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Abstract:

A number of researches have been made on the productive effect of ICT, including its relationship with corporate structure and business process. However, regarding the relationship between the development stage of ICT application and the productivity, only some conceptual frameworks of development stages had been suggested and no experimental study has been made. In this paper, using the individual data from *Information and Communication Technology Survey* Year 2006 of Ministry of Economy, Trade and Industry, we examine how the productivity changes according the stage of development of ICT, estimating the production function.

When we classify the stages of development of ICT application into three stages of *section-wise* system application, *company-wide* system application and *inter-company* system application, it became apparent that its effect on the productivity increases according to the development of stages. For instance, when we use the production function assuming that the difference of development stage would affect on TFP level, the company with developed *company-wide* system application has an added value productivity which is 1.065-fold higher than companies with section-wide system application. We also obtained an outcome that the company in which the *inter-company* system application is developed has the added value productivity which is 1.105-fold higher than companies with *company-wide* system application.

Keywords: ICT, Productivity, TFP (Total Factor Productivity), Production function

JEL codes: C51, D24, L23, L25

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In preparing this paper, we used analysis outcomes of individual data of *Information and Communication Technology Survey* Year 2006 provided by Ministry of Economy, Trade and Industry. We would like to extend our special thanks for those contributed to our research.

Stages in the Development of ICT and Firm's Productivity

Satoru Miyazaki/ Hiroki Idota / Hiroaki Miyoshi

1. Introduction

With prolonged economic stagnation or maturation of market, the management environment surrounding enterprises has become more and more severe. It is necessary for enterprises to exploit the market by themselves by developing products and services and to engage in the management innovation, like promotion of efficiency in the business process within the corporate. Some enterprises would develop a competition strategy in which they form an inter-corporate coalition to extend their business process to their business partners and clients.

For the establishment of such business process, Information Communication and Technology (ICT) will be an important technological base. ICT has been attracting attention as a tool which enables a management innovation. Half a century has passed since ICT started to be used in the corporate management. During this period, the technology has rapidly improved and it became a boom when it was featured as if it is a miracle drug for the management innovation.

However, it is not that the productivity improves in all enterprises introducing ICT. In order to improve the productivity, the mode of ICT utilization is important. A number of researches have been made on the productive effect of ICT, including its relationship with corporate structure and business process. However, regarding the relationship between the development stage of ICT application and the productivity, only some conceptual frameworks of development stages had been suggested and no experimental study has been made. In this paper, using the individual data from *Information and Communication Technology Survey* Year 2006 conducted by Ministry of Economy, Trade and Industry, we quantify how the productivity changes according the development stage of ICT, through the estimation of production function.

In this paper, hereinafter, in Chapter 2, we survey previous works on ICT and corporate productivity. In Chapter 3, we introduce ideas on development stages of ICT application. Then, in Chapter 4, we explain the model and data of experimental analysis and show outcomes of the experimental analysis in Chapter 5.

2. Survey on Previous Studies on ICT and Corporate Productivity

Since ‘Productivity Paradox’ started when Solow (1987) pointed out; "You can see the computer age everywhere but in the productivity statistics", various analyses have been made on the relationship between ICT and corporate productivity.

For instance, Strassman(1990), who was the CIO of Xerox Corporation, demonstrated that there was no correlation between the amount that a corporate invested in ICT and its business performance. In contrary, researchers like Brynjolfsson and Hitt (1996) or Lehr and Lichtenberg (1999) demonstrated that the ICT investment contributes to the improvement of corporate productivity, through analyses of corporate data, etc. Among such researchers, Brynjolfsson and Hitt (1996) analyzed 367 American enterprises from 1987 to 1993. They found out that the gross marginal product for ICT capital averaged 81% for the firms. It is far higher than its for non-ICT capital (6.26%) and that ‘Productivity Paradox’ has ceased by 1991. Likewise, Lehr and Lichtenberg (1999) concluded that ICT capital contributes to the improvement of labor productivity and the profit structure of ICT capital is of increasing returns, compared to other capitals.

It should be noted that companies, which are in the same industry and have similar capital structures and similar manufacturing technologies, had totally different performance. Strassman(1990) pointed out that this difference is caused not by know-how related to ICT but by ‘Management Value-added’ and suggested ‘Return-on-Management’ showing the efficiency of indirect tasks as the indicator of ICT investment effect. In Brynjolfsson and Hitt (1998) and Brynjolfsson, Hitt and Yang (2002), it has been confirmed, through corporate data analysis, that the productivity of ICT investment is higher in decentralized organizations than in centralized enterprises.

In a series of studies by Brynjolfsson, etc, it has been demonstrated that the corporate productivity does not increase in all enterprises which made ICT investment and that the productivity is high in enterprises with high human capital level and advanced organizational/management reform like the decentralization of decision-making. From outcomes of previous studies as above, studies related to ICT investment effect have been focusing not only on ICT but also on human capital, corporate organizational structure and management.

Also in Japan, researches have been focusing on the relationship among ICT, human capital and enterprise organization. For instance, Research Bureau of Economic Planning Agency (2000) conducted a survey involving 482 Japanese companies, in order to study the effect that ICT has on the productivity. According to this survey, enterprises do not think that it is effective in the quantitative aspect such as expansion of sales amount or clients and the commencement of new services while they believe that there are quality impacts such as improvement of services, communization of corporate information, and rationalization and efficiency of operations. In the same survey, the relationship between the introduction of ICT and corporate business configuration was examined, based on the method in Bresnahan et al. (1999) and Brynjolfsson and Hitt (1996). The research outcome shows that in enterprises with advanced ICT introduction, the level of human capital is higher and the organization is decentralized. Likewise, as to the relationship among ICT, human capital, organization and labor productivity, more the introduction of ICT is advanced, higher the level of human capital gets. Furthermore, more the flattening of corporate structures advance, higher labor productivity is enjoyed by the company. As research outcomes in the U.S. show, it was concluded that the introduction of ICT itself does not bring enough effects but related elements such as the quality of human capital and the organizational structure are important.

Office of Director-General for Policy Planning of Cabinet Office (2004) conducted a similar survey involving 1,423 Japanese enterprises on the relationship of corporate ICT introduction and productivity. According to this survey, enterprises do not think that it is effective in the quantitative aspect such as customer satisfaction, expansion of sales amount or improvement of added values while they believe that there are quality impacts such as improved business efficiency, reduced costs, smoother communication or communization of information. However, according to the quantitative analysis, in enterprises with advanced ICT introduction, the Total Factor Productivity (TFP) is higher than in enterprises with limited ICT introduction by about 15 %. Likewise, it has been demonstrated that the productivity is higher in companies engaged not only in ICT introduction but also in corporate organizational reform, efforts related to human capitals and follow-up examination of effects of ICT introduction than in those which have simply introduced ICT. Furthermore, in aspects like expansion of sales amount, improvement of customer satisfaction, amelioration of quality of products and services, improvement of added values and facilitation of corporate internal communication and information sharing, enterprises engaged in corporate organizational reform, efforts related to human capitals and follow-up examination of effects of ICT introduction have higher productivity than those which have simply introduced ICT.

Researches which measure the effect of introducing ICT in Japanese enterprises utilizing the production function are on the increase and Motohashi (2003), Shinozaki (2003), Nishimura and Minetaki (2004), Shinozaki (2005), Minetaki (2005), Kurokawa (2006), Kurokawa and Minetaki (2006), Hiromatsu and Kobayashi (2007), Takemura

(2008) and Shozugawa et al. (2009) are among such examples.

In brief, the corporate can improve its productivity by introducing ICT. However, it is not enough to simply introduce ICT but such effect can be obtained by strategically introducing ICT, reinforcing human capital using ICT and advancing the organizational reform.

3. Analysis Target

As mentioned above, many researches have been made on the relationship among ICT, business organization and human capital. In this paper, we conduct analyses focusing on development stages of ICT application. Gibson and Nolan (1974) classified stages of development of corporate EDP application into four categories, which are initiation stage, expansion stage, formalization stage and maturity stage. In the initiation stage, the accounting software aiming at reducing costs is introduced and in the expansion stage, the number of partial optimal software rapidly increases in all functions. In the formalization stage, the investment in information system is coordinated from the *company-wide* viewpoint. In the maturity stage, the investment in information system which contributes in corporate decision-making by technologies like database will be made. Later, Nolan (1979) modified development stages of EDP application into six stages and demonstrated that there is a shift point in EDP management between the first three stages (initiation stage, contagion stage and control stage) and the latter three stages (integration stage, data administration stage and maturity stage). C’est-a-dire, while the first three stages focus on the management of computers, the latter three stages focus on the management of data resource application. In other words, as the stage of development advances, the main interest of the concerned enterprise will shift from the computerization of routine tasks to the application of data to support decision-making.

In 1970’s to 1980’s where the model by Nolan was suggested, experimental studies using this model were conducted. However, many studies failed to make statistical verification (e.g. King and Kraemer, 1984: Benbasat et al., 1984). Therefore, it is understood that this model is a conceptual model of development stages of corporate ICT.

On the other hand, Ministry of Economy, Trade and Industry released the IT management power indicator as indicators to measure the level of IT applications (Ministry of Economy, Trade and Industry, 2006). It classifies enterprises into four groups which are ‘Nonperforming IT Assets Group’, ‘Sectional Optimization Group’, ‘Company-Wide Optimization Group’, ’Inter-Company/Inter-Industrial Optimization Group’, according to the level of IT application. It is believed that stages of ICT application will be different according to business category, scale, years since corporation was established, business policy, etc, we can assume that the enterprise with advanced ICT application will move to a higher stage and higher the stage, the productivity of the enterprise concerned will increase. Since 1969, in order to reinforce the competitiveness of ICT industry and to promote the policy aiming at revitalizing economy, industry and society through strategic application of ICT, Ministry of Economy, Trade and Industry has been conducting a survey on the situation of information processing in order to accurately figure out and analyze the situation and impacts of information processing (Ministry of Economy, Trade and Industry, 2010). Question items would be different every year considering changes in the environment but the continuous research has been made on items like corporate attribution, expenses related to information processing and impacts of ICT investment. In the survey for the fiscal year 2006, there is a question item considering development stages of ICT application. It classified ICT application into stages of section-wide, *company-wide* and *inter-company* and examined it by setting concrete measures and policies for each stage. For example, for the situation of section-wide ICT application, there are three items of (1) Realization of convenience in tasks and improvement of productivity, (2) Establishment of mechanism of information sharing and (3) Realization of speedy decision-making and improvement of task. In this paper, in order to utilize individual data of *Information and Communication Technology Survey*, we assume development stages of ICT application in **Table 1.**

Table 1 Stage of Development of ICT Application

Stage 0 : No ICT System Appied (Nonperforming IT Assets Group)
↓
Stage 1 : Application of Sectional System (Sectional Optimization Group)
Realization of Convinience in Tasks and Improvement of Productivity
Establishment of Information-Sharing Scheme
Realization of Speedy Decision-Making and Business Improvement
↓
Stage 2 : Application of Company-Wide System (Company-Wide Optimization Group)
Realization of Convinience in Tasks and Improvement of Productivity
Establishment of Information-Sharing Scheme
Realization of Speedy Decision-Making and Business Improvement
↓
Stage 3 : Application of Inter-Company System (Inter-Company Optimization Group)
Establishment of Business Cooperation Scheme
Information-Sharing for SCM
Scheme for Sharing Negative Information and Challenges and Improvement

In **Table 1,** we organized question items in *Information and Communication Technology Survey* 2006 based on IT management power indicator (Ministry of Economy, Trade and Industry, 2006) and classified corporate stages of development of ICT application into four stages, including Stage 0 where the section-wide system application is not enough, Stage 1 where the section-wide system application is developed, Stage 2 where the company-side system application is developed and Stage 3 where the *inter-company* system application is developed. In Stage 1 (Section-wide system application) and Stage 2 (*Company-wide* system application), ICT is first utilized to improve the convenience of tasks. Then, the mechanism of information sharing among organization members and as a result of information sharing, speedy decision-making and improvement of tasks will be realized. Such three steps are assumed. On the other hand, in Stage 3 (*Inter-company* system application), ICT is used through business tie-up. Therefore, e-commerce system and SCM (Supply Chain Management) will be developed as mechanisms of business cooperation and information sharing aiming at optimizing such systems will be made. Then, negative information and challenges will be shared and a mechanism for improvement and upgrading will be established for total optimization. Such three steps are assumed.

4. Experimental Analysis Model and Data

In this paper, we quantify how the productivity changes depending on the level of development of ICT by estimating production functions. Here, we explain the estimation model and data.

4.1. Estimation Model

In this paper, based on previous studies such as Kurokawa (2006), Takemura(2008) and Miyazaki and Miyoshi (2009), as a basic type, we use the following Cobb-Douglas production function:

$$Y_i = A \cdot KO_i^{\beta_1} \cdot KS_i^{\beta_2} \cdot L_i^{\beta_3}\ , \qquad (1)$$

Where Y_i is added aalue of enterprise i, A: is total factor productivity, KO is general capital (tangible fixed assets), KS is software capital, and L:is total number of employees.

Then, we need to incorporate the level of development of corporate ICT application in Eq. (1). In doing so, we need to consider the process in which the development of ICT application contributes to the increase of added value. Here, we suppose two processes, which are;

a) Process in which the overall production efficiency increases with development of ICT application, contributing to the increase of added value,

b) Process in which the efficiency of relevant software capital increases with ICT measures and policies, contributing to the increase of added value.

Considering these two possible processes, we estimate how the productivity changes with development of ICT application in Eqs. (2) and (3) as below:

$$Y_i = A\exp(Z + \sum_n \gamma_n D_{ni}) \cdot KO_i^{\beta_1} \cdot KS_i^{\beta_2} \cdot L_i^{\beta_3}, \tag{2}$$

$$Y_i = A \cdot KO_i^{\beta_1} \cdot KS_i^{\left(\beta_2 + \sum_n \gamma_n D_{ni}\right)} \cdot L_i^{\beta_3}. \tag{3}$$

D: Variable on the stage of development of ICT application

Eq. (2) is the production function supposing the increase of Total Factor Productivity (TFP) with development of ICT application and Eq. (3) is the production function supposing the increase of elasticity of added value with respect to software capital with ICT application.

In the actual regression analysis, we use following Eqs (4) to (6), which are prepared by taking natural logarithm of both members of each Eqs. of (1) to (3):.

Base Model $$\log Y_i = \alpha + \beta_1 \log KO_i + \beta_2 \log KS_i + \beta_3 \log L_i + u_i, \tag{4}$$

Model 1 $$\log Y_i = \alpha + \beta_1 \log KO_i + \beta_2 \log KS_i + \beta_3 \log L_i + \sum_n \gamma_n D_{ni} + u_i. \tag{5}$$

Model 2 $$\log Y_i = \alpha + \beta_1 \log KO_i + \beta_2 \log KS_i + \beta_3 \log L_i + \sum_n \gamma_n D_{ni} \cdot \log KS_i + u_i. \tag{6}$$

For convenience, we call Eqs (4) to (6), respectively ‘Base Model’, ‘Model 1’, and ‘Model 2’. In the estimation, as there is a concern of heteroscedasticity, we use White least squares method.

4.2. Data

In this paper, we match and integrate the information in Information and Communication Technology Survey 2006 and the corporate financial data in Nikkei NEEDS by using corporate names, etc, as keys and conduct analyses by using such data. As Information and Communication Technology Survey is covering the situation in the year preceding the research year, the data used in this paper is that of the fiscal year 2005. The number of sample companies is 307. Hereinafter, we explain about each variable.

First of all, as to the added value, which is the explained variable, we make up the settlement data for the fiscal year 2005 in Nikkei NEEDS with BOJ method and calculate at nominal prices and realize with industrial deflator[1].

Then, as to the explanatory variable, for the general capital, we realize the total tangible fixed asset in the settlement data for the fiscal year 2005 in Nikkei NEEDS with private non-residential investment deflator. In doing so, we assume that facilities are amortized in 10 years like in Hiromatsu and Kobayashi (2007) and we employ the average deflator of the past ten years (fiscal year 1996 to fiscal year 2005).

For the software capital, we obtain at nominal prices by adding the balance of software at the end of previous year in *Information and Communication Technology Survey* to the capitalized rental revenue of software. As in many previous studies, we obtain by dividing the rental revenue with the capital cost. Here, for the capital cost, we employed the sum of the average value of monthly data of long-term government bonds (10-year) of BOJ statistic in the fiscal year 2005 and the depreciation ratio of software[2]. In addition, we realize above software capital at nominal prices with the average BOJ's software price index of the past four years[3](fiscal year 2002 to 2005).

For the total number of employees, we used the data in *Information and Communication Technology Survey*. Here, the number of non-regular workers is also included. The basic amount of statistics of each variable is showing in Table 2.

Table 2 Basic Statistics

Variable	（Unit）	Average	S.D.	Minimum	Maximum
Added Value	（Million Yen）	57743.17	191249.72	110.88	2773371.28
General Capital	（Million Yen）	89908.03	556642.94	35.58	9546977.74
Software Capital	（Million Yen）	2727.83	8741.26	1.08	84184.41
Total Number of Employees	（Person）	3303.31	9714.68	47.00	144786.00

Note: The Amounts of money are all realized.

Variables related to the stage of development of ICT application is explained in the following section, together with the analysis result.

5. Analysis Result

5.1. Analysis Result in the Base Model

Before we examine the effect that the development of ICT application improves the productivity, we indicated the estimation result of the base model defined by Eq. (1) or (4) in Table 3. In this paper, the model does not assume homogeneous of degree 1 (constant returns to scale) but coefficients of all of three production factors are significant and the total of these coefficients is about 0.97. Therefore, we can consider that it is almost of constant returns to scale.

Table 3 Estimation results by Basic Model

	Coefficient	t value	p value
Constant Term	2.3431	9.10	0.000 ***
Total Number of Employees (Logarithm)	0.5767	10.40	0.000 ***
General Capital (Logarithm)	0.2519	6.46	0.000 ***
Software Capital (Logarithm)	0.1483	6.77	0.000 ***
R-square	0.8303		
Adjusted R-square	0.8287		
Durbin-Watson Ratio	1.7849		
F Value	494.3		0.000 ***
Number of Samples	307		

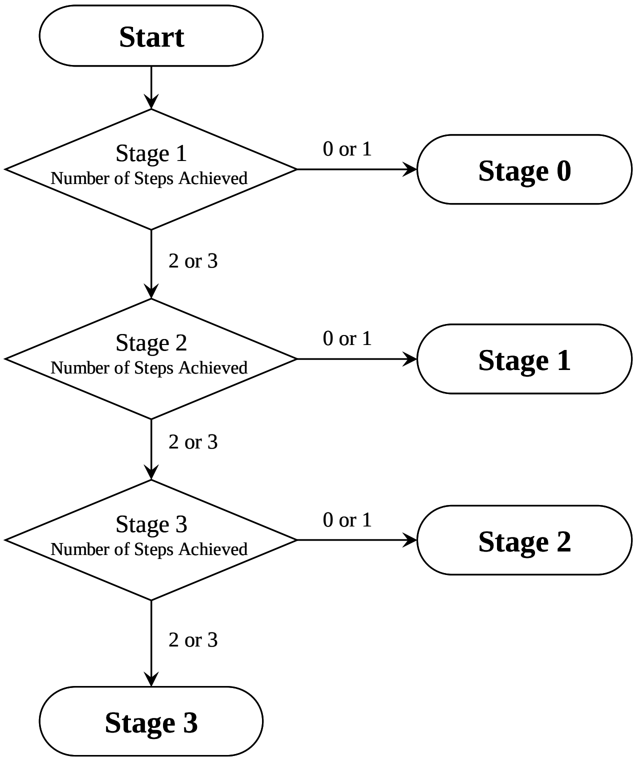
Note: *** Significant at 1% level.

5.2. Situation of Application of Information System and Productivity

As mentioned above, in *Information and Communication Technology Survey*, the application of information system was studied assuming the system establishment in three stages of *section-wise* system application, *company-wide* system application and *inter-company* system application. Here, as mentioned above, we assume four stages in Table 1 and quantify how the productivity changes depending on the development of ICT application by estimating the production function.

First of all, we explain the setting method for stage of development of corporate ICT application. In *Information and Communication Technology Survey*, for each step of each stage of ICT application indicated in **Table 1**, companies are asked to choose among four options of ’Fully realized’, ‘Partially realized’, ‘Hardly realized’ and ‘Not realized’. In this analysis, we consider that companies which answered ‘Fully realized’ and ‘Partially realized’ have achieved the relevant step and deem that companies which achieved two of three steps in each stage have reached at the relevant stage. Specifically, we set the stage of ICT application of each company, using the method in F**igure 1**.

Figure 1 Setting Method of ICT Application Stage of Sample Companies



The distribution of stages of development of ICT application based on the method in **Figure 1** is as in **Table 4**. Among 304 responded companies, there are only four companies which show the jump phenomenon where more than two steps are achieved in Stage 2 or 3 although less than two steps are met in Stage 1. Therefore, we can conclude that the development stage of ICT application will largely follow the gradual stage as in **Table 1**.

Table 4 Distribution of Stage of Development of ICT Application

Scope	Stage 0	Stage 1	Stage 2	Stage 3	Total	Average	S.D.
All	9 2.96%	37 12.17%	149 49.01%	109 35.86%	304 100%	2.178	0.754
Industry							
Manufacturing	4 2.52%	17 10.69%	79 49.69%	59 37.11%	159 100%	2.214	0.732
Non-Manufacturing	5 3.45%	20 13.79%	70 48.28%	50 34.48%	145 100%	2.138	0.778
Scale of Total Employees（Person）							
～499	5 7.14%	16 22.86%	38 54.29%	11 15.71%	70 100%	1.786	0.797
500～999	2 2.99%	9 13.43%	44 65.67%	12 17.91%	67 100%	1.985	0.663
1000～4999	2 1.57%	10 7.87%	55 43.31%	60 47.24%	127 100%	2.362	0.698
5000～	0 0.00%	2 5.00%	12 30.00%	26 65.00%	40 100%	2.600	0.591

When we see the distribution, there are few companies in which ICT application is limited to the inter-sectional stage like Stage 0 and Stage 1. The highest number of companies was in Stage 2, *company-wide* system application level but with the recent rapid growth of electronic business-to-business commerce, more than one third of companies have already attained to Stage 3.

When we see the distribution separately for the manufacturing industry and the non-manufacturing industry, it seems that there is no much difference. On the other hand, when we see the distribution by size of total employees, there is a tendency that greater the size, higher the percentage of companies achieving the higher stage.

We now consider whether there is an effect to improve the productivity when the stage of ICT application gets higher. Results of regression by Models 1 and 2 are indicated in **Table 5**.

Table 5 Estimation Results by Model 1 and 2 (1)

	Model 1				Model 2			
	Coefficient	t value	p value		Coefficient	t value	p value	
Constant Term	2.1981	8.71	0.000	***	2.4180	8.99	0.000	***
Total Number of Employees (Logarithm)	0.5607	10.19	0.000	***	0.5621	10.15	0.000	***
General Capital (Logarithm)	0.2644	6.80	0.000	***	0.2630	6.76	0.000	***
Software Capital (Logarithm)	0.1346	5.99	0.000	***	0.0986	2.98	0.003	***
Development Stage	0.1012	2.38	0.018	**	0.0161	2.13	0.034	**
R-square	0.8365				0.8360			
Adjusted R-square	0.8343				0.8338			
Durbin-Watson Ratio	1.7812				1.7830			
F Value	382.4		0.000	***	381.1		0.000	***
Number of Samples	304				304			

Note 1: *** Significant at 1%, ** Significant at 5%, * Significant at 10%.

Note 2: *Development Stage* is the value varying from 0 to 3, corresponding to the belonging stage.

We should particularly note the coefficient related to the development stage. In both models, the coefficient is plus and significant. It means that there is an effect to increase the productivity when the stage gets higher. That is to say, there is a tendency that the productivity will be higher in companies which are successful in the ICT application in broader areas. However, it is only an overall trend and there is a possibility that a general upward trend is observed although there is a backdrop or small decrease in midstream. We thus examine the differences of productivity by stage. In the measurement, we set *Stage 1 Dummy* in which the coefficient of companies belonging to Stage 1 is 1 and the coefficient for other companies is 0. Likewise, we create Stage 2 Dummy in which the efficient of companies of Stage 2 is 1 as well as *Stage 3 Dummy* in which the efficient of companies of Stage 3 is 1. By having all of these three dummy variables related to each stage as explanatory variables for Models 1 and 2, we can measure how much companies belonging to stages 1 to 3 increased the productivity comparing to companies in stage 0. **Table 6** shows the result of this measurement.

Table 6 Estimation Results by Model 1 and 2 (2)

	Model 1				Model 2			
	Coefficient	t value	p value		Coefficient	t value	p value	
Constant Term	2.0963	8.11	0.000	***	2.4119	8.94	0.000	***
Total Number of Employees (Logarithm)	0.5610	10.39	0.000	***	0.5626	10.25	0.000	***
General Capital (Logarithm)	0.2658	6.83	0.000	***	0.2637	6.75	0.000	***
Software Capital (Logarithm)	0.1338	5.95	0.000	***	0.0789	1.92	0.056	*
Stage1Dummy	0.2293	1.68	0.093	*	0.0368	1.12	0.264	
Stage2Dummy	0.2919	2.36	0.019	**	0.0520	1.71	0.087	*
Stage3Dummy	0.3920	2.96	0.003	***	0.0666	2.13	0.034	**
R-square	0.8367				0.8361			
Adjusted R-square	0.8334				0.8328			
Durbin-Watson Ratio	1.7759				1.7792			
F Value	253.6		0.000	***	252.6		0.000	***
Number of Samples	304				304			

Note: *** Significant at 1%, ** Significant at 5%, * Significant at 10%.

Here, the coefficients related to dummy variables in Stages 1 to 3 means the differences of productivity of companies belonging to each stage and companies in Stage 0. In Model 1 concerning the productive effect through increase of TFP, not only it is plus and statistically significant in all of three stages but also the value of coefficient increased as the stage gets higher. According to the measurement result, companies in Stage 1 have added value of exp (0.2293) = 1.258-fold compared to companies in Stage 0 which have the same level of total employees, general capital and software capital. Likewise, companies in Stage 2 have added value of exp (0.2919-0.2293) = 1.065-fold compared to companies in Stage 1 which have the same level of total employees, general capital and software capital and companies in Stage 3 have added value of exp (0.3920-0.2919) = 1.105-fold, compared to companies in Stage 2.

On the other hand, in Model 2 concerning the productive effect through the increase in the elasticity of added value with respect to software capital, it does not become significant in Stage 1. It became plus and statistically significant in Stages 2 and 3 and as the stage gets higher, the value of coefficient also increases. According to this estimation result, the elasticity of added value with respect to software capital of companies in Stage 2 will be higher by (0.0666-0.0520) = 0.014576, compared to companies in Stage 1 which have the same level of total employees, general capital and software capital.

6. Conclusion

In this paper, using the individual data from *Information and Communication Technology Survey* 2006 of Ministry of Economy, Trade and Industry, we quantified how the productivity changes according the stage of development of ICT, through the measurement of production function.

When we classifiied the stages of development of ICT application into three stages of *section-wise* system application, *company-wide* system application and *inter-company* system application, in both of the production function assuming the increase of productivity through TFP increase and the production function assuming the increase in the elasticity of added value with respect to software capital, we have confirmed the effect that ICT application enhances the productivity and the effect on the productivity expands according to the elevation of stages.

In order to link ICT application to greater improvement of productivity, the investment and application in *company-wide* levels is not sufficient and further development, such as *inter-company* networking with business partners, etc, will be necessary.

In the future, ICT will not limited to the expansion of *inter-company* system but also play a role as a community base where several persons collaborate on the network and find new values and directions. There, ICT will be an important community base for the open innovation where new products and services are developed not among specific engineers or persons in charge but in cooperation with business partners or ordinary consumers. For the improvement of productivity by ICT application, it is indispensible to think about the cooperation with several companies or clients.

Note

[1] We have also confirmed that when we realize the added value with GDP deflator, the analysis result is not much affected.

[2] According to Shinozaki (2003), we set the software depreciation ratio at 20%.

[3] As the legal amortization period is three years for software for sales and research and development and five years for other general software, we assume that in general, software is amortized in four years.

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