Forecasting the Influences of Information and Communication Technology on the Structural Changes of Japanese Industrial Sectors: A Study Using Statistical Analysis

Ubaidillah Zuhdi, Shunsuke Mori, Kazuhisa Kamegai

Abstract—The purpose of this study is to forecast the influences of information and communication technology (ICT) on the structural changes of Japanese economies. In this study, input-output (IO) and statistical approaches are used as analysis instruments. More specifically, this study employs Leontief IO coefficients and constrained multivariate regression (CMR) model in order to achieve the purpose. The periods of initial and forecast in this study are 2005 and 2015, respectively. In this study, ICT is represented by ICT capital stocks. This study conducts two levels of analysis, namely macro and micro. The results of macro level analysis show that the dynamics of Japanese economies on the forecast period, relative to the initial period, are not so high. We focus on (1) commerce, (2) business services and office supplies, and (3) personal services sectors when conducting the analysis of the micro level. Further, we analyze its specific IO coefficients when doing this analysis. The results of the analysis explain that ICT gives a strong influence on the changes of these coefficients from initial to forecast periods.

Keywords—Forecast, ICT, Structural changes, Japanese economies.

I. INTRODUCTION

PEOPLE use technology every day. They use this tool in doing their daily activities. For example, the transportation technologies (e.g., car, bus, train, and airplane) are used when someone moves from one place to other places where the distance between these locations are far. Another example is people use the stationeries (e.g., pen and pencil) when they do the writing activities. Such examples explain that technology is an inseparable thing in the daily life.

One of the frequently used technologies is information and communication technology (ICT). This technology is used by people on the several activities. For example, people employ the computer or laptop in doing their jobs. They use this tool for almost all jobs. The computer is also used in the macroscopic level activities, such as the processes of population census and presidential election. These descriptions describe that ICT is an important tool, both in micro and macro level activities.

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Many previous studies discussed ICT, including the topic of the relationship between ICT and the economic aspects of the specific nation(s). For example, [1] conducted the analysis in order to know the influences of ICT, which was represented by ICT capital stocks, on the structural changes of Japanese economies from 1985-2005. Reference [2] analyzed the influences of gross domestic product (GDP) and ICT, which were represented by GDP per capita and telephone lines per 100 people, on the structural changes of Indonesian industries from 1990-2005. These studies employed input-output (IO) and statistical analyses as analysis tools. On the other hand, [3] assessed the role of ICTs in enhancing the information regarding agriculture which are needed in fostering agribusiness and agricultural production in Tanzania.

The study conducts the forecasting process in order to know the impacts of ICT on the economic conditions of the particular nation(s), from the previous studies, however, is still limited. This process is important because it can predict these influences so the proper actions can be done in preparing what will be happened in the future. This study is conducted in order to fulfill this gap.

The purpose of this study is to forecast the influences of ICT on the structural changes of the economy conditions of a particular country. In this study, we focus on Japanese economies. We employ IO and statistical approaches in order to achieve the purpose. This study conducts two levels of analysis in order to get the comprehensive understanding regarding the influences, namely macro and micro.

II. METHODOLOGY

The methodology of this study is described as follows. The first step is to describe Japanese industrial sectors used in this study. We use these industries as the representation of Japanese economies. The details of the sectors are explained in Appendix. The second step is to determine the data represent ICT. For this study, these data are ICT capital stocks, namely computers (main parts and accessories) and telecommunications equipment. The data are obtained from [4].

The third step is to determine the structures of Japanese industrial sectors on the basis year. We use 2005 in this matter. This year is also used as a source of the analysis. The structures are represented by IO coefficients. We use Japanese IO table for 2005 as a source to calculate these coefficients. Reference

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[5] argued that the following equation is a formula to calculate the coefficients:

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

where a_{ij}, z_{ij}, and X_j are the input required by sector j from sector i to make one unit of product, the inter-industry sales by sector i to sector j, and the total outlay of the sector j, respectively. The fourth step is to forecast the structures of Japanese industrial sectors on 2015. We then use Constrained Multivariate Regression (CMR) model, the model which was proposed by [6], in conducting the forecast process. This model is a representation of the statistical analysis which is used in this study. The details of the model are described as follows.

T represents the year(s) of the analysis. The data represent the structures of Japanese industrial sectors, the matrices of IO coefficients, are defined by $a(t)$ where $t = 1 \dots T$. Further, in the calculation, the vectors of IO coefficients are used. In other words, this model is applied to each industrial sector of Japan through its IO coefficients. The explanatory variables used can be described as $x(k,t)$ where $k = 1 \dots k$. The following mathematical model, the representation of the CMR model, is employed as an elaboration of $a(t)$:

$$a(i,t) = b0(i) + \sum_k b(i,k) \times x(k,t) + e(i,t) \qquad (2)$$
$$a(i,t) \geq 0, \qquad \sum_i a(i,t) = 1.0$$

where $b0(i)$ and $b(i,k)$ explain the regression coefficients of the model. Because the coefficients are non-negative and these summations should be unity by the definition, the constraints among estimators are imposed. $e(i,t)$ explains the difference of original and estimated values. By using least square method, min. $\sum_i \sum_t e(i,t)^2$, we can obtain the parameters.

We determine the forecast explanatory variables before employing the CMR model. These variables are acquired by applying the linear regression method into the ICT capital stocks which were mentioned in the previous explanations. We conduct the forecasting process for the original explanatory variables in order to get the forecast influences of ICT on Japanese economies. We use the combination of original explanatory variables when using the model. In this study, the aim of using the model is to obtain the estimators for each IO coefficient. Afterward we calculate the IO coefficients of Japanese industrial sectors for the forecast period. Estimators and forecast explanatory variables are used in this calculation. By applying the formula of estimators multiplied by explanatory variables for each Japanese industrial sector, we can obtain the coefficients.

The fifth step is to determine the Leontief inverse matrix for each analysis period. Reference [5] explained that this matrix is also called total requirements matrix. In other words, this matrix is used in order to know the needs total of each Japanese industrial sector in producing and financing its product(s). They also described that the following equation describes the matrix:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{Lf} \qquad (3)$$

where $\mathbf{x}$, $\mathbf{I}$, $\mathbf{A}$, and $\mathbf{f}$ are the matrices of total outputs, $n \times n$ identity, IO coefficients, and final demands, respectively. The matrix of Leontief inverse is explained by $(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{L}$. From (3) we can say that the Leontief IO coefficients have an important role in the calculation of this matrix.

The sixth step is to conduct the macro level analysis. The purpose of this analysis is to know the overall condition of Japanese economies on the forecast period after receiving the influences of ICT. Leontief inverse matrix is used as a main tool in the analysis. More specifically, the ratios of Leontief inverse values of forecast and initial periods are applied in the analysis. These ratios are utilized in order to know the dynamics of Japanese economies on the forecast period, after receiving the influences of ICT, relative to the ones on the initial period. In addition, the values used are represented by the summations of the column amounts of Leontief inverse for all Japanese industrial sectors, or $\mathbf{L}_j$.

The seventh step is to conduct the micro level analysis. This discussion aims to know the condition of particular Japanese industrial sectors on the discussed periods. More specifically, the discussion on the level would like to analyze the influences of ICT on the changes of the economic conditions of these sectors from initial to forecast periods. We use the results of the previous study as the sources of the analysis. In other words, in this study, we also focus on (1) commerce, (2) business services and office supplies, and (3) personal services sectors. Further, we use some IO coefficients of these sectors in the analysis. These coefficients are used in order to analyze the economic conditions of discussed sectors. The conclusions of this study, and the further researches which are suggested from this study are described in the final step.

III. RESULTS AND DISCUSSIONS

A. Macro Level Analysis

Fig. 1 shows the ratios of Leontief inverse values of forecast and initial periods for all Japanese industries. From this Figure we can argue that the overall condition of Japanese economies on the forecast period, after receiving the influences of ICT, is similar with the one on the initial period. This phenomenon is strengthened by the fact that almost all industries are covered in the value between 0.9 and 1.1, which means the dynamics of Japanese economies on the forecast period, relative to the initial period, are not so high. In other words, from the macroscopic view, we can say that the influences of ICT on the structural changes of Japanese economies from initial to forecast periods are not so strong.

The decreasing pattern can be seen on the sector of research, the sector number 74. This pattern indicates that the needs total of this sector in financing its product(s) on the forecast period is less than the one on the initial period. We argue that this phenomenon appears because the Japanese research activities on the forecast period reduce comparing with the ones on the initial period. Further, this reduction shows that Japanese government would like to focus on the other aspects (e.g.,

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service and education) on the forecast period. The same pattern also appears on the sector number 4, the sector of forestry.
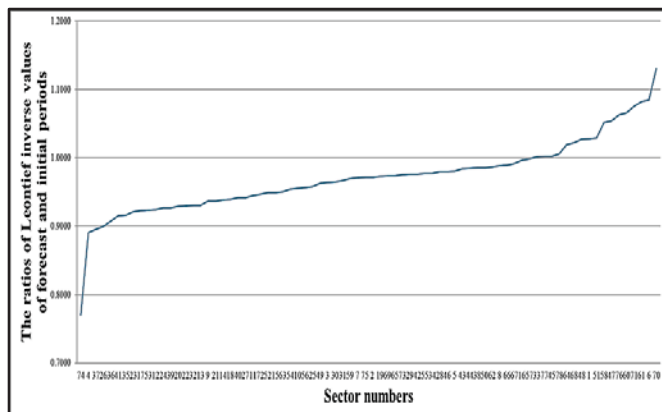

Fig. 1 The ratios of Leontief inverse values of forecast and initial periods, all Japanese industrial sectors

The opposite pattern can be seen on the communication sector, the sector number 70. This pattern indicates that the needs total of this sector in financing its product(s) on the forecast period is greater than the one on the initial period. This fact emphasizes our previous argument, namely Japanese government would like to focus on the other aspects rather than the research activities on the forecast period.

B. Micro Level Analysis

Fig. 2 describes the changes in $a_{70,59}$, the IO coefficient that describes the input from communication to commerce sectors, for 1985-2005. The numbers in this figure and the other ones represent 1985, 1990, 1995, 2000, and 2005, respectively. Table I explains the coefficients of the variation of the original and estimated values of this coefficient, and the correlation between these values on the same period. These results were used by [6] in order to explain the influence of ICT on the coefficient. They employed the same data of ICT capital stocks in representing ICT. They argued that, during 1985-2005, from the results, ICT had a strong influence on the coefficient.
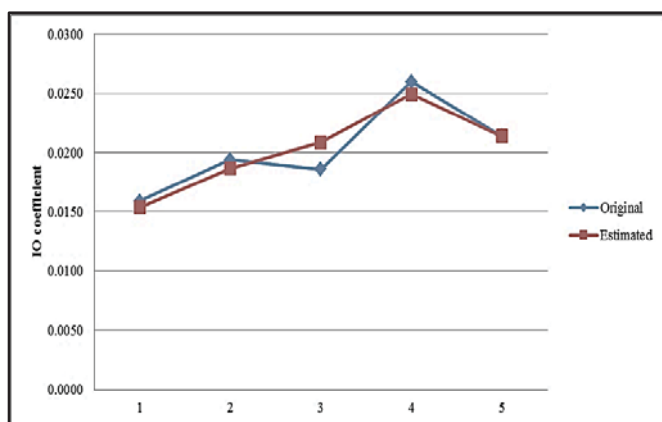

Fig. 2 The changes in $a_{70,59}$ from 1985-2005 (Source: [6] with the slight modifications)

TABLE I
THE COEFFICIENTS OF THE VARIATION OF THE ORIGINAL AND ESTIMATED VALUES OF $A_{70,59}$, AND THE CORRELATION (R) OF BOTH VALUES (1985-2005)

The coefficients of the variation		Correlation
Original	Estimated	
0.186	0.174	0.936

(Source: [6] with the slight modifications)

Fig. 3, on the other hand, describes the changes in $a_{70,59}$ for 1985-2015. The final number in this figure and the other ones represents the forecast period, 2015. We can say that, from the results in this figure, ICT gives a strong influence on the change of the coefficient from initial to forecast periods. We argue that this phenomenon happens because the role of ICT devices in the business activities between both sectors is becoming more important on the period. More specifically, these devices are important for both sectors because it can strengthen their communication when they make the business agreements between them. The same influence can also be seen on the $a_{72,59}$ and $a_{74,59}$. These coefficients describe the input from public administration and activities not elsewhere classified to commerce sectors, and from research to commerce sectors, respectively. The changes of the coefficients from 1985-2015 are explained in Figs. 4 and 5, respectively.
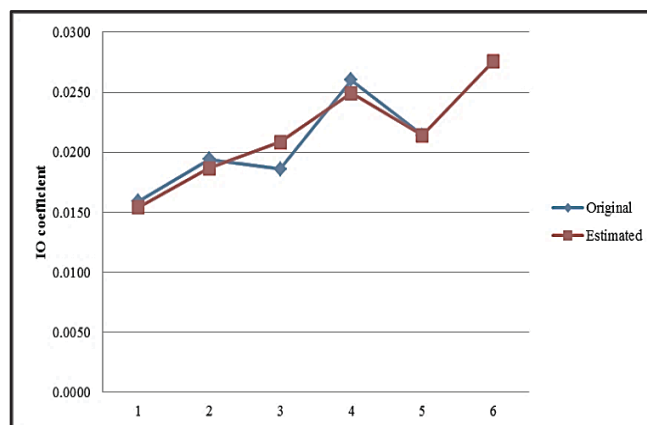

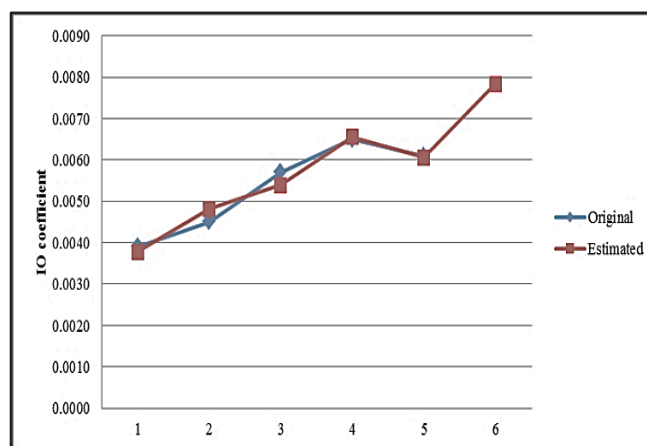Fig. 3 The changes in $a_{70,59}$ from 1985-2015

Fig. 4 The changes in $a_{72,59}$ from 1985-2015

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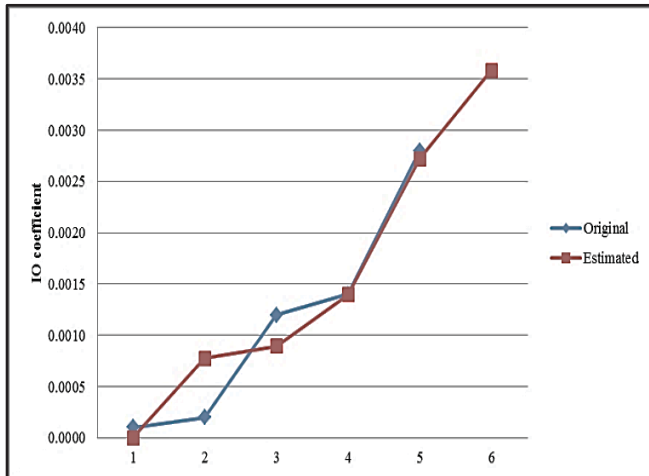International Journal of Information and Communication Engineering
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Fig. 5 The changes in $a_{74,59}$ from 1985-2015

Fig. 6 describes the changes in $a_{60,77}$, the IO coefficient that describes the input from finance and insurance to business services and office supplies sectors, for 1985-2005. Table II explains the coefficients of the variation of the original and estimated values of this coefficient, and the correlation between these values on the same period. These results were used by [6] in order to explain the influence of ICT on the coefficient. They employed the same data of ICT capital stocks in representing ICT. They argued that, during 1985-2005, from the results, ICT had a strong influence on the coefficient.
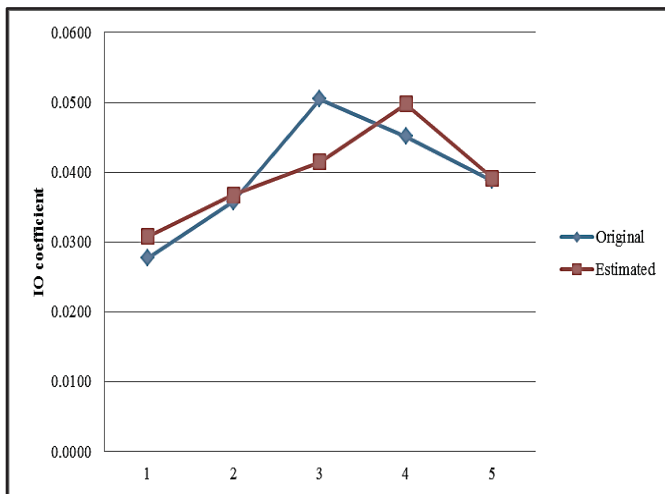

Fig. 6 The changes in $a_{60,77}$ from 1985-2005 (Source: [6] with the slight modifications)

TABLE II
THE COEFFICIENTS OF THE VARIATION OF THE ORIGINAL AND ESTIMATED
VALUES OF $A_{60,77}$, AND THE CORRELATION (R) OF BOTH VALUES (1985-2005)

The coefficients of the variation		Correlation
Original	Estimated	
0.221	0.175	0.793

(Source: [6] with the slight modifications)

Fig. 7, on the other hand, describes the changes in $a_{60,77}$ for 1985-2015. We can say that, from the results in this figure, ICT

gives a strong influence on the change of the coefficient from initial to forecast periods. We argue that this phenomenon happens because the role of ICT devices in the business activities between both sectors is becoming more crucial on the period. More specifically, these devices are important for both sectors because it can accelerate data transfer and communication when they make the business deals between them.
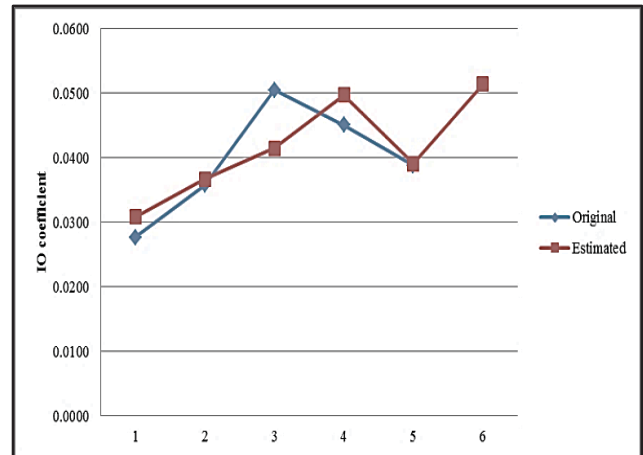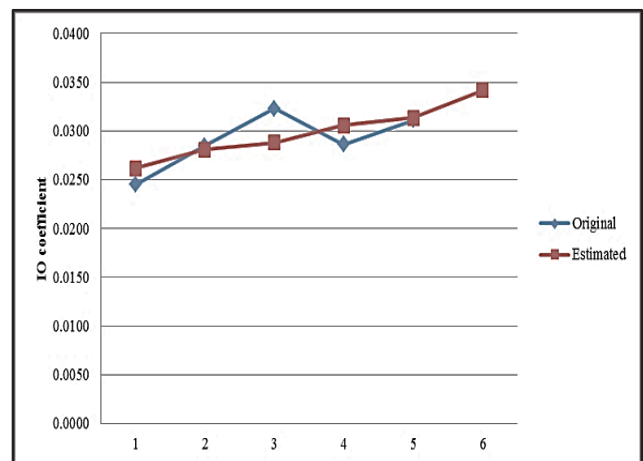

Fig. 7 The changes in $a_{60,77}$ from 1985-2015

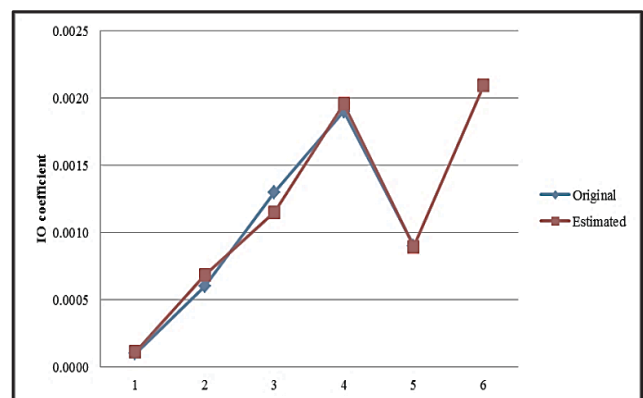Fig. 8 The changes in $a_{59,77}$ from 1985-2015

Fig. 9 The changes in $a_{74,77}$ from 1985-2015

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The same influence can also be seen on the $a_{59,77}$ and $a_{74,77}$. These coefficients describe the input from commerce to business services and office supplies sectors and from research to business services and office supplies sectors, respectively. The changes of the coefficients from 1985-2015 are explained in Figs. 8 and 9, respectively.

Fig. 10 explains the changes in $a_{59,78}$, the IO coefficient that describes the input from commerce to personal services sectors, for 1985-2005. Table III describes the coefficients of the variation of the original and estimated values of this coefficient, and the correlation between these values on the same period. These results were used by [6] in order to explain the influence of ICT on the coefficient. They employed the same data of ICT capital stocks in representing ICT. They argued that, during 1985-2005, from the results, ICT had a strong influence on the coefficient.

Fig. 11, on the other hand, describes the changes in $a_{59,78}$ for 1985-2015. We can say that, from the results in this figure, ICT gives a strong influence on the change of the coefficient from initial to forecast periods. We argue that this phenomenon happens because the role of ICT devices in the business activities between both sectors is becoming more vital on the period. More specifically, these devices are important for both sectors because it can accelerate the information transfer when they make the business transactions between them.

The same influence can also be seen on the $a_{70,78}$ and $a_{71,78}$. These coefficients describe the input from communication to personal services sectors, and from broadcasting to personal services sectors, respectively. The changes of the coefficients from 1985-2015 are explained in Figs. 12 and 13, respectively.

Fig. 11 The changes in $a_{59,78}$ from 1985-2015

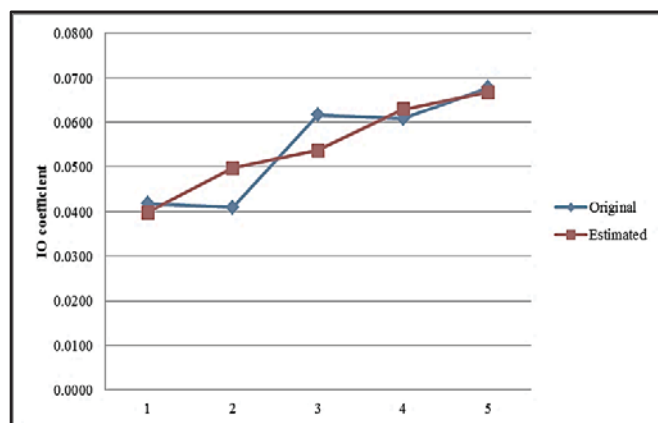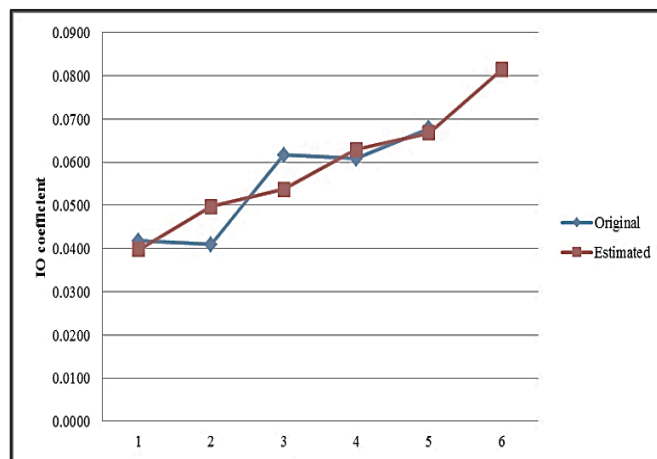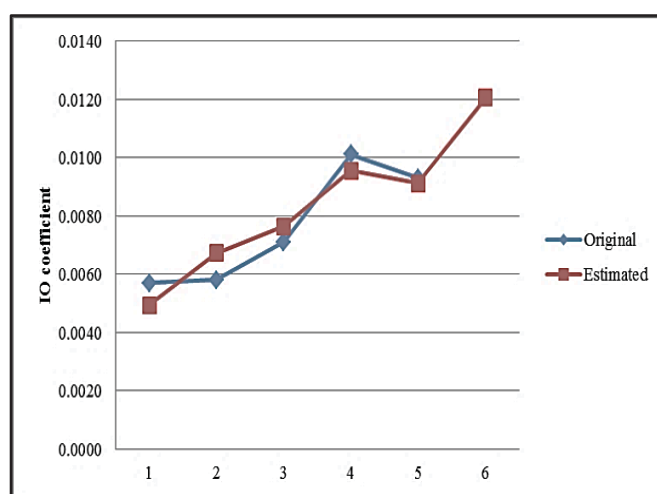

Fig. 12 The changes in $a_{70,78}$ from 1985-2015

Fig. 10 The changes in $a_{59,78}$ from 1985-2005 (Source: [6] with the slight modifications)

TABLE III
THE COEFFICIENTS OF THE VARIATION OF THE ORIGINAL AND ESTIMATED VALUES OF $A_{59,78}$, AND THE CORRELATION (R) OF BOTH VALUES (1985-2005)

The coefficients of the variation		Correlation
Original	Estimated	
0.227	0.197	0.868

(Source: [6] with the slight modifications)
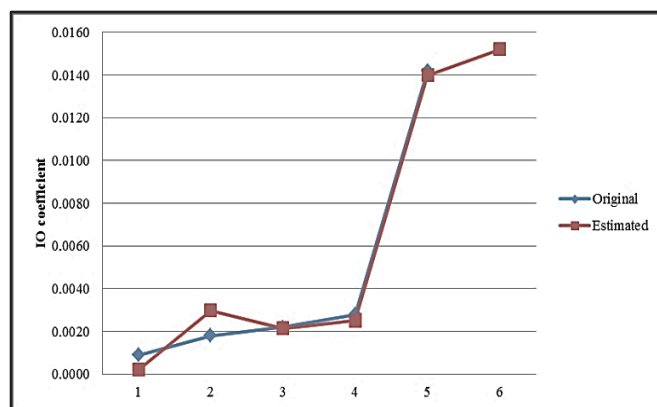

Fig. 13 The changes in $a_{71,78}$ from 1985-2015

IV. CONCLUSIONS AND FURTHER RESEARCHES

This study, as a continuation of previous studies, forecasted the influences of ICT on the structural changes of Japanese economies. In this study, IO and statistical approaches were used as analysis instruments. More specifically, this study employed Leontief IO coefficients and CMR model in order to

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achieve the purpose. The periods of initial and forecast in this study were 2005 and 2015, respectively. In this study, ICT was represented by ICT capital stocks. This study conducted two levels of analysis, namely macro and micro.

The results of macro level analysis showed that the dynamics of Japanese economies on the forecast period, relative to the initial period, were not so high. In other words, from the view of macroscopic, we could argue that the influences of ICT on the structural changes of Japanese industrial sectors from initial to forecast periods were not so strong. The unique phenomena could be seen on several sectors, namely the sectors of research and communication.

We focused on (1) commerce, (2) business services and office supplies, and (3) personal services sectors when conducting the analysis of the micro level. Further, we analyzed its specific IO coefficients when doing this analysis. The results of the analysis explained that ICT gave a strong influence on the changes of these coefficients from initial to forecast periods.

The forecasting processes, both in macro and micro levels, in order to investigate the influences of ICT on the structural changes of Japanese economies on the forecast period was done in this study. This study, however, only analyzed the smart parts of the IO coefficients changes of discussed sectors in the micro level analysis. In other words, the overall view regarding the changes of these industries not appeared in this study. This view is needed in order to get a thorough understanding regarding the influences on the structural changes of the sectors. This study suggests the overall analysis in order to get the view as a further research.

The other suggested further research is to conduct the international comparison on this topic. This comparison will describe the uniqueness of ICT influences on the structural changes of each analyzed country from initial to forecast periods. The interesting example is the comparison between developed and developing countries. Besides, this study also suggests the analysis of Japanese ICT policies which is based on the results of the current study for the future study. This analysis is needed in order to make the proper policy recommendations for a better Japanese economy.

APPENDIX

TABLE IV
JAPANESE INDUSTRIAL SECTORS USED IN THIS STUDY

No.	Sector name
1	crop cultivation
2	livestock
3	agricultural services
4	forestry
5	fisheries
6	metallic ores
7	nonmetallic 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

No.	Sector name
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	nonferrous metals
39	nonferrous 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

(Source: [1] with the slight modifications)

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