variable.[5] There are some interesting observations. For example, the size effect[6] cannot be found in some obstacles, such as financial difficulty. Instead, smaller firms are likely to list lack of human resources for training and know-hows as an obstacle. This point should be taken into account in policy making of human capital development in SMEs. There is very small technology effect, and only one significant coefficient is found in organization variable with financial difficulty. However, this needs careful interpretation, because a firm with organizational changes is supposed to face severe financial difficulty, as compared to the others. As for the desirable measure regressions, some positive coefficients of technology and organization are found for financial incentives, such as subsidy and tax treatment.

[5] This is a multiple choice question with a list of obstacles or measures for training.
[6] Negative coefficient means as the firm size increases, the probability of recognizing each obstacle becomes small.

3.3 Incentive system

Wage and promotion are important instruments for workers to work hard and improve productivity, and an appropriate incentive system is critical to firm's success. Incentive system is related to the organizational structure of firm. For example, if a firm transforms its organization to flatter one and delegates responsibility to individual workers, decentralized incentive system (pay for individual performance) may be better fitted. Use of information technology is also related. IT leads to increasing monitoring ability in employer, who can delegate more responsibility to employees, and a wage contract linked with individual workers becomes more efficient (Brynjolfsson and Hitt (1996)).

One of key issues in incentive system for Japanese firms is either performance based pay or seniority based pay. It is believed that seniority based pay and promotion is a key element of "Japanese employment system". Job vacancy is filled by an internal candidate, and promotion of worker (linked with wage) is considered, only when his just one step senior position becomes open. There is no leap frog in this promotion ladder. This kind of system used to work in Japan due to demographic characteristics (relatively abundant young workforce) and high growth expectation (EPA (1994)). However, it becomes harder for a firm to maintain it, and increasing number of firms have introduced performance based wage setting systems such as yearly contract base payment.

In the MITI-MOL survey, two questions are asked to see whether a firm will enhance performance linked wage system. The first question asks whether a firm strengthen wage's link with performance, for its base salary and bonus, respectively. Bonus is often linked with the performance of firm, and it has served as an instrument to keep flexibility of labor cost for Japanese firms (Hamada and Kurosaka (1986)). This question also distinguishes bonus's link with overall firm's performance and individual worker's performance. The second question asks the same kind of question, but for five different occupation categories, respectively. The following descriptive regression is conducted to see how incentive system changes are related to technology and organizational characteristics. Results are presented at Table 7a and 7b.

$$\Pr(increase\_performance\_payment) = \alpha + \beta_1 tech + \beta_2 org + \beta_3 ind + \beta_4 size + \varepsilon$$

In general, it is found that technology and organizational variable are positively correlated with firm's propensity to incentive payments, and it is more likely for bonuses to be used as an instrument for performance based payment. Therefore, it is confirmed that a firm with organizational change is more likely to depart from traditional Japanese seniority wage system, and seeking for new style of human resource management style. It is also noted that a positive link seems to be found more with the organization variable than with technology variables. For the regression by occupation, technology variables have a positive and significant coefficient in managers, and partly in R&D and sales workers, and there is no positive sign for administrative workers, while the organizational variable has a positive and significant coefficient for all occupations.

3.4 Job security

Job security, or limited port of entry into internal labor market is a crucial element for "Japanese employment management system". It is found that the wage profile by age for Japanese firms is steeper than that of the United States and some European countries (EPA (1994)). This implies that younger workers are paid less than their marginal productivity, while older ones are paid more. This inter-generation wage subsidization is possible, because employment opportunity is limited to new graduates for most of Japanese firms. In addition, younger workers are motivated to work for promotion competition and rapid salary increase. However, this system is questioned as well, by increasing number of firms applying performance based incentives and active external labor market policy by the government.

Changes in the job rotation system have some skill development implications as well. Job security enables worker to invest in firm specific human capital for efficient communication between colleagues and enhancing team work for firm's success. Swedish study shows that a firm with more manager's commitment to worker's skill development has lower job turnover rate (NUTEK (1996)). However, US study shows no significant relationship between high performance workplaces and job security, and it is interpreted that segmentation of internal labor market into "core workers" and "contingent workers" occurs in such organization (Osterman (1994)).

MITI-MOL survey asks whether a firm increases, does not change or decreases each of seven types of ways in coping with labor demand changes, as is shown in Table 8 To see how firm's preference of each type is related to technology and organizational characteristics, the following regression is conducted.

$$Pr(type\_of\_workforce\_change) = \alpha + \beta_1 tech + \beta_2 org + \beta_3 ind + \beta_4 size + \varepsilon$$

It is found that there is very little impact of technology, while some significant coefficients can been seen for the organizational variable. That is, a firm with organizational change is less likely to increase full time workers by cutting down the number of hiring new graduates, and maintain its flexibility by increasing in-house or cross firm labor transferring. It should be noted that there is not significant association between increasing number of temporary or contract workers and organizational change. Even for a firm with organizational changes, it tries to keep its internal employment system by internal rotation to cope with labor demand changes.

4 Labor productivity and employment growth

In this section, the relationship with firm level performance is investigated. The focus of this section is changes in labor productivity[7] and employment, instead of level, because there is no variable for the level of organizational characteristics. First cut information on technology and firm performance can be found in Table 9. It looks that labor productivity loss is less for higher technology level firms, while it is worse for firms with technology adoption from 1991 to 1994. On the other hand, there seems to be a positive employment effect of technology.

Next, statistical significance of this observation is tested by a fixed effect model (Table 10). The sign of coefficients is consistent with observations from Table 9, but statistical significance cannot be found for labor productivity regressions. There are number of potential reasons. One is data problem with productivity measurement (Baily and Gordon (1991)). Another is due to real effects, such as lags and mismanagement of information technology (Brynjolfsson (1993)). It is also found that productivity impact of IT depends on its application. For example, IT use for production management has more impacts, as compared to back office applications such as accounting system (Motohashi (1998a)). It is not necessary to go through whole discussion on "Solow's Productivity Paradox" here[8], but it is worthwhile to note that this is not a strange result in empirical literature (McGuckin et al. (1996)).

In contrast, there is very clear employment effects by technology. As compared to no-technology firms, positive and statistically significant coefficients are found, not only in tech-change firms, but also in high-tech and low-tech firms. Therefore, employment growth by technology adoption is not just a temporary one as a result of adjustment of firms into new environment.[9] On the other hand, organizational change leads to employment reduction, which may be due to an outcome of corporate restructuring in severe economic condition.

Detail look at employment impacts is done by the type of occupation. Empirical literature of skill biased technical progress suggests that technology adoption leads to relatively higher growth rate of white collars, as compared to

7 Value added for labor productivity is calculated from operating profit + labor compensation, because depreciation data is not available. This definition is different from typical definition of gross value added, which include the amount of depreciation.

8 Solow's paradox is extensively investigated in OECD (1996).

9 According to comparative study of France, Japan and the United States, the positive association between technology and employment growth is stronger in Japan than in the other two (Motohashi (1998b)).

blue collars (Berndt et al. (1992)). However, the results are not consistent with such literature. The sign of coefficients (not statistically significant) shows that administrative jobs seems to decrease by technology, as compared to other job categories.[10] Organizational change works employment loss for all categories, except sales workers. Again, the impact on administrative job is the greatest. To investigate employment impacts of information technology, it is necessary to depart from traditional view of job category (production workers vs non-production workers), and to take a detail look at inside white collar categories as well (Bresnahan (1997)).

5 Synthesis and concluding remarks

The followings are main points of changes in human resource strategy of Japanese firms.

- Skills: Greater needs of skill upgrading for every type of worker is found in a firm with technology adoption and/or organizational changes.
- Incentive system: Increasing number of firms apply performance based wage system, and this is more likely for a firm with technology and/or organizational changes.
- Job security: Japanese firms still manage to keep job security for existing workers by restricting new graduate hiring and shifting labor forces internally to cope with negative labor demand changes.

These elements of human resource strategy have to be treated as a system, and the Japanese management style is characterized as a complement relationship of firm specific skill development, seniority based incentive system and high job security by long term employment.[11] As is described before, an employee for Japanese firm (particularly white collar worker in large firm) can invest in firm specific human capital, which contributes to efficient internal communication and share the same value with colleagues, by long term employment. Due to the high retention rate of workers, subjective performance evaluation by supervisor is relatively easily introduced, and wage, as well as promotion is linked with seniority (with adjustment by supervisor's evaluation), instead of short term performance of workers. Seniority based payment also reduces over-competition among colleagues and encourage team works.[12]

MITI-MOL survey shows some changes in these compliment elements. First, technology adoption leads to higher skill requirement for every types of occupation. MITI-MOL survey distinguishes IT related skills and non-IT related skills. It should be noted that information technology opens up an opportunity of new work style, which requires higher IT skill. Since IT skill can be classified into general purpose human capital rather than firm specific human capital, increases in such skill requirement may affect complimentarities of Japanese system. Second, a firm with new technology is shifting its incentive system from seniority to performance based one. Due to relative changes in skill requirement, it is assumed that technology based firms begin to focus on objective performance evaluation system, instead of seniority system with subjective performance evaluation by supervisors.

On the other hand, difference in job security between technology based firms and non-technology ones cannot be found. Even for firms with organizational changes which mainly lead to workforce rationalization, they cope with labor demand changes by internal labor force movements. This can be interpreted that internal labor market policy is not easily affected. In addition, job security, or lower labor turnover is found to have a positive effect on worker's motivation and performance (Ichniowski et. al. (1997), Brynjolffson and Hitt (1996) and NUTEK (1996)). High retention rate of Japanese is difficult to be sustained without lack of active external labor market, while this is changing now by active labor market policy by the government and increasing number of mid-career hiring by firms in IT related high growth industry. In this sense, Japanese firm is supposed to face strong pressure to modify its human resource management strategy.

Organizational inertia and complementarity of various elements impede rapid adjustment in human resource strategy for Japanese firms. However, there are some signs of systematic changes. Severe economic situation after the burst of "bubbles" in Japanese economy causes firms to rationalize their business activities. Restructuring efforts leading to labor force suppression are one of main factors behind changes in human resource practices. Another one is technological progress, particularly in IT, which opens up substantial opportunity of new business style, requiring different kind of worker skills and incentive systems. One unsolved problem in this paper is the relationship of new work practices with firm's performance. Productivity impact may be revealed in a longer timeframe and with detailed look at systematic interactions of each components.

[10] Since only qualitative data (increase, no change or decrease) are available for changes in employment by occupation, this results are not so efficient as those from actual number data.

[11] Aoki and Okuno (1996) extensively discuss complementarity of internal labor market system for Japanese firms. Milgrom and Roberts (1992) also present systematic nature of human resource policy by using an example of Japanese system.

[12] Because decision making on promotion involves large number of individuals, it may induce a worker to spend substantial time to influence supervisors about his reputation. The opportunity cost associated with such influence activities can be mitigated by seniority system (Milgrom and Roberts (1992)).

Table 1 The share of firms adopting new technology (for 1182 firms)[13]

	1991	1994
Intra-firm network	34%	57%
Inter-firm network	16%	27%
Office Automation system	50%	70%

Table 2 The share of firm with organizational change by its technology adoption

Tech 91	Tech 94	# of firms	FLAT	INT-D	CUT	DIV	INT-O	FLEX	OUT
all	all	1182	29%	38%	50%	14%	18%	22%	21%
0	0	247	15%	26%	26%	6%	10%	9%	15%
0	1	159	26%	26%	41%	8%	13%	13%	14%
0	2	86	35%	41%	53%	17%	15%	31%	29%
0	3	32	28%	41%	66%	13%	19%	31%	13%
1	1	211	24%	38%	49%	14%	13%	18%	18%
1	2	90	41%	43%	69%	21%	29%	33%	33%
1	3	22	36%	55%	82%	27%	59%	41%	50%
2	1	174	37%	48%	57%	17%	25%	26%	23%
2	2	46	41%	65%	70%	26%	28%	30%	28%
3	3	115	35%	46%	68%	17%	26%	37%	26%

[13]Since all respondees of survey do not always give their answers to all questions, this number is different from the number of respondees. The same as follows.

Table 3 Regression : organizational change = f(technology adoption)[14]

	technology level in 1991			technology adopted during 91-94		
	0	1	2	0	1	2
flattering organization	-0.45***	-0.19	0.00	-0.26	0.04	0.16
	0.16	0.15	0.15	0.26	0.26	0.27
integrating divisions	-0.37**	-0.06	0.17	-0.28	-0.19	0.05
	0.15	0.15	0.15	0.24	0.25	0.26
supression of back office staffs	-0.88***	-0.26*	-0.22	-0.88***	-0.47*	-0.25
	0.15	0.15	0.16	0.25	0.25	0.27
diversification of office location	-0.64***	-0.11	-0.01	-0.41	-0.17	0.21
	0.19	0.18	0.18	0.31	0.32	0.33
integrating office location	-0.53***	-0.14	-0.01	-0.34	-0.09	0.13
	0.17	0.16	0.16	0.28	0.28	0.30
enhancing of flexible work time	-0.72***	-0.38**	-0.27	-0.64**	-0.45*	-0.04
	0.17	0.16	0.16	0.27	0.27	0.28
active use of outsourcing	-0.36**	-0.05	-0.12	0.23	0.39	0.76**
	0.16	0.16	0.16	0.31	0.32	0.33

Note : *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

[14]Dummy variables are arranged by setting the number of technologies = 3 as a base.

Table 4 Regression results; Skill change = f (technology, organizational change)

(For all firms: No-tech firms as a base)

		High-tech firm	Low-tech firm	Tech-change firm	Organization
Manager	IT related skill	0.627*** (0.155)	0.477*** (0.112)	0.800*** (0.112)	0.106*** (0.024)
	non IT skill	0.398*** (0.138)	0.143 (0.100)	0.352*** (0.100)	0.059*** (0.021)
Administrative	IT related skill	0.805*** (0.170)	0.856*** (0.115)	0.949*** (0.116)	0.119*** (0.028)
	non IT skill	0.524*** (0.139)	0.376*** (0.102)	0.604*** (0.102)	0.071*** (0.021)
R&D	IT related skill	0.666*** (0.181)	0.484*** (0.126)	0.649*** (0.125)	0.049* (0.026)
	non IT skill	0.54*** (0.159)	0.288** (0.117)	0.424*** (0.116)	0.029 (0.023)
Sales	IT related skill	0.813*** (0.164)	0.507*** (0.113)	0.574*** (0.113)	0.140*** (0.025)
	non IT skill	0.622*** (0.141)	0.254** (0.103)	0.429*** (0.103)	0.068*** (0.021)
Production	IT related skill	0.807*** (0.182)	0.390*** (0.127)	0.671*** (0.127)	0.056** (0.026)
	non IT skill	0.696*** (0.168)	0.228* (0.122)	0.359*** (0.122)	0.047* (0.024)

Table 4 Continued

(For tech firms only: Tech-change firms as a base)

		High-tech firm	Low-tech firm	Organization
Manager	IT related skill	-0.190 (0.138)	-0.330*** (0.091)	0.111*** (0.026)
	non IT skill	0.049 (0.123)	-0.212*** (0.082)	0.055** (0.023)
Administrative	IT related skill	-0.141 (0.162)	-0.098 (0.105)	0.087*** (0.031)
	non IT skill	-0.068 (0.123)	-0.236*** (0.082)	0.060*** (0.023)
R&D	IT related skill	-0.018 (0.168)	-0.165 (0.106)	0.061** (0.029)
	non IT skill	0.120 (0.141)	-0.128 (0.094)	0.035 (0.025)
Sales	IT related skill	0.226 (0.150)	-0.065 (0.094)	0.117*** (0.027)
	non IT skill	0.212* (0.126)	-0.171** (0.084)	0.056** (0.023)
Production	IT related skill	0.149 (0.164)	-0.277*** (0.103)	0.075*** (0.028)
	non IT skill	0.356** (0.148)	-0.132 (0.098)	0.047* (0.026)

Note : *** · statistical significance at 1% level
** statistical significance at 5% level
* statistical significance at 10% level

Table 5 Regression · Obstacle for HRD = f (technology, organizational change)

	%of firm	Size effect	High-tech	Low-tech	Tech-change	Organization
Lack of personel working for coordination of training	40%	—		+		
Lack of time for training	38%	-				
Lack of know-how for training	30%	—	-			
Lack of instructor	26%	—		+		
Lack of knowledge on the contents of training	23%					
Lack of in-house training center	18%	—				
Financial difficulty	15%					++
Lack of training center nearby	5%					
Lack of institution for consultation on training	4%	—				

Note : +++ : positive significant coefficient at 1 % level
++ : positive significant coefficient at 5 % level
+ : positive significant coefficient at 10 % level
— : negative significant coefficient at 1 % level
-- : negative significant coefficient at 5 % level
- : negative significant coefficient at 10 % level

Table 6 Regression · Measures for training = f (technology, organizational change)

	% of firm	Size effect	High-tech	Low-tech	Tech-change	Organization
Subsiaries to training	42%					++
Increasing opportunity of training	40%	—				+
Increasing information dissemination	38%		+			
Diversifying training contents in public institution	35%	—				
Tax measures for training	33%			+	++	+
Official evaluation for training outcomes	20%	-				

Note : +++ : positive significant coefficient at 1 % level
++ : positive significant coefficient at 5 % level
+ : positive significant coefficient at 10 % level
— : negative significant coefficient at 1 % level
-- : negative significant coefficient at 5 % level
- : negative significant coefficient at 10 % level

Table 7a Regression by wage and performance type

	base salary		bonus	
	worker's	firm's	worker's	firm's
High-tech firm	0.202	0.324**	0.377**	0.271
	0.146	0.144	0.169	0.176
Low-tech firm	0.289***	0.049	0.265**	0.238**
	0.104	0.102	0.113	0.118
Tech-change	0.170*	0.082	0.344***	0.276**
firm	0.102	0.101	0.112	0.117
Organization	0.063***	0.074***	0.118***	0.090***
	0.023	0.022	0.028	0.029

Note : *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

Table 7b Regression by occupation

	manager	administrative	R&D	sales	production
High-tech firm	0.175	0.027	0.021	0.135	0.169
	0.163	0.155	0.174	0.167	0.172
Low-tech firm	0.353***	0.152	0.153	0.218*	0.206*
	0.114	0.109	0.124	0.117	0.120
Tech-change	0.228**	0.166	0.289**	0.227*	0.155
firm	0.112	0.108	0.124	0.116	0.119
Organization	0.070***	0.081***	0.067**	0.077***	0.058**
	0.026	0.024	0.027	0.026	0.026

Note : *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

Table 8 Regression results : the style of labor force increases = f (technology, organization)

	High-tech firm		Low-tech firm		Tech-change firm		Organization	
Hiring new graduates	0.084	(0.137)	0.061	(0.098)	0.100	(0.097)	-0.086***	(0.021)
Hiring mid-careers	0.068	(0.141)	0.029	(0.099)	0.059	(0.099)	-0.030	(0.021)
Teporary staff contract	0.154	(0.158)	0.075	(0.115)	0.187	(0.114)	0.013	(0.023)
Part time workers	0.047	(0.147)	-0.051	(0.104)	-0.096	(0.103)	0.003	(0.022)
In-house transfer	0.257*	(0.153)	0.105	(0.111)	0.214*	(0.109)	0.079***	(0.023)
Cross-firm transter-1	-0.089	(0.156)	-0.091	(0.117)	0.105	(0.115)	0.069***	(0.024)
Cross-firm transfer-2	0.025	(0.181)	0.036	(0.137)	0.188	(0.135)	0.057***	(0.027)

Note : *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

Table 9 Summary statistics of labor productivity and employment by technology

Tech 91	Tech 94	# of firms	EMP91	LP91	lpgr	empgr
all	all	1182	5.69	1.99	-6.19%	0.89%
0	0	247	5.07	2.01	-3.46%	-2.20%
0	1	159	5.26	1.97	-6.87%	1 84%
0	2	86	5.84	2.09	-8.94%	4.97%
0	3	32	6.08	2.04	-15.94%	0.25%
1	1	211	5.39	1.97	-8.23%	-1.16%
1	2	90	6.05	2.03	-7 11%	3.29%
1	3	22	6.70	1.67	-0.74%	0.94%
2	1	174	6.09	1.94	-5.99%	3.60%
2	2	46	6.19	1.86	-2.03%	1 93%
3	3	115	6.59	2.08	-4.38%	0.87%

Table 10 Regression results · productivity and employment by technology and organizational change

Dependent variable=labor productivity growth

	(1)	(2)	(3)
High-tech firm	0.0053	0.0004	-
	0.0561	0.0562	-
Low-tech firm	-0.0190	-0.0256	-
	0.0407	0.0411	-
Tech-change firm	-0.0188	-0.0245	-
	0.0368	0.0372	-
Organization	-	0.0099	0.0090
	-	0.0099	0.0085
N=	745	745	745

Dependent variable=employment growth

	(1)	(2)	(3)
High-tech firm	0.0476**	0.0530**	-
	0.0231	0.0232	-
Low-tech firm	0.0489***	0.0531***	-
	0.0173	0.0173	-
Tech-change firm	0.0434***	0.0486***	-
	0.0158	0.0159	-
Organization	-	-0.0092**	-0.0077**
	-	0.0036	0.0036
N=	745	745	745

Note · *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

Table 11 Regression results: Employment effect by occupation

	manager	administrative	R&D	sales	production
High-tech firm	0.077	0.032	-0.004	-0.158	0.018
	0.134	0.135	0.138	0.135	0.141
Low-tech firm	0.070	-0.104	0.065	0.097	-0.001
	0.095	0.095	0.099	0.097	0.099
Tech-change firm	0.123	-0.044	0.249**	0.111	0.114
	0.095	0.094	0.099	0.096	0.099
Organization	-0.074***	-0.113***	-0.047**	-0.009	-0.090***
	0.021	0.021	0.021	0.021	0.021

Note : *** : statistical significance at 1% level
** : statistical significance at 5% level
* : statistical significance at 10% level

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PARAMETRIC ESTIMATION OF TECHNICAL AND ALLOCATIVE EFFICIENCIES AND PRODUCTIVITY CHANGES: A CASE STUDY*

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1 Introduction

The increased availability of firm level data has led to a renewed interest in the components of productivity change in different sectors of the economy. Simultaneously, recent years have seen a rapid development of efficiency and productivity change measurement techniques. Nonparametric methods like DEA became increasingly popular, and parametric models became sufficiently elaborate to capture other sources of productivity change than technological change[1]. At present parametric models are able to distinguish between technological change (the movement of the technological frontier through time) and the change of allocative and technical efficiency. Allocative efficiency is related to sub-optimality of the input mix. A firm may improve its efficiency (reduce its cost) by adapting its input mix to prevailing market prices. Technical efficiency is related to slacks in inputs: the actual level of output can be achieved with less inputs. It is well known that both kinds of efficiency cannot be estimated simultaneously unless panel data are available. For this reason early studies that estimated allocative efficiencies had to assume that firms were fully technically efficient (see e.g. Atkinson and Halvorsen 1984, 1986 for examples of estimating allocative efficiencies from cross-sectional data and Oum and Zhang 1995 for a time series example). Furthermore, in the absence of panel data, estimates of technical efficiencies can only be obtained by imposing some structure on the disturbances of the model (the stochastic frontier approach).

With panel data available, less restrictive models can be applied which include both kinds of efficiency as well as technological change. Recent examples are

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[1] Recent developments in this area are documented in the October 1996 issue of The Journal of Productivity Analysis.