RCSSディスカッションペーパーシリーズ ISSN-1347-636X
第76号　2008年11月
Discussion Paper Series
No.76　November, 2008

Substitutability of IT Capital and Heterogeneously-educated Workers in Japan

Kazunori Minetaki

Takeshi Nakazawa

RCSS

文部科学大臣認定　共同利用・共同研究拠点
関西大学ソシオネットワーク戦略研究機構
関西大学ソシオネットワーク戦略研究センター
（文部科学省私立大学学術フロンティア推進拠点）

Research Center of Socionetwork Strategies,
"Academic Frontier" Project for Private Universities, 2003-2009
Supported by Ministry of Education, Culture, Sports, Science and Technology
The Research Institute for Socionetwork Strategies,
Joint Usage / Research Center, MEXT, Japan
Kansai University
Suita, Osaka, 564-8680 Japan
URL: http://www.rcss.kansai-u.ac.jp
http://www.socionetwork.jp
e-mail: rcss@jm.kansai-u.ac.jp
tel: 06-6368-1228
fax. 06-6330-3304

Substitutability of IT Capital and Heterogeneously-educated Workers in Japan

Kazunori Minetaki

Takeshi Nakazawa

RCSS

文部科学大臣認定　共同利用・共同研究拠点
関西大学ソシオネットワーク戦略研究機構
関西大学ソシオネットワーク戦略研究センター
（文部科学省私立大学学術フロンティア推進拠点）

Research Center of Socionetwork Strategies,
"Academic Frontier" Project for Private Universities, 2003-2009
Supported by Ministry of Education, Culture, Sports, Science and Technology
The Research Institute for Socionetwork Strategies,
Joint Usage / Research Center, MEXT, Japan
Kansai University
Suita, Osaka, 564-8680 Japan
URL: http://www.rcss.kansai-u.ac.jp
http://www.socionetwork.jp
e-mail: rcss@jm.kansai-u.ac.jp
tel: 06-6368-1228
fax. 06-6330-3304

Substitutability of IT Capital and Heterogeneously-educated Workers in Japan

Kazunori Minetaki*
The Research Institute for Socionetwork Strategies, Kansai University
3-3-35, Yamate-cho, Suita, Osaka, 564-8680, Japan.
Phone: +81-6-6368-1228 Fax: +81-6-6330-3304
E-Mail: minetaki@rcss.kansai-u.ac.jp

Takeshi Nakazawa**
The Research Institute for Socionetwork Strategies, Kansai University
3-3-35, Yamate-cho, Suita, Osaka, 564-8680, Japan.
Phone: +81-6-6368-1228 Fax: +81-6-6330-3304
E-Mail: nakazawa@rcss.kansai-u.ac.jp

Abstract

In this paper, we analyze the relationship between IT capital and Heterogeneously-educated workers, for example, young workers, older, highly educated workers, and workers with a low level of education, in each industry. The elasticity of substitution among production inputs shows us whether the relationship is one of substitutability or complementary behavior.

We assume the firm's behavior represents cost minimization under imperfect competition following Nishimura and Minetaki [1]. Under imperfect competition, there are quasi-fixed inputs in the short period. We use the translog-cost function for the formation of a firm's behavior, and we can find which inputs are variable, and which inputs are quasi-fixed inputs used to estimate the translog-cost function.

From our empirical study, the relationships among IT capital and young workers with low education have shown substitutability in all industries from 1999-2005. This result is the same as the result in 1980-1998, which is shown in Nishimura and Minetaki [1]. On the other hand, the relationships among IT capital and highly educated workers are different.

In food, textiles, fabricated metal, transportation equipment, construction, finance, transportation and equipment, and service, the relationships among IT capital and young, highly educated workers shows substitutability from 1999-2005. In primary metal, general machinery, instruments, and commerce, the relationships among IT capital and older, highly educated workers shows substitutability from 1999-2005. Complementariness between IT capital and highly educated workers was not seen in 1999-2005. However, Nishimura and Minetaki [1] show that there has been complementariness between IT capital and highly educated workers in several industries from 1980-1998.

We speculate that the main reason is that the skills of highly educated workers have become obsolete for high-speed Information Communication Technology. Broadband has expanded and spread Information Communication Technology, and this has changed the circumstance of office work. In other words, business software, such as CAD and ERP can replace the skills of highly educated workers.

Keywords: substitutability, complementariness, translog-cost function

* Senior Researcher for Statistical Analysis.
** Postdoctoral Fellow.

1. Introduction

In this paper we analyze the impact of advances in IT on demand for labor inputs, thereby expanding upon the discussion presented in this paper.

To be a little more specific, we disaggregate labor in terms of age and education level and look at whether IT capital is a substitute or complement for each particular type of labor input, that is, whether IT capital has a labor-saving impact or instead acts to boost the value of (and hence demand for) labor. The average age of Japan's workforce is steadily increasing, and a solid understanding of the impact of IT investment on the labor market is vital to policymakers tasked with drafting measures relating to education and human capital.

To consider whether particular pairs of production factors might be substitutes or complements, we must first determine which factors are variable in the short term and which are quasi-fixed. If all production factors are variable, then cost minimization on the part of the producer will ensure that each input's price is equal to its marginal product, and this information can then be used to estimate cost functions and thereby measure whether pairs of factors are substitutes or complements. However, if some production factors are quasi-fixed, then the standard procedure cannot be applied, as there is no guarantee that prices will equal marginal products.

In the context of the Japanese economy—which has such a wide variety of labor and capital types—it is clearly inappropriate to assume that all production factors are variable or that all capital factors are quasi-fixed while all labor inputs are variable (this assumption is often made in US and European empirical research). For example, stocks of certain types of capital (such as computers) can be changed with very little notice, while certain types of labor input (such as head-office management staff) are difficult to vary in the short term. We have therefore avoided *a priori* assumptions wherever possible in this paper, instead relying on the data to tell us which inputs are quasi-fixed and which can be treated as variable.

We briefly summarize each section. Section 2 shows the analytical framework for our empirical study. Section 3 discusses the estimation results, and Allen-Uzawa's elasticity of substitution is calculated in Section 4. Section 5 is the conclusion.

2. Analytical framework

Given that our focus is on substitutability or complementarity between production factors, we must use a cost function that is sufficiently flexible to allow for both possibilities. The most popular functional form for this purpose is the translog form, and this is what we use for the variable cost function in the analysis that follows.

Let *n* denote the number of variable inputs. As we explained in this paper, our analysis assumes the existence of two different types of capital (IT capital stock, non-IT capital stock), and four different types of labor (young, low-educated workers, old, low educated workers, young, highly educated workers, and old, highly educated workers).

According to Nishimura and Minetaki [1] and Kurokawa et al. [2], in this paper we consider a generalized production function with *n* variable factors of production and *m* quasi-fixed factors:

$$Y = F\left(x_1, \ldots, x_i, \ldots, x_n; z_1, \ldots, z_j, \ldots z_m; A\right) \qquad \cdots(1)$$

Here x_i denotes the *i*th variable factor and z_j the *j*th quasi-fixed factor. *A* is a parameter denoting the state (level) of the production technology.

We now make two assumptions regarding this generalized production function. First, we assume that it can be expressed as the product of a "production capacity function" and a "capacity utilization function". We then assume that the production capacity function and capacity utilization function are both homogenous and that the production function obtained by multiplying these two functions together exhibits constant returns to scale.

<u>Assumption 1</u>

$$Y = F\left(x_1, \ldots, x_i, \ldots, x_n; z_1, \ldots, z_j, \ldots z_m; A\right) = G\left(x_1, \ldots, x_i, \ldots, x_n; A\right) S\left(z_1, \ldots, z_j, \ldots z_m; A\right) \qquad \cdots(2)$$

Here S denotes the production capacity function of quasi-fixed factors and G denotes the capacity utilization function of variable factors. Let us consider an oil-refining company as an example of how to interpret these functions. The company's refining capacity depends on factors that cannot be easily varied in the short term, such as land, buildings, tanks, and other large equipment. The company's maintenance workers and management teams should also be viewed as fixed inputs in the short run. These "quasi-fixed" factors determine the company's maximum output capacity at any one time, and are therefore viewed as inputs to the company's production capacity function S.

In the short run, however, the company treats its production capacity as given (exogenous) and seeks to maximize its profits by determining the optimal levels of variable inputs such as crude oil, services of trucks and other equipment, and labor provided by on-site workers. In other words, the company's variable inputs determine what proportion of production capacity is actually used.

<u>Assumption 2</u>

The capacity utilization function G is homogenous of degree k, and the production capacity function S is homogenous of degree $1–k$.

We have made these assumptions so as to ensure that the production function is homogenous of degree one in all inputs. Thus we are implicitly assuming that production exhibits constant returns to scale in the long run (where quasi-fixed factors are optimally adjusted), such that multiplying the amount of each input by λ also increases output by a factor of λ. Quasi-fixed factors are fixed in the short run but variable in the long run. We now assume that the amount of each quasi-fixed factor used in a given period's production must be determined one period before that production takes place. It is straightforward to extend our analysis to the case where some of the inputs must be determined further in advance, but this would make the notation somewhat more cumbersome, and we have chosen the simplest approach so as to streamline the following discussion.

<u>Assumption 3</u>

The amount of each quasi-fixed factor used in a given period's production must be determined one period before that production takes place.

Next, we show how the short-term variable cost function can be defined under these assumptions.

The variable cost function corresponding to production function F is defined as:

$$C_V\left(p_1,\ldots,p_i,\ldots,p_n,Y,S;A\right)=\underset{x_1,\ldots,x_n}{Min}\sum_{i=1}^{n}p_i x_i$$
$$\text{subject to } Y=G\left(x_1,\ldots,x_i,\ldots,x_n\right)S \qquad \cdots(3)$$

With some manipulation, we are able to express this as the product of a function that depends solely on the output level and production capacity, and a function that depends solely on the technology parameter and the prices of variable factors.

$$C_V\left(p_1,\ldots,p_i,\ldots,p_n,Y,S;A\right)=c_v\left(p_1,\ldots,p_i,\ldots,p_n;A\right)\left(\frac{Y}{S}\right)^{1/k} \qquad \cdots(4)$$

Note that c_v is homogenous of degree one in the prices of variable factors. We may then use Shephard's lemma to write variable cost shares as follows:

$$\frac{p_i x_i}{C_V}=\frac{p_i}{c_v\left(p_1,\ldots,p_i,\ldots,p_n;A\right)}\frac{\partial c_v\left(p_1,\ldots,p_i,\ldots,p_n;A\right)}{\partial p_i} \qquad \cdots(5)$$

We derived the variable cost function C_V:

$$C_V\left(p_1,\Lambda\ ,p_i,\Lambda\ ,p_n,Y,S;A\right)=c_v\left(p_1,\Lambda\ ,p_i,\Lambda\ ,p_n;A\right)\left(\frac{Y}{S}\right)^{1/k}\quad\cdots(6)$$

We now assume that c_v takes the following form:

$$\log c_v\left(p_1,\mathrm{K}\ ,p_n;A\right)=\alpha(A)+\sum_{i=1}^{n}\beta_i(A)\log p_i+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}(A)\log p_i\log p_j\quad\cdots(7)$$

In order for C_V to be a cost function, c_v must be non-decreasing and homogenous of degree one in variable input prices $(p_1,\ldots,p_n)$. It can be shown that the following restrictions on parameters of c_v are sufficient to satisfy these requirements

$$\sum_{i=1}^{n}\beta_i(A)=1,\sum_{i=1}^{n}\gamma_{ij}(A)=0,\sum_{j=1}^{n}\gamma_{ij}(A)=0\quad\cdots(8)$$

We may then use Shephard's lemma to derive the following cost-share function.

$$\frac{p_i x_i}{C_V}=\beta_i(A)+\sum_{j=1}^{n}\gamma_{ij}(A)\left(\log p_j-\log p_1\right)\quad\cdots(9)$$

Here $i=2,\ldots,n$. This function can then be estimated using information about variable factor cost shares and prices.

Another requirement is that C_V should be concave in variable input prices $(p_1,\ldots,p_n)$ [1]. This requirement is satisfied if and only if c_v is concave.

We have already explained why it is important to distinguish between variable and quasi-fixed production factors. We now explain how checking the concavity of the estimated cost function provides important information in this regard. The concavity property of cost functions derives from the assumption that the decision-maker: (1) is free to choose the level of each production input; and (2) minimizes total cost by adjusting the level of each production input in response to changes in its price. In other words, if the estimated parameters for a cost function that includes $(x_1,\ldots,x_n)$ as inputs satisfy the concavity requirement, then this would be consistent with $(x_1,\ldots,x_n)$ being variable inputs. On the other hand, failure to satisfy the concavity requirement would point to the inclusion of one or more factors that cannot be freely adjusted in the short term. This use of cost function concavity to distinguish between variable and quasi-fixed inputs is central to the analysis in this paper.

Let us now consider the potential impact of a change in production technology, which would correspond to a change in the production function parameter A. If we assume that we are dealing with a so-called "Hicks-neutral" technology, then under our capacity-cum-utilization framework we can write $G(x_1,\ldots,x_i,\ldots,x_n;A_H)=A_H\,G^*(x_1,\ldots,x_i,\ldots,x_n)$ for some G^*, which means that technological progress does not affect the parameters β_i and γ_{ii}. On the other hand, non-Hicks-neutral technological progress might alter the values of these parameters. There is no *a priori* reason to assume that technological progress is Hicks-neutral, and so we have allowed for the possibility that cost- function parameters might change over time as a result of technological progress, and have focused on the approximate timing of technological changes within the period of observation.

We allow for the possibility of non-Hicks-neutral changes in production technology by incorporating period dummy variables into our framework, estimating cost-share functions with the following form:

[1] In general, it is difficult to express the concavity requirement as a condition that must be satisfied by cost-function parameters β_i and γ_{ii}. As such, the cost- share function is customarily estimated by assuming (only) homogeneity of degree one, after which the estimated parameters can be checked to determine whether or not they satisfy the concavity requirement.

$$\frac{p_i x_i}{C_V} = \left(\beta_i + \sum_k \beta^I_{i,s_k} D^I_{i,s_k} \right) + \left(\sum_{j=2}^{n} \gamma_{ij} \right) \left(\log p_j - \log p_1 \right) \qquad i = 2, \ldots$$

$\cdots$(10)

Here $D^I_{i,sk}$ is intercept and dummies. If these dummies are found to be statistically significant, then that would imply that a non-Hicks-neutral change in production technology occurred at time s_k.

3. Estimation results

Our data set covers two types of capital stock (IT capital, other capital) and four types of labor (young, low-educated workers, young, highly educated workers, older, low educated workers, and older, highly educated workers). So we must work with a large number of possible input combinations when checking to see which factors can be classified as variable inputs, which we do by estimating cost- share functions and then checking to see whether the estimated parameters are consistent with the concavity requirement that must be satisfied by the cost function.

We employ a heuristic approach in our attempt to identify variable production factors. With respect to capital stock, we postulate that "structural capital" (buildings and structures) is more likely to be quasi-fixed than "non-IT capital" (machines and tools and transportation equipment (mostly automobiles)), and that non-IT capital is more likely to be quasi-fixed than IT capital. This characterization is consistent with Fraumeni [3], who reports that the service life of IT stock is roughly 3-5 years, which compares with 8-15 years for machines & tools and automobiles and more than 20 years for structural capital[2]. With respect to labor inputs, we postulate that young workers with low levels of education are less likely to be quasi-fixed than other workers, but we make no other assumptions regarding their rankings. Finally, we assume that IT stock is the most variable among all factor inputs, and therefore use IT stock as "factor 1" in our regression equation. This turns out to be a satisfactory assumption, as all industries were eventually found to have a cost function satisfying the concavity requirement that included IT capital among its inputs.

The first step is to identify variable inputs for each industry. For all industries we have two labor input dimensions (young versus older, low educated versus highly educated) and thus, four types of labor input.

The equation to be estimated is equation (10). We now estimate cost-share functions using three stages least square method where the sample period is 1999-2005 and check to see whether the estimated cost-function parameters are consistent with the concavity requirement. In this step, we ignore technological change and thus perform the estimations without period dummies. We do not expect to obtain particularly sharp results due to our tacit assumption that there was no technological change over the period in question, but we can still hope to identify "reasonable" combinations of factor inputs by looking for cases in which all estimated γ_{ii} values are negative with some level of statistical significance.

We begin with five factor inputs. If the results turn out to be unsatisfactory, then we take this as a sign that the set of inputs includes one or more quasi-fixed factors, and repeat the procedure with a smaller number of inputs. We do this until we are able to identify variable production factors for each industry.

In the second step we re-estimate the cost- share functions after adding period dummies to allow for the possibility of technological change over the sample period. The estimation results of cost-share functions are shown in Table 1.

[2] Our own analysis (conducted prior to this research) also suggested that IT capital was likely to be a variable production factor.

Table 1 Estimation Results

[1] Manufacturing

1. Food 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.5765	0.0631	***
β_3	0.2920	0.0344	***
γ_{22}	-0.1042	0.0110	***
γ_{23}	0.0286	0.0076	***
γ_{33}	-0.0533	0.0058	***

***: 1% level, **: 5% level, *:10% level statistically significant

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.8425
YH(young worker with high educational level)	0.8764

2. Textiles 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.0084	0.0217	
Dummy for β_2 (2002)	-0.0067	0.0013	***
β_3	0.0831	0.0192	***
γ_{22}	-0.0109	0.0018	***
γ_{23}	0.0141	0.0016	***
γ_{33}	-0.0183	-0.0018	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.7959
YH(young worker with high educational level)	0.6575

3. Chemicals 1 = IT, 2 = YL

	Coef.	Std. Err	
β_2	0.2313	0.0529	***
γ_{22}	-0.0250	0.0081	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.574

4. Clay & Stone 1 = IT, 2 = YL

	Coef.	Std. Err	
β_2	0.4498	0.1166	***
γ_{22}	-0.0480	0.0174	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.5207

5. Primary metal 1 = IT, 2 = YL, 3 = OH

	Coef.	Std. Err	
β_2	0.1842	0.2108	
Dummy for β_2 (2001)	-0.0635	0.0153	***
β_3	0.244	0.134	*
γ_{22}	-0.0406	0.0231	*
γ_{23}	0.0215	0.0109	**
γ_{33}	-0.040	0.011	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.6394
OH(older worker with high educational level)	0.8806

6. Fabricated metal 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.1602	0.0496	
Dummy for β_2 (2001)	-0.0313	0.0059	***
β_3	0.0856	0.0158	***
γ_{22}	-0.0305	0.0069	***
γ_{23}	0.0143	0.0019	***
γ_{33}	-.01869	.00127	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.3175
YH(young worker with high educational level)	0.9959

7. General Machinery 1 = IT, 2 = YL, 3 = OH

	Coef.	Std. Err	
β_2	0.1592	0.1110	
Dummy for β_2 (2001)	-0.0390	0.0073	***
β_3	0.18511	0.059752	***
Dummy for β_3 (2001)	-.01056	.0044	**
γ_{22}	-0.0328	0.0114	***
γ_{23}	0.0158	0.0059	***
γ_{33}	-0.02906	0.00378	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.6446
OH(older worker with high educational level)	0.9691

8. Electronic machinery 1 = IT, 2 = YL

	Coef.	Std. Err	
β_2	0.1896	0.0231	***
Dummy for β_2 (2001)	-0.0180	0.0050	***
γ_{22}	-0.0255	0.0046	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.8308

9. Transportation equipment 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.5977	0.1021	***
β_3	0.2440	0.0490	***
Dummy for β_3 (2002)	0.0278	0.0054	***
γ_{22}	-0.0537	0.0121	***
γ_{23}	-0.0226	0.0082	***
γ_{33}	-0.0144	0.0044	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.7561
YH(young worker with high educational level)	0.9348

10. Instrument 1 = IT, 2 = YL, 3 = OH

	Coef.	Std. Err	
β_2	0.4093	0.0834	***
β_3	0.4200	0.0412	***
Dummy for β_3 (2004)	0.0149	0.0050	***
γ_{22}	-0.0369	0.0076	***
γ_{23}	-0.0079	0.0037	***
γ_{33}	-0.0349	-0.0033	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.8315
OH(older worker with high educational level)	0.9673

[2] Non- manufacturing

1. Construction 1 = IT, 2 = YL

	Coef.	Std. Err	
β_2	0.5198	0.0858	***
Dummy for β_2 (2004)	0.0681	0.0183	***
γ_{22}	-0.0503	0.0183	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.7351

2. Commerce 1 = IT, 2 = YL, 3 = OH

	Coef.	Std. Err	
β_2	0.0278	0.1221	
Dummy for β_2 (2001)	-0.0259	0.0113	**
β_3	1.4654	0.2344	***
Dummy for β_3 (2001)	-0.0372	0.0075	***
γ_{22}	-0.0790	0.0173	***
γ_{23}	0.0772	0.0105	***
γ_{33}	-0.2888	0.0408	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.7492
OH(older worker with high educational level)	0.9083

3. Finance 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.1565	0.0563	***
β_3	0.7875	0.1253	***
γ_{22}	-0.0499	0.0071	***
γ_{23}	0.0280	0.0124	**
γ_{33}	-0.1481	0.0240	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.8289
YH(young worker with high educational level)	0.7423

4. Transportation & Communication 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.3422	0.0763	***
Dummy for β_2 (2001)	-0.0149	0.0070	***
β_3	0.5461	0.0722	***
γ_{22}	-0.0245	0.0117	***
γ_{23}	-0.0679	0.0094	***
γ_{33}	-0.0258	0.0070	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.8001
YH(young worker with high educational level)	0.8485

5. Service 1 = IT, 2 = YL, 3 = YH

	Coef.	Std. Err	
β_2	0.0635	0.0292	**
β_3	0.1131	0.0231	***
γ_{22}	-0.0257	0.0047	***
γ_{23}	0.0143	0.0038	***
γ_{33}	-0.0307	0.0032	***

Share Equation	Adjusted R-square
YL(young worker with low educational level)	0.2269
YH(young worker with high educational level)	0.5958

4. Allen-Uzawa's elasticity of substitution

We calculate the Allen-Uzawa's elasticity of substitution among variable inputs. The Allen-Uzawa's elasticity of substitution is defined as follows.

$$AES_{ij} = \frac{C_V \dfrac{\partial^2 C_V}{\partial p_i \partial p_j}}{\dfrac{\partial C_V}{\partial p_j} \dfrac{\partial C_V}{\partial p_i}} = \frac{\gamma_{ij}}{\eta_i \eta_j} + 1$$

$\cdots$(11)[3]

Table 2 shows the Allen-Uzawa's elasticity of substitution among variable inputs. In every industry, IT capital and young workers with a low educational level are substitutes from 1999-2005. This result is the same as the result in 1980-1998, which is shown in Nishimura and Minetaki [1].

On the other hand, the relationships among IT capital and highly educated workers are different. In food, textiles, fabricated metal, transportation equipment, construction, finance, transportation and communication, and services, the relationship among IT capital and young, highly educated workers is substitutability from 1999-2005. In primary metal, general machinery, instruments, and commerce, the relationships among IT capital and older, highly educated workers is substitutability from 1999-2005.

The complementariness between IT capital and highly educated workers was not seen from 1999-2005. Nishimura and Minetaki [1] show that there has been complementariness between IT capital and highly educated workers in several industries from 1980-1998. In food, textiles, fabricated metal, general machinery, electronic machinery, and instruments, there has been a complementary relationship between IT capital and highly educated workers from 1980-1998 according to Nishimura and Minetaki [1].

However, the strength of complementariness between IT capital and highly educated workers was weaker in the earlier period compared to the latter period of 1980-1998 in almost all above- mentioned industries. In primary metal, transportation & equipment, finance, commerce, and transportation & communication, the highly educated worker was quasi-fixed input from 1980-1998. But the highly educated worker is considered as the variable input from 1998-2005, and their relationship with IT capital is substitutability.

---

[3] In translog- cost function, the elasticity of input is equal to the cost share as follows:

$$\eta_i = \frac{\partial \ln c_v}{\partial \ln p_i} = \frac{p_i x_i}{C_V} = s_i$$ (s_i :cost share)

Table 2

Substitutability and complementarity. Allen-Uzawa's elasticity of substitution
(1999-2005)

Manufacturing			
Food		Textile	
	1999-2005		1999-2005
IT&YL	1.5247	IT&YL	0.9380
IT&YH	1.5060	IT&YH	1.2378
YL&YH	3.2321	YL&YH	13.9224
Chemicals		Stone & clay	
	1999-2005		1999-2005
IT&YL	1.3998	IT&YL	1.4384
Pri.metal		Fab.metal	
	1999-2005		1999-2005
IT&YL	1.1935	IT&YL	1.2899
IT&OH	2.0635	IT&YH	1.3848
YL&OH	10.9223	YL&YH	20.9736
Gen.machinery		Elec.machinery	
	1999-2005		1999-2005
IT&YL	1.2208	IT&YL	1.4733
IT&OH	1.6146		
YL&OH	8.2167		
Trans.equipment		Instruments	
	1999-2005		1999-2005
IT&YL	1.4457	IT&YL	1.6777
IT&YH	3.2038	IT&OH	0.6168
YL&YH	0.9899	YL&OH	1.1886

Non- Manufacturing			
Construc.		Trade	
	1999-2005		1999-2005
IT&YL	1.2449	IT&YL	1.0156
		IT&OH	3.4670
		YL&OH	5.0172
Finance		Trans. & commu.	
	1999-2005		1999-2005
IT&YL	1.6693	IT&YL	1.7275
IT&YH	3.1021	IT&YH	5.8682
YL&YH	14.0467	YL&YH	-15.3138
Services			
	1999-2005		
IT&YL	1.3063		
IT&OH	1.7888		
YL&OH	17.6271		

Notes: IT=IT capital. YL=young worker with low educational level. YH=young worker with high educational level. OH=older worker with high educational level.

5. Conclusion

The main conclusion of our empirical study is that relationships among IT capital and highly educated workers have become relationships of substitutability from1999-2005 in many industries, which were complementary from 1980-1998.

We speculate the reason is that the speed of Information Communication Technology has increased rapidly while the skills of highly educated workers have become obsolete.

Broadband has expanded and spread Information Communication Technology, and this has changed the circumstance of office work. Moreover, business software, like CAD and ERP can replace the skills of highly educated workers.

At the same time, the labor market has become more flexible, so that non- regular work has rapidly increased in Japan. For the firm, the highly educated worker becomes neither a variable input, nor a quasi-fixed input. This makes the relationship between IT capital and highly educated workers change to substitutability more easily.

Workers need to upgrade their skills to meet to the changes in Information Communication Technology. Today it is not enough for highly educated workers to only use IT capital, but they should also draw on and utilize new knowledge for their businesses by using software and the Internet. If workers cannot make this change, they will be replaced by IT capital.

References

1. Nishimura G.Kiyohiko, Minetaki K., Information Communication Technology and the Japanese Economy (in Japanese), Yuuhikaku, 2004 May.

2. Kurokawa F., Minetaki K., Nishimura G.Kiyohiko, Shirai M., "Effects of Information Technology and Aging Work Force on Labor Demand and Technological Progress in Japanese Industries:1980-1998", The Economics of an Aging Population: Macroeconomic Issues, ESRI Studies Series on Ageing, pp.75-156, Edward Elgar, 2002 April.

3. Fraumeni, B. M., "The Measurement of Depreciation in the U.S. National Income and Product Accounts", *Survey of Current Business*, pp.7-23, 1997 July.