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Analysis of Influences of ICT on Structural Changes in Japanese Commerce, Business Services and Office Supplies, and Personal Services Sectors Using Multivariate Analysis: 1985–2005

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Abstract. *This study analyzes influences of Information and Communication Technology (ICT) in the structural changes of Japanese industrial sectors from 1985 through 2005. ICT is represented by two explanatory variables, computers (including main parts and accessories) and telecommunications equipment. We investigate influences by the Constrained Multivariate Regression (CMR) model and test the statistical significance of this model by the Likelihood Ratio Test (LRT) method. We then perform microscopic analysis, focusing on the commerce, business services and office supplies, and personal services sectors. The results show that these variables, separately and jointly, had significant influence on structural changes in Japanese industrial sectors, including the analyzed ones. The patterns of influence in analyzed sectors are, however, different. Based on this difference, we can say that during 1985–2005 the business circumstances of the analyzed sectors were dissimilar.*

Keywords*: ICT, Industrial Structural Changes, CMR, LRT, Japan*

1. Introduction

Nowadays, our daily activities are inseparable from technology. For example, people who enjoy games use video game devices in pursuing their hobby, and people usually use transportation tools, such as trains and cars, for their daily commute. The importance of technology is also mentioned by Grübler (1998):

"*And through technology humans have acquired powerful capabilities to transform their natural environments locally, regionally, and, more recently globally.*"

One technology that permeates our society is Information and Communication Technology (ICT), such as computers. In recent years, almost all people use computers in their homes, schools, and offices, making computers an important aspect in everyday life. A similar phenomenon is also observed regarding mobile Internet devices. There are many previous studies of ICT. Purnomo and Lee (2010) investigated the readiness and perception barriers of agricultural extension officers toward ICT program implementation.

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Their study focused on officers connected with public organizations in the Indonesian Ministry of Agriculture. Chigona et al. (2010) explored factors affecting ICT integration in teaching and learning activities. Their study focused on schools in disadvantaged communities in the Western Cape, South Africa. Sharma and Singh (2011) conducted a study of the performance and impact of ICT in universities in the Western Himalaya Region, India. Sudaryanto (2011) investigated factors influencing adoption of computers in East Java On-Farm Agribusiness (EJOFA), and implications for developing sustainable agriculture.

Zuhdi et al. (2012) compared the role of ICT sectors in national economic structural changes of specific countries. Specifically, they investigated the influences of ICT in changes of the Input–Output (IO) activities of industrial sectors in Indonesia and Japan to examine macroeconomic structural changes.

However, the analysis of statistical significance was not well discussed in their study. This discussion is important because it can analyze the business circumstances of the sectors and can clarify the chances of enhancing business activities of industrial sectors. This study is conducted to fulfill this gap.

This study analyzes the influences of ICT in structural changes of industrial sectors of Japan, one of the most developed countries in the world, and one where ICT has been eagerly developed. The analysis period is 1985–2005. We develop a statistical tool to investigate influences reflecting the properties of IO activity vectors. We also perform a deeper analysis on particular sectors to obtain more detailed information related to ICT influences. The remainder of this paper is arranged as follows. Chapter 2 describes the methodology of this study. Chapter 3 explores the calculation results and analysis of these results. Chapter 4 gives conclusions and suggests areas for further research.

2. Methodology

The methodology of this study is as follows. First, we aggregate some sectors in the Japanese IO tables for 1985, 1990, 1995, 2000, and 2005 to get the same number of industrial sectors. The number of Japanese industrial sectors for these years was 84, 91, 93, 104, and 108, respectively. These sectors are reclassified into 78 sectors.

We next do the calculation in order to get IO coefficient matrices for each year in the analysis period. Miller and Blair (2009) gave the following equation for this calculation:

$$a_{ij} = \frac{z_{ij}}{X_j}. \qquad (1)$$

where, a_{ij}, z_{ij}, and X_j are the input needed from industry i to produce one unit of production in industry j, inter-industry sales by sector i to sector j, and total production of sector j, respectively. Further, a_{ij} represents the IO coefficient from sector i to sector j.

Next, we calculate the influence of the explanatory variables, which were computers (hereafter, including main parts and accessories) and telecommunications equipment, on Japanese industrial structural changes. These changes are represented by dynamic changes in the IO coefficient vectors extracted from the IO tables. To conduct this calculation, we develop a Constrained Multivariate Regression (CMR) model.

Data for the variables are obtained from the website of the Japanese Ministry of Internal Affairs and Communications. As with the main data, these variables hold data for 1985, 1990, 1995, 2000, and 2005. A detailed description of the CMR model is as follows. We begin by defining the years of analysis as T (here, 1985, 1990, 1995, 2000, and 2005). We can then define the data representing Japanese industrial structural changes, IO coefficient matrices, as $a(t)$ t = 1…T. In this calculation, the vector of the IO coefficient is used, meaning that this model is applied to each industrial sector of Japan through the IO coefficient of the sector. The explanatory variables used can be represented as $x(k,t)$ k = 1…k. The following mathematical model, a representation of the CMR model, is employed as an elaboration of $a(t)$:

$$a(i,t) = b0(i) + \sum_k b(i,k) \times x(k,t) + e(i,t)$$

$$a(i,t) \geq 0, \quad \sum_i a(i,t) = 1.0 \,. \qquad (2)$$

where $b0(i)$ and $b(i,k)$ explain the regression coefficients of the model. Since coefficients are nonnegative and these sums should be unity by definition, constraints among estimators are imposed. $e(i,t)$ describes the difference of original and estimated values. One can obtain the parameters by the least squares method, $\min. \sum_i \sum_t e(i,t)^2$.

Next, we test the statistical significance of estimators in the fitted model with the Likelihood Ratio Test (LRT) method. This method is based on calculation of $-N(\ln S - \ln S_0)$, where N and S are the total amount of data and the results of performance function optimization, respectively. N is given by $K \times M \times T$, where K, M, and T are the number of sectors that give input for the discussed sector(s), the number of discussed sectors, and the number of periods, respectively. The degrees of freedom are given by (K-1) × M × (number of removed explanatory variables). The statistical significance of an explanatory variable is given by $-N(\ln S - \ln S_0)$, which follows a χ^2 distribution. We take 0.05 as the level of significance, and thus use the 0.05 level of the χ^2 distribution. The degrees of freedom are 78 × 1 × 2 = 156 for the joint explanatory variables and 78 × 1 × 1 = 78 for separate explanatory variables. The cutoff scores for statistical significance are $\chi^2_{0.05}$ (156) = 185.86 and $\chi^2_{0.05}$ (78) = 99.33. We use these scores to investigate the statistical significance of the explanatory variables on each Japanese industrial sector. A particular explanatory variable is said to significantly influence a specific sector if its significance score is greater than the cutoff score. We use three null hypotheses to emphasize the results of this method. These are

- **Hypothesis 1:** Computers had no influence on structural changes of Japanese industrial sectors from 1985–2005.
- **Hypothesis 2:** Telecommunications equipment had no influence on structural changes of Japanese industrial sectors from 1985–2005.
- **Hypothesis 3:** Computers and telecommunications equipment jointly had no influence on structural changes of Japanese industrial sectors from 1985–2005.

The previous calculations can be simplified as follows. We first describe the original data of the five periods of the IO coefficient matrices of 78 Japanese industrial sectors as $A(t,i,j)$. The vectors of explanatory variables $Ex\_x(k,t)$ are used as sources of influences on the data. We use the CMR model to calculate the influence of these variables on Japanese industrial structural changes in the analysis period. We then describe the influenced original IO coefficient matrices as an estimated IO coefficient matrices, $A\_est(t,i,j)$. To perform the calculation we use the General Algebraic Modeling System (GAMS) software, which is software for analyzing high-level modeling systems for optimization and mathematical programming (GAMS, n.d.). The next step is a test using the LRT method to determine the statistical significance of estimators in the fitted model.

We next perform a deeper analysis, analysis of microscopic, namely an analysis focuses on specific sectors. In this study, this analysis focuses on the commerce, business services and office supplies, and personal services sectors. The sector numbers for these sectors are 59, 77, and 78, respectively. The reason for choosing these sectors is because the explanatory variables seem to directly impact transaction activities in the sectors. We calculate the standard deviation of the original

IO coefficients of these sectors as a first step of this analysis. The calculation for estimated IO coefficients is ignored because the results of this calculation generally follow the previous one. The purpose of this calculation is to know the magnitude of the changes of the original IO coefficients over the period of analysis. For each focused sector, we choose the ten coefficients with the highest standard deviations. These top ten coefficients represent inputs with dynamic changes. From these coefficients we choose one with an increasing pattern as a target for analysis. We also discuss input changes from value added sectors to analyzed sectors. The coefficient of variation and amount of correlation (R) are used to gain deeper insights related to influences of the variables in these sectors. After this analysis, we describe the conclusions of this study and possible topics for further research.

3. Results and Analysis

3.1. The Results of LRT Calculation

We firstly calculate the LRT to estimate the CMR model. The summary of this calculation is described in Table 1. From information in this table, we can assert that computers significantly influenced the structural changes of a majority of Japanese industrial sectors from 1985 to 2005. Exceptions are seen for the petroleum refinery products, coal products, and steel products sectors. Similar results are obtained for the influences of telecommunications equipment, which significantly influenced the structural changes of all Japanese industrial sectors from 1985–2005 except for the non-metallic ores, basic and intermediate chemical products, and gas and heat supply sectors. Because both explanatory variables significantly influenced the structural changes of a majority of Japanese industrial sectors from 1985 to 2005, we reject the first and second null hypotheses. The combination of explanatory variables used significantly influenced the structural changes of all Japanese industrial sectors from 1985–2005. This is a stronger result than the previous one. Based on this result, we then reject the third null hypothesis.

Table 1. Summary of LRT calculations (null model base)

No	Explanatory variable	Number of sectors significantly influenced	Number of sectors not significantly influenced
1	Computers	75	3
2	Telecommunications equipment	75	3
3	Combination of both	78	0

3.2. Microscopic Analysis

3.2.1. Commerce Sector

Table 2 describes the top ten original IO coefficients of commerce sectors as determined by standard deviation over the period from 1985–2005. Based on the information in this table, the most dynamic input is from the real estate agencies and rental services sector, sector number 61. For analysis we choose $a_{70,59}$, the IO coefficient that describes input from the communication sector to the commerce sector, because this coefficient has an increasing pattern.

Table 2. Top ten original IO coefficients in the commerce sector by standard deviation (1985–2005)

No.	Input–output coefficient	Standard deviation	Mean
1	*a61,59*	0.0094	0.0376
2	*a71,59*	0.0082	0.0037
3	*a65,59*	0.0079	0.0314
4	*a60,59*	0.0074	0.0529
5	*a77,59*	0.0055	0.0607
6	*a70,59*	0.0038	0.0203
7	*a59,59*	0.0037	0.0147
8	*a19,59*	0.0029	0.0081
9	*a55,59*	0.0021	0.0103
10	*a26,59*	0.0016	0.0023

Figure 1 shows the change in $a_{70,59}$ for 1985–2005. Numbers in this and other figures represent the analysis years 1985, 1990, 1995, 2000, and 2005. Table 3 shows the coefficient of variation of both original and estimated values of this coefficient and the correlation between the values over the same period. These results indicate that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{70,59}$.

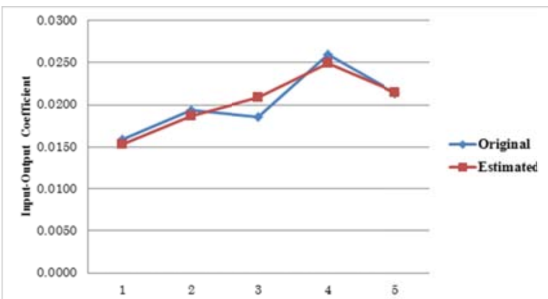

Figure 1. Changes in $a_{70,59}$ from 1985–2005

Table 3. Coefficient of variation of original and estimated values of $a_{70,59}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.186	0.174	0.936

Changes in $a_{70,59}$ indicate that during 1985–2005 ICT devices strengthened the relationship between the commerce and communication sectors. The role of these devices in this relationship can be explained as follows. The commerce sector needs communication services, such as postal and mail delivery services, to conduct its business activities. The communication sector, as an outsider, can provide these services. As time passes, the quality and quantity of ICT devices significantly advances. The emergence of computers and telecommunications equipment is evidence of this growth. These devices increase the intensity of cooperation between the commerce and communication sectors, especially input from the communication sector, since the devices expedite the flow of information between both sectors.

Figure 2 shows changes of $a_{79,59}$, input from the value added sector to the commerce sector, during 1985–2005. This figure shows an increasing–decreasing pattern in this coefficient. An increase is evident for 1985–1995, while a decreasing pattern emerged for 1995–2005. Table 4 shows the coefficient of variation of both the original and estimated values of this coefficient, and the correlation between the values over the same period. These results suggest that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{79,59}$.

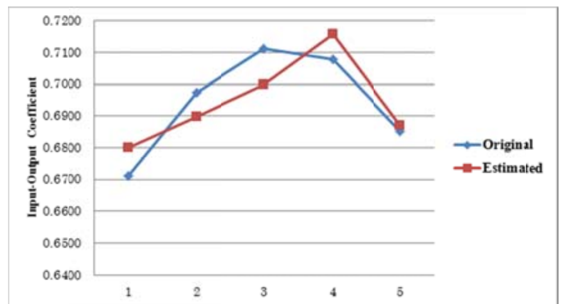

Figure 2. Changes in $a_{79,59}$ from 1985–2005

Table 4. Coefficient of variation of both original and estimated values of $a_{79,59}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.024	0.020	0.833

Increasing input from the value added sector to particular sector implies that the goods price of this sector will rise. Therefore, Figure 2 suggests that during 1985–1995 the price of commerce sector outputs increased. This pattern, refers to the original data of this IO coefficient, did not continue in the following years of analysis. From the estimated data for this IO coefficient, however, this pattern continued through 2000. This shows that ICT devices had a positive impact on increasing the price of commerce sector outputs, especially during 1995–2000.

We believe that an increasing pattern in estimated $a_{79,59}$ during 1995–2000 appeared due to economic conditions. Unemployment in Japan continuously rose during slow growth years, further accelerating in 1999 (United Nations, 2000). Therefore, in this period sectors should have taken steps to maintain good quality outputs and attractive prices without adding employees.

ICT devices, represented by computers and telecommunications equipment, can support sectors in that goal by, for example supporting quality assurance activities. Note, however, that device installation costs can be high, so sectors need to maintain an attractive price to maintain cash flow balances when these devices are employed. This argument explains the increasing pattern in estimated $a_{79,59}$ for 1995–2000.

3.2.2. Business Services and Office Supplies Sector

Table 5 shows the top ten original IO coefficients for the business services and office supplies sector, relative to standard deviation during 1985–2005. This table shows that the most dynamic input is from the publishing and printing sector, sector number 19. For analysis, we choose the $a_{60,77}$ IO coefficient, which describes input from the finance and insurance sector to the business services and office supplies sector, because this coefficient has an increasing pattern.

Table 5. Top ten original IO coefficients of the business services and office supplies sector by standard deviation (1985–2005)

No	Input–output coefficient	Standard deviation	Mean
1	*a19,77*	0.0291	0.0431
2	*a71,77*	0.0237	0.0427
3	*a47,77*	0.0116	0.0213
4	*a60,77*	0.0087	0.0396
5	*a77,77*	0.0086	0.1038
6	*a18,77*	0.0078	0.0141
7	*a46,77*	0.0071	0.0163
8	*a61,77*	0.0051	0.0120
9	*a43,77*	0.0047	0.0071
10	*a42,77*	0.0040	0.0066

Figure 3 shows changes in $a_{60,77}$ during 1985–2005. Table 6 shows the coefficient of variation of both the original and estimated values of this coefficient and the correlation of these values over the same period. These results suggest that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{60,77}$.

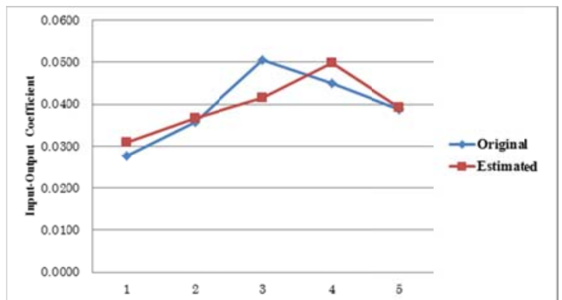

Figure 3. Changes in $a_{60,77}$ from 1985–2005

Table 6. Coefficient of variation of both original and estimated values of $a_{60,77}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.221	0.175	0.793

Changes in $a_{60,77}$ indicate that during 1985–2005 ICT devices supported the relationship between the finance and insurance sector and the business services and office supplies sector. An interesting condition occurred during 1995–2000: a decreasing pattern is observed in the original data, but an increasing pattern appears in the estimated data. We believe that this difference is due to economic condition in Japan during this period. As mentioned above, unemployment in Japan increased further in 1999. Both sectors were influenced by this condition to some extent. Particular sector that experiences this condition need to search for ways to increase performance, including providing good service, without adding employees. ICT devices, such as computers and telecommunications equipment, are one way of doing so. These devices can reduce human error and thus help to maintain performance. This may be a factor behind the increasing pattern seen in the estimated $a_{60,77}$ for 1995–2000.

Figure 4 shows changes in $a_{79,77}$, input from the value added sector to the business services and office supplies sector during 1985–2005. This figure shows a generally increasing pattern in this coefficient. Table 7 shows the coefficient of variation for both the original and estimated values of this coefficient, and correlation of the values over the same period. These results suggest that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{79,77}$.

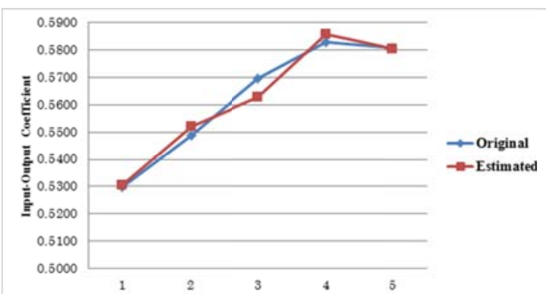

Figure 4. Changes in $a_{79,77}$ from 1985–2005

Table 7. Coefficient of variation of both original and estimated values of $a_{79,77}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.040	0.040	0.984

Increased input from the value added sector to particular sector suggests that the goods price of this sector will rise. Therefore, Figure 4 suggests that during 1985–2000 the price of outputs of the business services and office supplies sector increased. In 2000–2005, a slight decrease appeared. Both IO coefficients show the same pattern, suggesting that ICT devices had a positive impact on increasing the price of the goods of the business services and office supplies sector, especially during 1985–2000.

3.2.3. Personal Services Sector

Table 8 shows the top ten original IO coefficients of the personal services sector, relative to standard deviation for 1985–2005. This table shows that the most dynamic input is from the commerce sector, sector number 59. For analysis, we choose the IO coefficient that describes input from this sector to the personal services sector, $a_{59,78}$, because this coefficient has an increasing pattern.

Table 8. Top ten original IO coefficients of the personal services sector by standard deviation (1985–2005)

No.	Input–output coefficient	Standard deviation	Mean
1	*a59,78*	0.0124	0.0546
2	*a77,78*	0.0077	0.0357
3	*a78,78*	0.0057	0.0165
4	*a71,78*	0.0055	0.0044
5	*a61,78*	0.0051	0.0199
6	*a72,78*	0.0039	0.0053
7	*a60,78*	0.0038	0.0202
8	*a26,78*	0.0031	0.0050
9	*a10,78*	0.0029	0.0367
10	*a58,78*	0.0029	0.0084

Figure 5 shows the changes in $a_{59,78}$ during 1985–2005. Table 9 shows the coefficient of variation for both the original and estimated values of this coefficient and the correlation of these values over the same period. These results suggest that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{59,78}$.

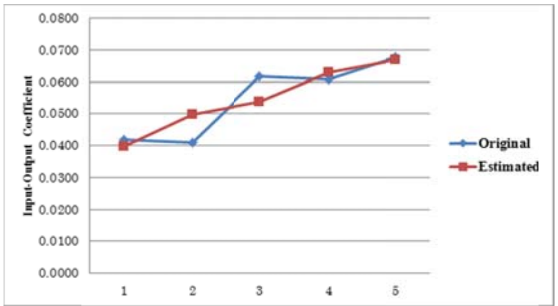

Figure 5. Changes in $a_{59,78}$ from 1985–2005

Table 9. Coefficient of variation of both original and estimated values of $a_{59,78}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.227	0.197	0.868

Changes in $a_{59,78}$ indicate that during 1985–2005 ICT devices well supported the relationship between the commerce and personal services sectors. An increasing pattern clearly appeared in this period, in both the original and estimated data. We believe that this pattern appears because of characteristics of the personal services sector. This sector needs a "field" to market its products, and the commerce sector provides this. Figure 5 suggests that support from the commerce sector increases from year to year. ICT devices, especially computers, promote this connection because they can expedite the flow of information. In other words, these devices strengthen business activities between both sectors.

Figure 6 describes changes in $a_{79,78}$, input from the value added sector to the personal services sector, from 1985–2005. This figure shows a generally decreasing pattern in this coefficient. Table 10 shows the coefficient of variation of both the original and estimated values of this coefficient, and the correlation of these values over the same period. These results suggest that our model well follows historical changes. In other words, during 1985–2005 the explanatory variables had a strong influence on $a_{79,78}$.

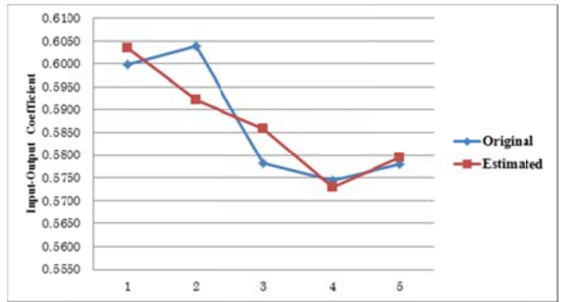

Figure 6. Changes in $a_{79,78}$ from 1985–2005

Table 10. Coefficient of variation of both original and estimated values of $a_{79,78}$ and correlation (R) of both values (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	
0.024	0.020	0.851

Decreased input from the value added sector to particular sector suggests that the goods price of this sector will fall. Therefore, Figure 6 suggests that during 1985–2000 the output price of the personal services sector tended to decrease. We suggest that this downturn appears due to the adoption of ICT devices in the personal services sector. Sectors that utilize ICT devices in production activities will be more efficient than those that do not. This efficiency will reduce operating costs. Further, this reduction will decrease the price of products. In other words, sectors that utilize ICT devices in their business activities will be more competitive in market than those that do not.

4. Conclusions and Further Research

This study analyzed the influences of ICT in structural changes of Japanese industrial sectors during 1985–2005. In this study, we considered ICT to be represented by ICT capital stock. More specifically, ICT capital stock is represented by computers and telecommunications equipment. Both of these technologies were used as explanatory variables. We employed the CMR model as an analysis tool and used the LRT method to test the statistical significance of estimators in the fitted model. We also conducted hypothesis testing to bolster the strength of the results. We then performed deeper analysis, focusing microscopically on the commerce, business services and office supplies, and personal services sectors. We used standard deviations, coefficients of variation, and correlations to obtain a deeper understanding of the influences of these variables in the examined sectors.

The results showed that in the analysis period these variables, separately and jointly, had a significant influence on structural changes of Japanese industrial sectors, including the analyzed sectors. From the statistical significance of the analyzed sectors, structural change of the commerce sector was more strongly influenced by telecommunications equipment than by computers. An opposite phenomenon was seen for the structural change of the business services and office supplies sector. The structural change of the personal services sector, in contrast, was equally influenced by both explanatory variables.

The results also show that the patterns of influence due to the explanatory variables differ among analyzed sectors. This difference is clearly observed in input from the value added sector. We believe that the implementation of ICT devices in the business activities of these sectors, and economic conditions, such as unemployment rates, influence this difference. These phenomena support the conclusion that in 1985–2005 the business circumstances of the analyzed sectors were dissimilar.

This study could analyze the influences of ICT in structural changes of Japanese industrial sectors from 1985–2005, especially focusing on the structural changes of ICT-related sectors. The scope of this study, however, should be expanded further. For instance, analysis of sectors, such as the agricultural and manufacturing sectors, would allow broader observation of the influences of ICT. Further analysis of, for example, structural changes in capital formation coefficients, would more comprehensively show the influences of ICT by sector.

Finally, investigating this topic at the international level is also suggested for further research. Such a comparison would reveal the characteristics of industrial structural changes in the compared countries.

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