Statistical Analysis of Influences of ICT on Industrial Structure Changes from 1985 through 2005: The Case of Japan

Ubaidillah Zuhdi
Department of Industrial Administration, Graduate School of Science and Technology,
Tokyo University of Science, Noda, Japan
School of Business and Management, Institut Teknologi Bandung, Bandung, Indonesia
Email: ubaidillah.zuhdi@gmail.com

Shunsuke Mori and Kazuhisa Kamegai
Department of Industrial Administration, Tokyo University of Science, Noda, Japan
Email: sh_mori@rs.noda.tus.ac.jp and kamegai@rs.tus.ac.jp

***Abstract*—The purpose of this study is to analyze the role that information and communication technology (ICT) has played in changes of Japanese industrial structure; this analysis will be conducted by statistical analysis on input-output (IO) tables. In this study, we focus on ICT capital stock as the key driver, where ICT capital stock comprises computers (including computer accessories) and telecommunications equipment available during 1985 to 2005. Constrained multivariate regression (CMR) modeling is employed for analysis. A likelihood ratio test (LRT) is used for evaluating the statistical significance of model. At the macro level, this study analyzes the results of LRT calculations; at the micro level, this study analyzes the changes of IO coefficients. LRT calculation results confirms that the explanatory variables (computers, main parts and accessories; telecommunications equipment) induced structural changes in most (jointly, in all) Japanese industrial sectors from 1985 through 2005. The CMR model results show that the impact of these explanatory variables on the IO coefficients differed by sector. These differing effects reveal that internal factors in industrial sectors are more complex than macro-level factors and that further investigation is needed to clarify the discovered micro-level differences.**

***Index Terms*—ICT, industrial structure changes, constrained multivariate regression, likelihood ratio test, Japan**

I. Introduction

Technology is used every day by people around the world. For example, people use transportation tools, such as cars, motorcycles, and trains when they commute. Moreover, people use technology in their hobbies, too, such as photography, travel, and sports. Such examples affirm that technology is inseparable from modern daily life.

The importance of technology has also been studied by many researchers. Technology now affects, and is affected by, nearly every aspect of human life [1]. Technology is a major factor in the path of history and the shape of society [2]. For the future, green technology will have an important role in power generation as countries efforts to reduce dependence imported and polluting fuels and pursue energy independence [3].

One frequently used class of technology is information and communication technology (ICT). The use of ICT has recently become highly visible. We frequently see people using phones, both fixed line and mobile, for communicating with others, and a similar pattern can be seen in the use of the Internet. Nearly every aspect of modern society relies on the Internet. The Internet has become a powerful tool for both micro- and macro-level activities. Millions of people spend time each day accessing and creating information online [4].

ICT has been studied extensively. Ref. [5] explored the correlations between different dimensions of ICT investment and aspects of human development. Their research examined 51 countries, which were divided into three groups based on income: high, middle, and low. Ref. [6] developed the definitions and hierarchies necessary for rigorous study of ICT. Ref. [7] assessed the role of ICT in enhancing access to agricultural information for developing agriculture and agribusiness in Tanzania.

Ref. [8] examined the spatial correlation between investment in ICT and economic growth of economy by using the generalized method of moments. Their study focused on OPEC member countries from 1990 to 2007. Ref. [9] investigated the role of ICT sectors in structural changes of the Indonesian economy from 1990 to 2005 by decomposition analysis, a tool for analyzing input-output (IO) data. Ref. [10] used an IO approach to explore how to encourage the growth of ICT sectors in Indonesia.

Corresponding author: Ubaidillah Zuhdi
Email: ubaidillah.zuhdi@gmail.com

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Ref. [11] used decomposition analysis to compare the role of ICT sectors in national economic structural changes in Japan and Indonesia. Ref. [12] employed two methods, decomposition analysis and simple output multipliers, to analyze the role of ICT sectors in the Japanese national economy from 1995 to 2005. The results of those different methods of calculation were compared to highlight alternate perspectives on the role of ICT sectors.

Statistical analysis of the role of ICT in national economies is still insufficiently studied, however. A statistical approach is important because it can quantify the influence of ICT in the economic activities of a country. Further, this kind of study can offer insight into methods for strengthening economic activity in the studied country. This study is conducted to contribute to filling the gap in the literature.

The purpose of this study is to analyze the role of ICT in changes of the industrial structure of a country; this study proceeds by statistical analysis on IO tables. The target country in this study is Japan. The period of analysis for this study is 1985 to 2005. In order to achieve the purpose, we develop a constrained multivariate regression (CMR) model and evaluate this model by using the likelihood ratio test (LRT) to calculate the statistical significance of the fitted estimators.

This paper is arranged as follows. The methodology of this study is explored in section II. Section III explains the results of calculation and analysis related to these results. Section IV describes the conclusions of this study and suggests areas for further research.

II. Methodology

In this study, ICT is represented by ICT capital stock; specifically, by computers, main parts and accessories, and telecommunications equipment. We develop a CMR model to analyze changes in industrial structure by regarding them as dynamic changes in IO coefficient vectors extracted from IO tables. The LRT method is then used to evaluate the statistical model. This study focuses on two analyses: (1) LRT calculations at the macro level and (2) IO coefficients at the micro level.

The method of this study can be summarized as follows. First, we concord the Japanese IO tables for 1985, 1990, 1995, 2000, and 2005 to equalize the number of industrial sectors. The number of sectors in the IO tables for 1985, 1990, 1995, 2000, and 2005 was 84, 91, 93, 104, and 108, respectively. There are 78 sectors after concordance; those sectors are displayed in the Appendix.

Second, we calculate the IO coefficient matrices for each year in the analyzed period. We use the following equation from [13]:

$$a_{ij} = \frac{z_{ij}}{X_j}, \tag{1}$$

where z_{ij} is the level of inter-industry sales from sector i to sector j and X_j is the total production of sector j. The right-hand side, a_{ij}, represents the IO coefficient from sector i to sector j; that is, the input needed from industry i to produce one unit of output from industry j.

Third, we use a CMR model to calculate the influences of explanatory variables used in this study—computers and telecommunications equipment—on changes in Japanese industrial structure. The data for those variables are obtained from the website of the Japanese Ministry of Public Management, Home Affairs, Posts and Telecommunications [14]. The statistical significance of the estimators in the fitted model is tested by the LRT method.

The LRT method as used in this study can be described as follows. We first index the years of analysis as T. In this study, we study the years (indices) 1985 (1), 1990 (2), 1995 (3), 2000 (4), and 2005 (5). Then, we can define the data representing Japanese industrial structure (i.e., the IO coefficient matrices) by $a(t)$ t = 1…T. In this calculation, IO coefficients are vector entries. In other words, CMR model is applied to each industrial sector of Japan through the IO coefficient of that sector. The explanatory variables used can be described as $x(k,t)$ k = 1…k. The function $a(t)$ is extended in the model to

$$a(i,t) = b_0(i) + \sum_k b(i,k) \times x(k,t) + e(i,t)$$

$$a(i,t) \geq 0, \ \sum_i a(i,t) = 1.0, \tag{2}$$

where $b_0(i)$ and $b(i,k)$ are the regression coefficients of the model. Since IO coefficients are non-negative and should sum to unity by definition, constraints among estimators are imposed. The error term $e(i,t)$ describes the difference between original and estimated values. By least squares minimization, that is, by using the object function $\min\left(\sum_i \sum_t e(i,t)^2\right)$, one can obtain the parameters. Above model, actually, representing CMR model used in this study. We then formulate the data from the 5 data years and the 78 Japanese industrial sectors in the IO coefficient matrices as the function $A(t,i,j)$. The vectors of explanatory variables, $Ex\_\mathbf{x}(k,t)$, are used as a source of influences for that data.

The LRT method is based on calculating $-N(\ln S - \ln S_0)$, 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 number of sectors which give input for discussed sector(s), number of discussed sector(s), and number of periods, respectively. The degrees of freedom is given by $(K - 1) \times M \times$(number of removed explanatory variables). The statistical significance of an explanatory variable is given by $-N(\ln S - \ln S_0)$, which follows a $\chi 2$ distribution. In this study, we take 0.05 as the level of significance. Therefore, we use the 0.05 level of $\chi 2$ distribution in applying LRT method. The degrees of freedom used in this study are 78×1×2 = 156 for the explanatory variables jointly and 78×1×1 = 78 for the explanatory variables separately. The cutoff scores for statistical significance in this study are $\chi 2_{0.05}$ (156) = 185.86 and $\chi 2_{0.05}$ (78) = 99.33. We use these in calculating the statistical significance of the explanatory variables for each Japanese industrial sector.

An explanatory variable significantly influences a particular sector if its calculated significance score is greater than the cutoff score.

The LRT calculations in this study are performed by the GAMS software, a system for analyzing high-level optimization models and mathematical programming [15]. We analyze the results of that calculation at the macro level. This analysis uses hypothesis testing. Three null hypotheses are used in this study.

- **Hypothesis 1:** Computers, including computer accessories, had no influence on Japanese industrial structure changes from 1985 to 2005
- **Hypothesis 2:** Telecommunications equipment had no influence on Japanese industrial structure changes from 1985 to 2005
- **Hypothesis 3:** Computers and telecommunications equipment jointly had no influence on Japanese industrial structure changes from 1985 to 2005.

We use the null model, in which the value of k is constant, as a base in testing those hypotheses.

Finally, we analyze the influences of explanatory variables used in this study at the micro level. More specifically, this analysis investigates the influences of those variables on the changes in IO coefficients, a_{ij}, for specific sectors. This part of the analysis focuses on the following sectors: (1) commerce, (2) finance and insurance, (3) broadcasting, and (4) business services and office supplies. These sectors are chosen because the ICT is expected to directly impact transactions in these sectors.

For each analyzed sector, the representation of changes in IO coefficients is chosen from the top ten sectors giving the highest input to that sector. The coefficient of variation is used to analyze the original and estimated values of the IO coefficients at the micro level. The degree of correlation between the values is also used to explore the influences of explanatory variables at the industry level. As in the macroeconomic case, microeconomic analysis is performed by using the GAMS software.

III. Results and Analysis

A. Macroeconomic Analysis

This subsection discusses the results of LRT analysis of the role of the explanatory variables used in this study, computers and telecommunications equipment, in changes in Japanese industrial structure from 1985 to 2005. The results are used to test the null hypotheses discussed earlier. Because all sectors are discussed, the analysis in this subsection is also called macroeconomic analysis.

A summary of the LRT calculations which evaluate the CMR model are seen in Table I. From information in that table, we can assert that computers significantly influenced the structure of a majority of Japanese industrial sectors from 1985 to 2005. The exceptions are (1) petroleum refinery products, (2) coal products, and (3) steel products sectors. Similar results are obtained for the influences of telecommunications equipment, which significantly influenced the structure of all Japanese industrial sectors from 1985 to 2005 except for (1) non-metallic ores, (2) basic and intermediate chemical products, and (3) gas and heat supply sectors. Because both explanatory variables significantly influence the structure 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 in this study significantly influenced the structure changes of all Japanese industrial sectors from 1985 to 2005. This is a stronger result than for the explanatory variables separately. We can say thus reject the third null hypothesis.

The above results show that the combination of explanatory variables used in this study played a significant role in changes in Japanese industrial structure between 1985 and 2005. For specific sectors, only one of the explanatory variable was significant; this differed by sector. For example, computers significantly influenced the non-metallic ores sector, but telecommunications equipment did not. We conclude from these results that the development of ICT broadly affected Japan during the study period.

B. Microeconomic Analysis

The previous subsection analyzed the influences of computers and telecommunications equipment at the macro level. This subsection analyzes the influences of those variables at a lower level, the IO coefficient level; as such, the analysis is at the micro level. We focus on the following sectors: (1) commerce, (2) finance and insurance, (3) broadcasting, and (4) business services and office supplies. The aim of this analysis is to investigate the influences of ICT capital stock in changes in the IO coefficients for the listed sectors. The years analyzed in this section are 1985, 1990, 1995, 2000, and 2005; these are indexed as described in Section II. The word of "original" represents pure data of IO coefficients while "estimated" represents the data of IO coefficients after receiving the influences from explanatory variables. Each selected sector is analyzed in detail below.

B.1 Commerce Sector

Fig. 1 shows the changes in one specific IO coefficient, $a_{61,59}$, which represents the input given by the real estate agencies and rental services sector, sector 61, to the commerce sector, sector 59, between 1985 and 2005. A downward trend appears in these changes. Table II compares the coefficients of variation of the original and the estimated values of that coefficient and also shows the correlation (R) of these values. From these results, we can conclude that our model results model the historical changes well. We conclude that the explanatory variables significantly influenced $a_{61,59}$ from 1985 to 2005.

TABLE I.
SUMMARY OF LRT CALCULATIONS (NULL MODEL AS A 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 1 and 2	78	0

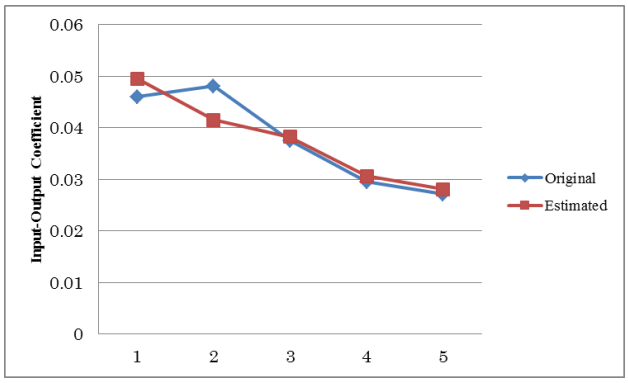

Figure 1. Changes in $a_{61,59}$ from 1985 to 2005.

TABLE II.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{61,59}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.914
0.251	0.229	

Fig. 2 shows the changes in another specific IO coefficient, $a_{70,59}$, representing input from the communication sector, sector 70, to the commerce sector, sector 59, between 1985 and 2005. An upward trend is found for this case. Table III lists the coefficients of variation of both the original and estimated values of that coefficient. This table also displays the correlation of both values. Again, we can conclude from analysis results that our model reflects historical changes, and so we can say that the explanatory variables strongly influenced $a_{70,59}$ from 1985 to 2005.

Explanatory variables used in this study affected the commerce sector differently. This difference shows that, for this sector, the microeconomic circumstances are more complex than the macroeconomic characteristic. This complexity is caused by the commerce sector itself, which uses communications media to market its products. The role of the communication sector, which is represented by its input to the commerce sector, is entwined with the activities of commerce. The strong influences of the explanatory variables used in this study and the increasing trend in estimated value from 1985 to 2005 in this relationship between commerce and communications show that ICT bolsters their relationship. This support occurs when information sharing and communication facilitate business activity between those sectors.

In contrast, the opposite phenomenon appears in the relationship between the real estate and rental services sector and the commerce sector. This relationship had a downward trend in the period between 1985 and 2005, in both original and estimated values. This decline in activity might be caused by an increase in competition between these sectors. This possibility and the strong influences of the explanatory variables in this relationship suggest that ICT weakens the relationship between these two sectors.

B.2 Finance and Insurance Sector

Fig. 3 shows the changes of $a_{61,60}$, the IO coefficient representing input from the real estate agencies and rental services sector, sector 61, to the finance and insurance sector, sector 60, between 1985 and 2005. A downward trend is seen in these changes. Table IV compares the coefficients of variation of the original and the estimated values of that coefficient as well as the correlation of these values. From these results, we conclude that our model results reflect historical changes, and so we can say that the explanatory variables significantly influenced $a_{61,60}$ from 1985 to 2005.

Fig. 4 shows the changes in $a_{77,60}$, the IO coefficient that represents input from the business services and office supplies sector, sector 77, to the finance and insurance sector, sector 60, in the period between 1985 and 2005. Here, an upward trend is observed. Table V shows the coefficients of variation of both original and estimated values of that coefficient and also shows the correlation of both values. As we did in the other cases, we conclude that our model reflects historical changes, and so we can say that the explanatory variables significantly influenced $a_{77,60}$ from 1985 to 2005.

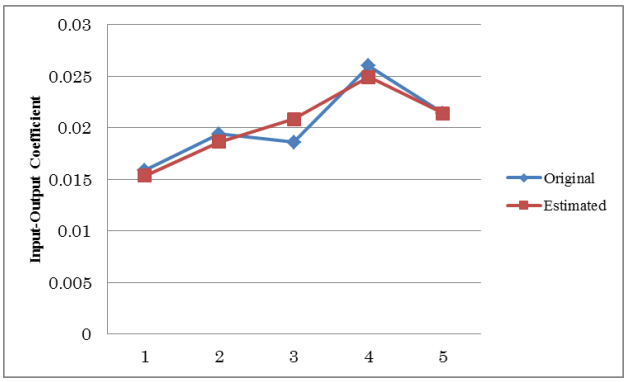

Figure 2. Changes in $a_{70,59}$ from 1985 to 2005.

TABLE III.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{70,59}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.936
0.186	0.174	

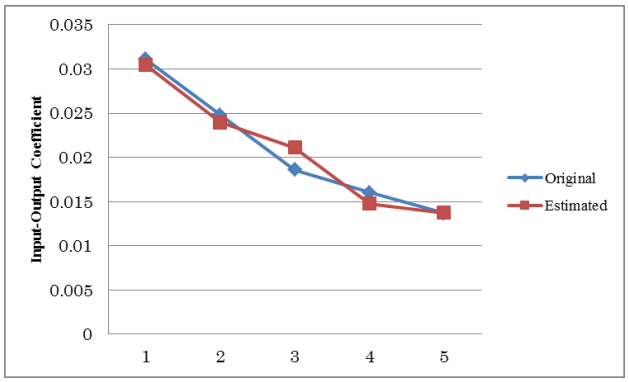

Figure 3. Changes in $a_{61,60}$ from 1985 to 2005.

TABLE IV.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{61,60}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.977
0.340	0.331	

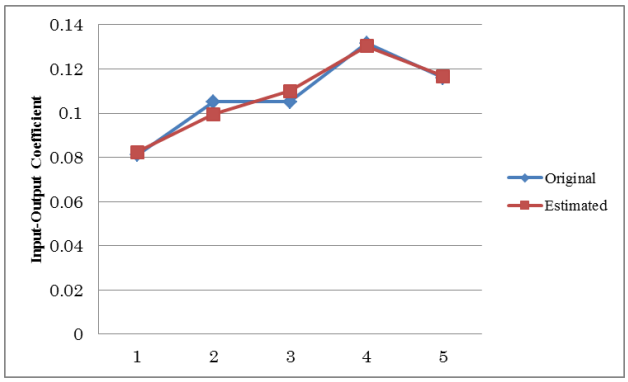

Figure 4. Changes in $a_{77,60}$ from 1985 to 2005.

TABLE V.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{77,60}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.978
0.172	0.168	

The explanatory variables affected the IO coefficients of the finance and insurance sector differently at the micro level. This difference shows, for this sector, the microeconomic circumstances are more complex than the macroeconomic characteristic. This complexity is caused by the finance and insurance sector itself; this sector needs input from the business services and office supplies sector to maintain its cash flow. That is, the role of the business services and office supplies sector, which is represented by input to the finance and insurance sector, is important for the activities of the finance and insurance sector. Strong influences from the explanatory variables and the upward trend in estimated value from 1985 to 2005 of this relationship support the contention that computers and telecommunications equipment promote the strength of this relationship. The support arises from facilities for communications and information sharing. Such activities will further accelerate business activities between the sectors.

The opposite trend appears in the relationship between the real estate agencies and rental services sector and the finance and insurance sectors. This relationship shows a downward trend in the period between 1985 and 2005, in both original and estimated values. This decline might be caused by similarity between the sectors, which would result in increased in competition between them. This possibility and strong influences from the explanatory variables clarify that these variables negatively support the existence of this relationship.

B.3 Broadcasting Sector

Fig. 5 shows changes in $a_{46,71}$, the IO coefficient that represents input from the electrical appliance sector, sector 46, to the broadcasting sector, sector 71, in the period between 1985 and 2005. A downward trend can be seen in these changes. Table VI compares the coefficients of variation of the original and estimated values of $a_{46,71}$ and the correlation of these values. From these results, we conclude that our model results reflect historical changes, and so we can say that the explanatory variables strongly influenced $a_{46,71}$ from 1985 to 2005.

Fig. 6 shows the changes in $a_{77,71}$, the IO coefficient that represents input from the business services and office supplies sector, sector 77, to the broadcasting sector, sector 71 in the period between 1985 and 2005. A different pattern appears here, where the trend is upward. Table VII shows the coefficients of variation of both original and estimated values of $a_{77,71}$, and also shows the correlation of both values. From these results, we conclude that our model results reflect historical changes, and so the explanatory variables exhibited a strong influence on $a_{77,71}$ from 1985 to 2005.

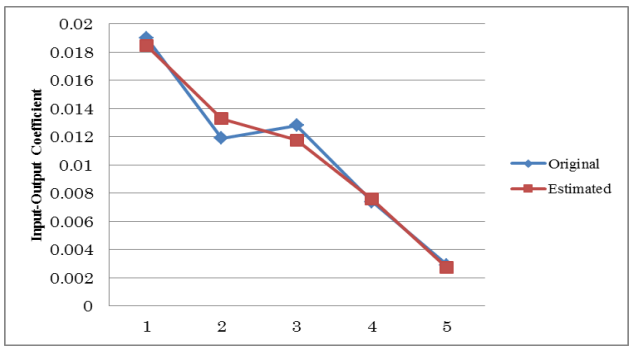

Figure 5. Changes in $a_{46,71}$ from 1985 through 2005.

TABLE VI.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{46,71}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.988
0.560	0.553	

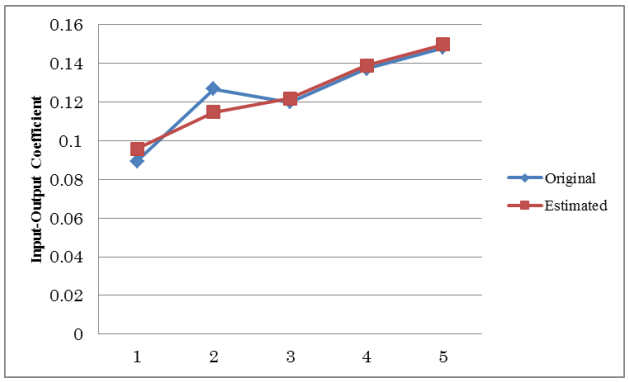

Figure 6. Changes in $a_{77,71}$ from 1985 through 2005.

TABLE VII.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{77,71}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.950
0.178	0.170	

The explanatory variables affected the IO coefficients of the broadcasting sector differently at the micro level. This difference is evidence that, for this sector, the microeconomic circumstances are more complex than macroeconomic characteristic. This complexity is caused by the broadcasting sector itself. This sector needs the information supplied by the business services and office supplies sector to conduct its activities. The role of the business services and office supplies sector, which is represented by input to the broadcast sector, is integral to the activities of the broadcasting sector. Both strong influences from the explanatory variables and the upward trend in estimated value from 1985 to 2005 suggest reasons why these variables strengthen this relationship. Communication and information sharing accelerate business activity between these sectors.

The opposite trend appears for the relationship between the electrical appliance sector and the broadcasting sector. This relationship had a downward trend in the period between 1985 and 2005, in both original and estimated values. This downward trend might be caused by preference changes in the broadcasting sector when choosing suppliers. That is, in the period between 1985 and 2005, there was a decrease in the dependence of the broadcasting sector on products from the electrical appliance sector. This change and the strong influences of explanatory variables in this relationship show that these variables negatively support the existence of this relationship.

B.4 Business Services and Office Supplies Sector

Fig. 7 shows changes in $a_{19,77,}$ the IO coefficient that represents input from the publishing and printing sector, sector 19, to the business services and office supplies sector, sector 77, in the period between 1985 and 2005. A downward trend is seen in these changes. Table VIII compares the coefficients of variation of the original and estimated values of $a_{19,77}$ and shows the correlation of these values. From these results, we conclude that our model reflects historical changes, and so we can say that explanatory variables strongly influenced $a_{19,77}$ from 1985 through 2005.

Fig. 8 shows changes in $a_{59,77}$, the IO coefficient that represents input from the commerce sector, sector 59, to the business services and office supplies sector, sector 77, in the period between 1985 and 2005. Here, an upward trend is seen. Table IX shows the coefficients of variation of both original and estimated values of $a_{59,77}$. This table also includes the correlation of both values. From these results, we conclude that our model results reflect historical changes, and so the explanatory variables used in this study strongly influenced $a_{59,77}$ from 1985 to 2005.

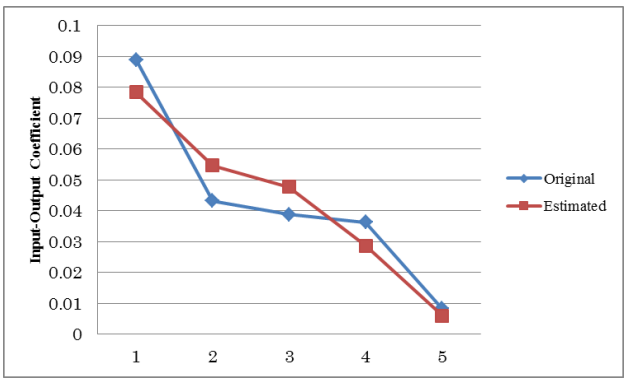

Figure 7. Changes in $a_{19,77}$ from 1985 through 2005.

TABLE VIII.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{19,77}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.941
0.674	0.634	

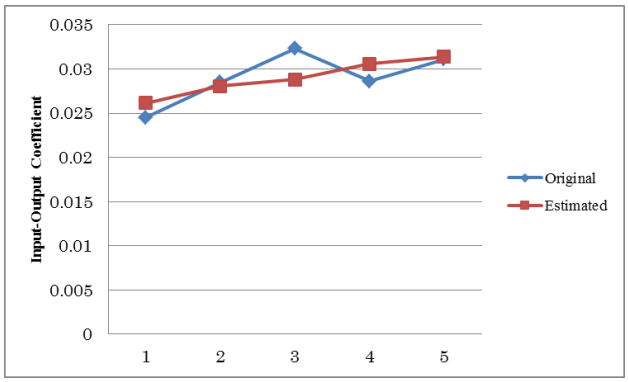

Figure 8. Changes in $a_{59,77}$ from 1985 through 2005.

TABLE IX.
COEFFICIENTS OF VARIATION OF BOTH ORIGINAL AND ESTIMATED VALUES OF $A_{59,77}$ AND CORRELATION (R) OF BOTH VALUES (1985–2005)

Coefficient of variation		Correlation
Original	Estimated	0.687
0.103	0.071	

The explanatory variables impacted the IO coefficients of the business services and office supplies sector differently at the micro level. This difference shows that, for this sector, the microeconomic circumstances are more complex than macroeconomic characteristic. This complexity is caused by the business services and office supplies sector itself. This sector relies on the activities that the commerce sector provides. In other words, the role of the commerce sector, which is represented by input to the business services and office supplies sector, is important to the activities of the business services and office supplies sector. The strong influences of the explanatory variables and the upward trend in estimated value from 1985 to 2005 in this relationship provide evidence that these variables strengthen this relationship. Communication and information sharing facilitate business activity between these sectors.

The opposite trend exists in the relationship between the publishing and printing sector and the business services and office supplies sector. This relationship exhibits a downward trend in the period between 1985 and 2005, in both original and estimated values. This weakening might be caused by an increase in competition between these sectors. Moreover, the growth in the eco-business concept in recent years might be a reason for this decline. The eco-business concept will make businesses consider environmental sustainability when conducting business activities. The publishing and printing sector uses large amounts of natural resources for its business activities. Therefore, sectors implementing the eco-business concept will tend to avoid the publishing and printing sector when making business agreements. Both the downward trend and strong influences from the explanatory variables explain that these variables negatively support the existence of this relationship.

IV. CONCLUSIONS AND AREAS FOR FURTHER RESEARCH

This study analyzed the role of ICT in changes in Japanese industrial structure from 1985 to 2005. In this study, ICT was represented by ICT capital stock, which comprises computers (including computer accessories) and telecommunications equipment. CMR modeling and LRT method were employed as an analytic tool. This study focused on two levels of analysis: (1) analysis of LRT calculation at the macro level and (2) analysis of IO coefficients at the micro level.

Hypothesis testing was used for macroeconomic analysis. The standard null hypotheses were used. The results of LRT calculation showed that both explanatory variables significantly influenced the structure of most (jointly, of all) Japanese industrial sectors from 1985 to 2005.

Microeconomic analysis focused on the (1) commerce, (2) finance and insurance, (3) broadcasting, and (4) business services and office supplies sectors. These sectors were chosen because the explanatory variables were intuitively linked to the activities of those sectors. The objective of the analysis was to investigate the influences of the explanatory variables on the IO coefficients of the chosen sectors. The results of this analysis showed that explanatory variables used in this study gave different impacts to the IO coefficients of the chosen sectors in micro level. In our analysis, the microeconomic circumstances were more complex than the macroeconomic characteristic.

This study analyzed the influences of ICT capital stock on the industrial structure changes of Japan from 1985 through 2005. The scope of this study, however, was narrow, and broader studies should be undertaken in the future. Specifically, we suggest adding other explanatory variables, such as education and export-import activities, for analyzing industrial structure changes in Japan. Additionally, further investigation to clarify microeconomic differences observed in this study would be of interest to us. More data are becoming available, and extending the period of analysis will allow deeper analysis. Extending this technique to international comparisons is also a suggested area for further research from this study. Such a comparison will show similarities and differences in the industrial structure changes of compared countries. Finally, we have made no policy suggestions in this study. We hope that our study will stimulate further research and discussion on appropriate economic policies.

REFERENCES

[1] A. Grubler, *Technology and Global Change*. Cambridge: Cambridge University Press, 1998.

[2] E. Braun, "The changing role of technology in society", http://epub.oeaw.ac.at/ita/ita-manuscript/ita_10_03.pdf, 2010, Accessed 19 October 2013.

[3] D. S. Abraham, "The battle for new resources: Minor minerals in green technologies", http://www.rieti.go.jp/jp/publications/pdp/12p005.pdf, 2012, Accessed 19 October 2013.

[4] M. Peitz and J. Waldfogel, *The Oxford Handbook of the Digital Economy: Edited by Martin Peitz and Joel Waldfogel*. NY: Oxford University Press, 2012.

[5] F. O. Bankole, F. Shirazi, and I. Brown, "Investigating the impact of ICT investments on human development," The Electronic Journal of Information Systems in Developing Countries, vol. 48, 8, pp. 1–19, 2011.

[6] C. M. Zuppo, "Defining ICT in a boundaryless world: The development of a working hierarchy," International Journal of Managing Information Technology (IJMIT), vol. 4, pp. 13–22, 2011. doi:10.5121/ijmit.2012.4302.

[7] W. P. Mtega and A. C. Msungu, "Using information and communication technologies for enhancing the accessibility of agricultural information for improved agricultural production in Tanzania," The Electronic Journal of Information Systems in Developing Countries, vol. 56, 1, pp. 1–14, 2013.

[8] E. H. Nasab and M. Aghaei, "The effect of ICT on economic growth: Further evidence," International Bulletin of Business Administration, vol. 5, pp. 46–56, 2009.

[9] U. Zuhdi, D. S. Utomo, and D. T. Alamanda, "Analyzing the role of ICT sector to the national economic structural change: The case of Indonesia," Jurnal Manajemen Teknologi, vol. 10, pp. 299–307, 2011.

[10] U. Zuhdi, N. A. R. Putranto, and A. D. Prasetyo, "Encouraging ICT sectors using input – output approach: The case of Indonesia", Adv. Sci. Lett., vol. 20, no. 1, pp. 199-202, January 2014. doi:10.1166/asl.2014.5269.

[11] U. Zuhdi, S. Mori, and K. Kamegai, "Analyzing the role of ICT sector to the national economic structural changes by decomposition analysis: The case of Indonesia and Japan," Procedia – Social and Behavioral Sciences, vol. 65, pp. 749–754, December 2012. doi:10.1016/j.sbspro.2012.11.194.

[12] U. Zuhdi, "The other perspective related to the role of ICT sectors in national economy: The case of Japan", Adv. Sci. Lett., vol. 20, no. 2, pp. 483-486, February 2014. doi:10.1166/asl.2014.5334.

[13] R. E. Miller and P. D. Blair, *Input–Output Analysis: Foundations and Extensions–2nd Ed.* NY: Cambridge University Press, 2009.

[14] Japanese Ministry of Public Management, Home Affairs, Posts and Telecommunications, "2009 White paper of information and communication: Reference", http://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h21/data/html/l6c00000.html, Accessed 19 October 2013.

[15] GAMS, "Welcome to the GAMS home page!", http://www.gams.com/, Accessed 26 August 2013.

APPENDIX

JAPANESE INDUSTRIAL SECTORS USED IN THIS STUDY

1	Crop cultivation
2	Livestock
3	Agricultural services
4	Forestry
5	Fisheries
6	Metallic ores
7	Non-metallic ores
8	Coal mining, crude petroleum, and natural gas
9	Foods
10	Beverages
11	Feeds and organic fertilizer not elsewhere classified
12	Tobacco
13	Textile products
14	Wearing apparel and other textile products
15	Timber and wooden products
16	Furniture and fixtures
17	Pulp and paper
18	Paper products
19	Publishing and printing
20	Chemical fertilizer
21	Basic industrial inorganic chemicals
22	Basic and intermediate chemical products
23	Synthetic resins
24	Synthetic fibers
25	Final chemical products not elsewhere classified
26	Petroleum refinery products
27	Coal products
28	Plastic products
29	Rubber products
30	Leather, fur, skins, and miscellaneous leather products
31	Glass and glass products
32	Cement and cement products
33	Pottery, china, and earthenware
34	Other ceramic, stone, and clay products
35	Pig iron and crude steel
36	Steel products
37	Steel castings and forgings and other steel products
38	Non-ferrous metals
39	Non-ferrous metal products
40	Metal products for construction and architecture
41	Other metal products
42	General industrial machinery

43	Special industrial machinery
44	Other general machines
45	Machinery for office and service industry
46	Electrical appliance
47	Motor vehicles and repair of motor vehicles
48	Ships and repair of ships
49	Other transportation equipment and repair of transportation equipment
50	Precision instruments
51	Miscellaneous manufacturing products
52	Building construction
53	Repair of construction
54	Civil
55	Electricity
56	Gas and heat supply
57	Water supply
58	Waste management service
59	Commerce
60	Finance and insurance
61	Real estate agencies and rental services
62	House rent
63	Railway
64	Road transport (except transport by private cars)
65	Self-transport by private cars
66	Water transport
67	Air transport
68	Storage facility service
69	Services relating to transport
70	Communication
71	Broadcasting
72	Public administration and activities not elsewhere classified
73	Education
74	Research
75	Medical service, health, and social security
76	Other public services
77	Business services and office supplies
78	Personal services

Ubaidillah Zuhdi was born in Gresik, East Java, Indonesia, on 28 October 1984. He graduated from SMUN 5 Surabaya in 2003 and then entered the Department of Industrial Engineering of Institut Teknologi Bandung (ITB) in Bandung, Indonesia. He finished his bachelor's degree in 2008 and continued to his degree in Master of Science in Management, at the School of Business and Management (SBM)-ITB in 2009. In 2010, he began a double master's degree program organized by SBM-ITB and the Department of Industrial Administration of Tokyo University of Science (TUS), Noda, Japan. He received a scholarship from Japan Student Services Organization when he joined that program. He received his master's degree from SBM-ITB and TUS in 2012. His research interests include macroeconomics, microeconomics, ICT, creative industry, and input-output analysis.

On 2008, he joined a provider of data communication, Internet and value-added services in Jakarta, Indonesia, as a Junior Officer. He left this position in 2009 to continue his studies. He is currently pursuing his PhD at the Department of Industrial Administration of TUS.

Mr. Zuhdi is currently a member of the Entrepreneurship and Technology Management group at SBM-ITB and a Teaching Assistant at TUS. He is also a member of the International Input-Output Association. He received the Mahaka Media Award for Outstanding Scholar 2011 from SBM-ITB on 2011.

Shunsuke Mori was born in 1953. He received a Doctor of Engineering degree from Tokyo University in 1981. He became a Research Assistant in the Industrial Administration Department, Tokyo University of Science in 1981. He became Associate Professor in 1989 and a Professor in 1994. His research field is systems engineering, assessment of global warming, and model development for environmental technologies.

From 1981–1983, he was an Invited Researcher at the Economic Planning Agency. From 1986–1987, he was a Science Researcher at the International Institute for Applied Systems Analysis (Austria). From 1987–1993, he was an Invited Researcher at the National Institute for Science and Technology Policy. From 2002–2007, he was the Chief Researcher at the Research Institute of Innovative Technology for the Earth. He is currently Dean of the Graduate School of Science and Technology, Tokyo University of Science.

Prof. Mori has participated in Intergovernmental Panel on Climate Change (IPCC) activities in the following capacities: Lead Author (modeling team), Special Report of Emission Scenarios, Cambridge Press, 2000; Lead Author, Third Assessment Report of IPCC, WG-III, Chapter 9, Cambridge Press, 2001; Expert Reviewer, Fourth Assessment Report of IPCC, WG-III, 2006 and also Fifth Assessment Report of IPCC, WG-III, 2006. He is also a senior member of the Japan Institute of Energy.

Kazuhisa Kamegai received his PhD in Physics from the Graduate School of Science, The University of Tokyo, in 2004. He was a Postdoctoral Fellow at the Institute of Astronomy, The University of Tokyo. He worked as an Aerospace Project Research Associate at the Institute of Space and Astronautical Science (ISAS), Japan Aerospace Exploration Agency (JAXA). Currently, he is an Assistant Professor in the Department of Industrial Administration, Faculty of Science and Technology at Tokyo University of Science.