The influences of the information and communication technology on the structural changes of Japanese energy sectors from 1985 through 2005: a statistical analysis

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Abstract: The purpose of this study is to analyse the influences of information and communication technology (ICT) on the structural changes of Japanese energy sectors from 1985–2005. In this study, ICT is represented by two explanatory variables, namely: 1) computers, main parts and accessories; 2) telecommunications equipment. We employ a statistical tool in investigating the influences quantitatively, namely constrained multivariate regression (CMR) model. Likelihood ratio test (LRT) method is applied in order to test the statistical significance of estimators in the fitted model. In this study, we focus on: 1) coal mining, crude petroleum, and natural gas; 2) petroleum refinery products; 3) coal products sectors. We then conduct the deeper analysis, the microscopic analysis, for each analysed sector. The results show that the explanatory variables gave the significant influences on the structural changes of analysed sectors during the period of the analysis. Besides, the results also describe that, in microscopic investigation, ICT instruments had a strong influence on the relationship between analysed and other sectors during 1985–2005.

Keywords: information and communication technology; ICT; structural changes; energy sectors; constrained multivariate regression; CMR; Likelihood ratio test; LRT; Japan.

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1 Introduction

Komala and Prasad (2014) argued that the key component determines the economic development of all sectors in any region is energy. Wu et al. (2014) described that the material basis of the development of the national economy is energy. In the more specific discussion, Ng et al. (2014) explained that the essential source of the renewable energy for the future in many countries is a solar energy. These arguments emphasise that, today, energy is an important aspect in the society.

Another important aspect in the human life is technology. One of the frequently used technologies is information and communication technology (ICT). The evidence is, we frequently see people using phones, fixed line and mobile, when they communicate with others. The similar pattern can be observed in the use of the internet and computer. Almost all aspects of the modern society depend on these tools. In other words, internet and computer have become powerful instruments for both micro and macro level activities.

There are many previous studies connected energy and industry in one discussion. For example, Lu et al. (2013) investigated the current efficiency and situation of the new energy vehicle in the market of China. Sireli and Ozan (2013) examined the possibility of the electric utilities' transfer of US from closed to open systems, while taking actions towards the orientation of the new market. Besides, Zuhdi and Mori (2012) analysed the structural changes of Indonesian energy sectors from 1990to 2005 using structural decomposition analysis (SDA), one of the analysis tools in input-output (IO) analysis. They also conducted the international comparison between Indonesia and Japan in order to know the uniqueness on the pattern of the gross output change and decomposition factors value of the energy sectors of these analysed countries.

On the other hand, Zuhdi (2014) discussed the efforts to increase the total output of Japanese energy sectors in the future using IO analysis. More specifically, he employed a demand-pull IO quantity model as an analysis instrument. The study investigates the relationship between ICT and the energy sectors of the specific country, however, is still limited. This study is conducted in order to bridge the gap.

The study which the topic is close with the investigation was done by Stallo et al. (2010). They reviewed the possible applications of ICTs to the sector of the renewable energy. Authors argue that ICT affects the energy sectors because it can improve the efficiency of these sectors when they conduct their business activities. Further, this enhancement will increase the performance of the sectors. Based on this explanation, the further investigation regarding the relationship is important because it can open the opportunity to improve the performance of the sectors through ICT.

The purpose of this study is to analyse the influences of ICT on the structural changes of the energy sectors of the specific country. In this study, we focus on Japan. The period of the analysis of this study is from 1985–2005. We use the statistical analysis in order to achieve the objective. This paper is organised as follows. Section 2 describes in more details the previous works which the topic is related to the energy issues. The methodology of this study is explained on the Section 3. The calculation results and analysis of these outputs are elaborated on the Section 4. The final section explains the conclusions of this study and suggestions for the further research.

2 Literature review

This section explains in more details the previous works which the main topic is energy. For instance, Andersson et al. (2014) addressed the uncertainty which is related to the future cash flows in the projects of the hydropower upgrade, and determined the optimal investment time and capacity choice by using the analysis of real options. Barty et al. (2014) conducted a sensitivity analysis of the problem of the electricity production when the integer parameters describing the outages scheduling were set. Fertig et al. (2014) investigated how the system of the pumped hydropower storage can operate in the market of Germany to maximise gains given the expectations of the increasing spot price volatility.

Gourtani et al. (2014) explained the stochastic programming framework of the multi-objective two-stage bilevel model for a dominant electricity producer to decide an optimal trading strategy in the market of the deregulated electricity spot in a medium-term time horizon. Granado et al. (2014) evaluated the energy storage value for domestic houses in the existence of the renewable micro generation such as solar collectors and small wind turbines. Scharff et al. (2014) presented an overview of the decision-making process of the power generating enterprise on the market of Nordic electricity, and described how the uncertainties impacted this process.

Schröder (2014) explained a model of the electricity dispatch with the expansion of the endogenous electricity generation capacity for Germany from 2010–2035. The target of this previous study was to quantify how the fuel and carbon price risk affect the investment incentives of the plants of the thermal power. Zéphyr et al. (2014) investigated the adaptive version of progressive hedging algorithm (PHA), as an option for the classical version. They explained that, in principle, the classical algorithm can be ameliorated in the terms of:

1 the rate of the convergence
2 the iterations number.

Babrowski et al. (2014) analysed the advantages and disadvantages of optimising energy system models using the approaches of the myopic instead of perfect foresight approaches. Bourne et al. (2013) developed the model of the techno-economic that provides the initial evaluation of the wind energy potential of a site bypassing the complex numerical weather prediction models. Their study focused on the city of Adelaide, Australia. Besides, Gürbüz et al. (2013) predicted the net energy consumption (NEC) of Turkey using the approaches of classical and neural networks based on a meta-heuristic algorithm which is known as the artificial bee colony (ABC) algorithm.

On the other hand, one of the purposes of the study which was conducted by Cremer et al. (2003) is, qualitatively and quantitatively, to analyse the direct and indirect impacts of ICT appliances, services, and systems on the consumption of energy in Germany. They employed a bottom-up approach as a tool of the analysis. Khayyat et al. (2014) examined the changes of the productivity in Japan and South Korea during 1973–2006 and 1980–2009, respectively, in order to measure how investment in ICT affects the demand of energy. They employed and extended the model of the dynamic factor demand in their work. From above explanations we can argue that the contribution of ICT on the energy sectors has not been discussed widely in the existing literatures although the rapid progress and influences of this technology on the economy and society can be seen clearly.

3 Methodology

As mentioned in the Section 1, the purpose of this study is to investigate the influences of ICT on Japanese energy sector’s structural changes from 1985–2005. We employ a statistical tool in conducting the empirical analysis. In this study, ICT is represented by ICT stocks. Japanese IO tables for 1985, 1990, 1995, 2000, and 2005 are used as data of this study. The tables for 1985 and 1990 are obtained from the Management and Coordination Agency Government of Japan (1989, 1994), respectively. On the other hand, the others tables are gotten from the website of Japanese Ministry of Internal Affairs and Communications (n.d.b).

The methodology of this study refers to the previous study which was conducted by Zuhdi et al. (2013). This methodology is described as follows. First, we do the aggregation process for above IO tables to get the same industrial sectors number. The number of Japanese industrial sectors for above years was 84, 91, 93, 104, and 108, respectively. These sectors are reclassified into the 78 industries. A detailed description of these sectors is given in Appendix 1. Japanese energy sectors used in this study are explained in Table 1.

Table 1 Japanese energy sectors used in this study

No.	*Sector name*	*Sector number*
1	Coal mining, crude petroleum, and natural gas	8
2	Petroleum refinery products	26
3	Coal products	27

The next step is to do the calculation in order to get the IO coefficient matrices for each year in the analysis period. Miller and Blair (2009) explained that this coefficient is obtained by applying the following equation:

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

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

Third, we calculate the influences of the explanatory variables which describe ICT stocks, computers (main parts and accessories) and telecommunications equipment, on the structural changes of Japanese industrial sectors. These changes are represented by the dynamic changes in the IO coefficient vectors of these sectors which are extracted from the IO tables. We use the model which was developed by Zuhdi et al. (2013), constrained multivariate regression (CMR) model, in conducting the calculation. The data of the variables are obtained from the website of Japanese Ministry of Internal Affairs and Communications (n.d.a). As with the main data, the data of the variables for 1985, 1990, 1995, 2000, and 2005 are used in this study.

The details description of the model is described as follows. In the beginning, the years of the analysis are defined as T. In this study, we define 1985, 1990, 1995, 2000, and 2005 as T. Thus, we can define the data represents Japanese industrial structure changes, IO coefficient matrices, as $a(t)$ t = 1…T. Further, in the calculation, the vectors of IO coefficient are used. In other words, in this study, the model is applied to each industrial sector of Japan through its IO coefficient. The explanatory variables used can be described as $x(k, t)$ $k = 1\ldots k$. The following mathematical model, the representation of the CMR model, is employed as an elaboration of $a(t)$:

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

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

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

Fourth, we test the statistical significance of estimators in the fitted model using the likelihood ratio test (LRT) method. This method is based on the calculation formula of $-2N(ln\ S - ln\ S_0)$, where N and S are the numbers of data, and the results of the performance function optimisation, respectively. N is given by $K \times M \times T$ where K, M, and T are the number of sectors which give the input for the discussed sector(s), the number of the discussed sector(s), and the numbers of periods, respectively. The degree of freedom is given by $(K - 1) \times M \times$ [the number(s) of the removed explanatory variable(s)]. The statistical significance of the explanatory variable is given by the formula which follows the $\chi 2$ distribution. In this study, we take 0.05 as the level of significance. Therefore, we use the 0.05 level of the $\chi 2$ distribution in conducting the test.

In this study, we use the combination of explanatory variables when applying the method. Thus, the value of the degree of freedom used in this study is $78 \times 1 \times 2 = 156$.

The cut-off score for the statistical significance in this study is $\chi 2_{0.05}$ (156) = 185.86. We use this score to investigate the statistical significance of explanatory variables on the Japanese industrial sectors. The combination of these variables is called to significantly influence a specific sector if its significance score is greater than the cut-off score. In this study, three null hypotheses are used to emphasise the results of the test, namely:

- *Hypothesis 1:* computers and telecommunications equipment jointly had no influence on the structural change of the Japanese coal mining, crude petroleum, and natural gas sector from 1985–2005.
- *Hypothesis 2:* computers and telecommunications equipment jointly had no influence on the structural change of the Japanese petroleum refinery products sector from 1985–2005.
- *Hypothesis 3:* computers and telecommunications equipment jointly had no influence on the structural change of the Japanese coal products sector from 1985–2005.

Previous calculation steps can be simplified as follows. In the beginning, we describe the original data of the five points period 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 the source of influences for the data. We use the CMR model which was developed by Zuhdi et al. (2013) in order to calculate the influences of these variables on Japanese industrial structural changes in the analysis period. We then describe the influenced original IO coefficient matrices as estimated IO coefficient matrices, $A\_est(t, i, j)$. In this study, the general algebraic modelling system (GAMS) software, the software for analysing the high level modelling system for optimisation and mathematical programming (GAMS, n.d.), is used in order to conduct the calculation[1]. The test using LRT method is done in the next step. The purpose of this test is to know the statistical significance of estimators in the fitted model. In this study, we use the combination of explanatory variables when implementing this method. Three null hypotheses are employed to emphasise the results of the test.

Fifth, we conduct the deeper analysis, the microscopic analysis, for the analysed sectors. We calculate the standard deviation of the original IO coefficients of these sectors as a first step of this analysis. The computation for the estimated IO coefficients is ignored because the results of this computation generally follow the previous one. The purpose of the calculation is to know the magnitude of the changes of original IO coefficients on the period of the analysis. For each discussed sector, we choose the top ten coefficients viewed from the standard deviation value. The standard deviation values of these coefficients are simultaneously higher than the internal average values. The coefficients represent the inputs which have the dynamic change. From the coefficients we choose the one which have an increasing pattern on the original data as a target for the analysis. The coefficients of the variation, and the amount of the correlation (R) are used to gain the deeper insights regarding the influences of the variables on the focused sectors. After finishing the analysis section, we describe the conclusions of this study, and further researches which are suggested from this study.

4 Results and analysis

4.1 LRT calculation results

Table 2 describes the summary of the LRT calculation for this study. From the information in this table, we can argue that the combination of explanatory variables used in this study had the significant influences on the structural changes of all Japanese energy sectors on the period of the analysis. Therefore, we reject all null hypotheses.

Table 2 The summary of the LRT calculation

No.	*Sector name*	*The statistical significance ($\chi 2$) of the combination of explanatory variables*	*The influence of explanatory variables*
1	Coal mining, crude petroleum, and natural gas	943.20	Significant
2	Petroleum refinery products	519.86	Significant
3	Coal products	1581.89	Significant

From Table 2 we can also see that the sector which gets the highest influence from the combination is the coal products. On the other hand, the lowest influence value is owned by the petroleum refinery products sector. The discussions about the influences of explanatory variables used in this study on the analysed sectors in micro level can be seen on the following sub-section.

4.2 Microscopic analysis

4.2.1 The sector of coal mining, crude petroleum, and natural gas

Table 3 describes the top ten original IO coefficients of the coal mining, crude petroleum, and natural gas sector viewed from the value of the standard deviation during 1985–2005. From the information in this table, we can argue that the most dynamic input is the input from the business services and office supplies sector, sector number 77. We choose $a_{60,08}$, the IO coefficient describes the input from finance and insurance to coal mining, crude petroleum, and natural gas sectors, as a source of the analysis because this coefficient had an increasing pattern in the analysis period.

Figure 1 explains the changes of $a_{60,08}$ from 1985–2005. Numbers in this figure, also in other figures, represent the analysis years, namely 1985, 1990, 1995, 2000, and 2005, respectively. Table 4 shows the coefficients of the variation of the original and estimated values of the coefficient, and the correlation of these values on the analysis period. From these results we can observe that our model well follow the historical changes. In other words, we can argue that, during 1985–2005, the combination of explanatory variables used in this study had a strong influence in $a_{60,08}$.

Table 3 Top ten original IO coefficients of the coal mining, crude petroleum, and natural gas sector viewed from the standard deviation value (1985–2005)

No.	*IO coefficient*	*Standard deviation*	*Mean*
1	$a_{77,08}$	0.0255	0.0614
2	$a_{55,08}$	0.0080	0.0730
3	$a_{60,08}$	0.0076	0.0492
4	$a_{44,08}$	0.0076	0.0040
5	$a_{74,08}$	0.0070	0.0137
6	$a_{36,08}$	0.0056	0.0100
7	$a_{72,08}$	0.0054	0.0211
8	$a_{70,08}$	0.0047	0.0162
9	$a_{08,08}$	0.0044	0.0025
10	$a_{41,08}$	0.0040	0.0258

Figure 1 Changes in $a_{60,08}$ from 1985–2005 (see online version for colours)

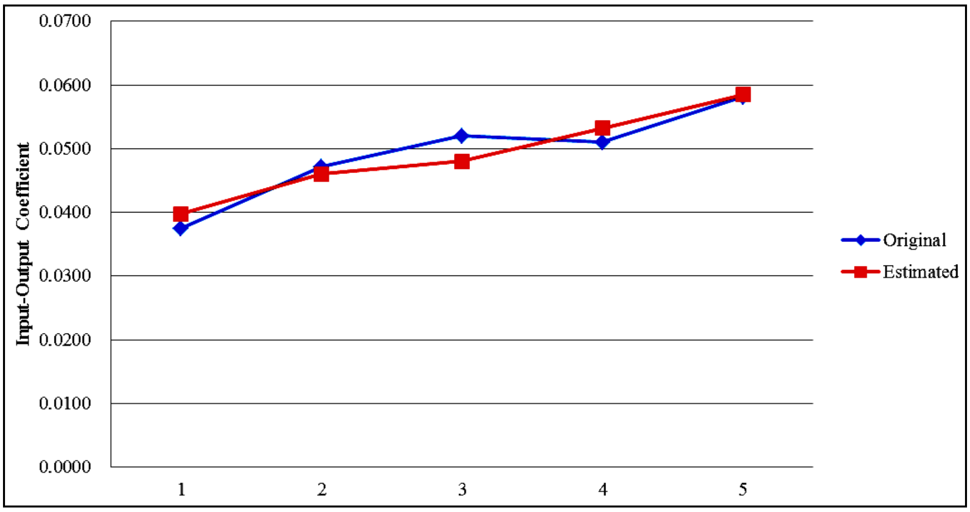

Table 4 The coefficient of the variation of the original and estimated values of $a_{60,08}$, and the correlation (R) of both values (1985–2005)

The coefficients of the variation		*Correlation*
Original	*Estimated*	
0.155	0.145	0.939

The phenomenon in $a_{60,08}$ indicates that, during 1985–2005, ICT devices have strengthened the relationship between coal mining, crude petroleum, and natural gas, and finance and insurance sectors. The role of these devices in this relationship can be described as follows. In this period, a flare-up condition was happened in the world economic circumstances. This turbulent was happened especially because of the end of Cold and Gulf wars. The increasing of the price of the crude oil before the end of these wars was the evidence of the condition. The contribution of the finance and insurance sector to the coal mining, crude petroleum, and natural gas sector reaffirms that the management of the primary energy supply in the global market during the analysis period was complicated. ICT devices could support this management because it could increase the security when the business transactions which involved energy were happened in this period.

Besides, the quality and quantity of ICT tools significantly move forward over time. For instance, internet has been expanded and penetrated very rapidly in 1990's as the price of personal computers went down rapidly. Clearly, the technological innovations as well as the software development have influenced the business structures. The consequence of these enhancements is the increasing of the intensity of the cooperation between above sectors. In other words, during the analysis period, the relationship between the industries became stronger because of the growth of ICT instruments.

4.2.2 The sector of petroleum refinery products

Table 5 shows the top ten original IO coefficients of the petroleum refinery products sector viewed from the value of the standard deviation during 1985–2005. From the information in this table, the most dynamic input is the input from the coal mining, crude petroleum, and natural gas sector, sector number 8. We choose $a_{68,26}$, the IO coefficient describes the input from storage facility service to petroleum refinery products sectors, as a source of the analysis because this coefficient had an increasing pattern in the analysis period.

Table 5 Top ten original IO coefficients of the petroleum refinery products sector viewed from the standard deviation value (1985–2005)

No.	*IO coefficient*	*Standard deviation*	*Mean*
1	$a_{08,26}$	0.1079	0.4996
2	$a_{26,26}$	0.0140	0.0344
3	$a_{59,26}$	0.0067	0.0130
4	$a_{60,26}$	0.0059	0.0144
5	$a_{68,26}$	0.0047	0.0081
6	$a_{66,26}$	0.0042	0.0089
7	$a_{77,26}$	0.0033	0.0064
8	$a_{44,26}$	0.0021	0.0009
9	$a_{46,26}$	0.0018	0.0008
10	$a_{74,26}$	0.0015	0.0031

Figure 2 explains the changes of $a_{68,26}$ from 1985–2005. Table 6 shows the coefficient of the variation of the original and estimated values of this coefficient, and the correlation of these values on the period of the analysis. From these results we can observe that our model well follow the historical changes. In other words, we can argue that, during 1985–2005, the combination of explanatory variables used in this study had a strong influence in $a_{68,26}$.

The phenomenon in $a_{68,26}$ indicates that, during 1985–2005, ICT tools have strengthened the relationship between petroleum refinery products and storage facility service sectors. The role of these tools in this relationship is described as follows. During the analysis period, the petroleum refinery products sector needed places and assistances for keeping its outputs. In other words, the management of the energy security was an important aspect in this period. Rapid price and political events changes in this period reaffirmed this need. The storage facility service sector, as an outsider, could provide the services. ICT tools could bridge the relationship because these devices could monitor the commodities all day. Consequently, the safety of the products could be guaranteed. Besides, using the tools, the condition of products could be easily checked.

Figure 2 Changes in $a_{68,26}$ from 1985–2005 (see online version for colours)

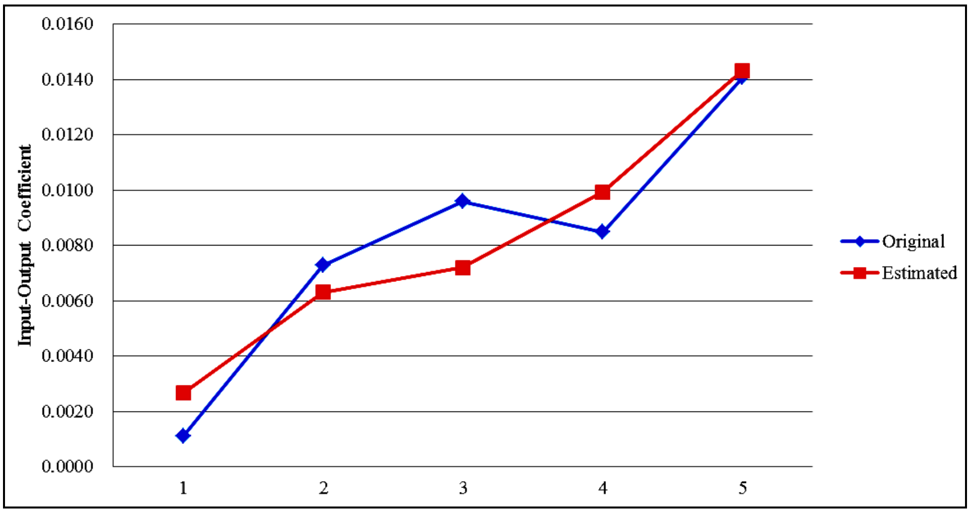

Table 6 The coefficients of the variation of the original and estimated values of $a_{68,26}$, and the correlation (R) of both values (1985–2005)

The coefficients of the variation		Correlation
Original	*Estimated*	
0.578	0.539	0.934

Quality and quantity of ICT devices will be better over time. The consequence of this improvement is the increasing of the level of the cooperation between above industries. In other words, the relationship between the sectors during the analysis period became deeper because of the growth of the devices.

4.2.3 The sector of coal products

Table 7 shows the top ten original IO coefficients of the coal products sector viewed from the value of the standard deviation during 1985–2005. From the information in this table, the most dynamic input is the input from the coal mining, crude petroleum, and natural gas sector, sector number 8. We choose $a_{59,27}$, the IO coefficient describes the input from commerce to coal products sectors, as a source of the analysis because this coefficient had an increasing pattern in the analysis period.

Table 7 Top ten original IO coefficients of the coal products sector viewed from the standard deviation value (1985–2005)

No.	*IO coefficient*	*Standard deviation*	*Mean*
1	$a_{08,27}$	0.0870	0.3623
2	$a_{27,27}$	0.0212	0.0676
3	$a_{51,27}$	0.0164	0.0083
4	$a_{26,27}$	0.0142	0.0837
5	$a_{64,27}$	0.0126	0.0288
6	$a_{77,27}$	0.0117	0.0225
7	$a_{59,27}$	0.0113	0.0491
8	$a_{66,27}$	0.0097	0.0327
9	$a_{68,27}$	0.0065	0.0075
10	$a_{44,27}$	0.0047	0.0021

Figure 3 Changes in $a_{59,27}$ from 1985–2005 (see online version for colours)

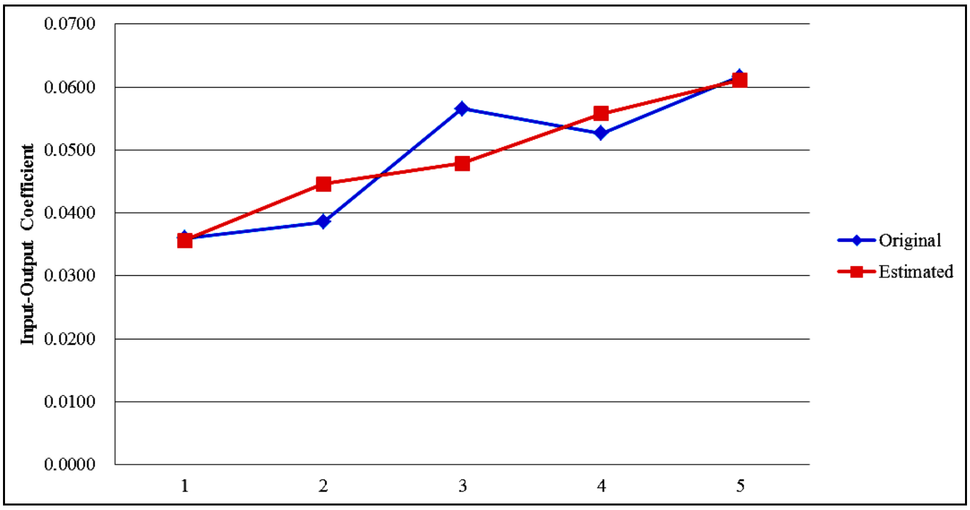

Table 8 The coefficients of the variation of the original and estimated values of $a_{59,27}$, and the correlation (R) of both values (1985–2005)

The coefficients of the variation		*Correlation*
Original	*Estimated*	
0.230	0.202	0.871

Figure 3 explains the changes of $a_{59,27}$ from 1985–2005. Table 8 shows the coefficients of the variation of the original and estimated values of this coefficient, and the correlation of these values on the period of the analysis. From these results we can observe that our model well follow the historical changes. In other words, we can argue that, during 1985–2005, the combination of explanatory variables used in this study had a strong influence in $a_{59,27}$.

The phenomenon in $a_{59,27}$ indicates that, during 1985–2005, ICT devices have strengthened the relationship between coal products and commerce sectors. The role of these devices in this relationship is described as follows. During the analysis period, the coal products sector needed the media or field in order to market its outcomes. The commerce sector, as an outsider, could provide this media. ICT devices could support this relationship because these tools could make the process of the information exchange between the sectors better.

Quality and quantity of ICT tools significantly move forward in the future period. The consequence of this enhancement is the increasing of the level of business activities between above sectors. In other words, during the analysis period, the relationship between the industries became more robust because of the improvement of ICT instruments.

5 Conclusions and further research

This study analysed the influences of ICT on the changes of the structure of Japanese energy sectors from 1985–2005. In this study, ICT was represented by ICT capital stocks. More specifically, ICT capital stocks were deputised by:

1 computers, main parts and accessories

2 telecommunications equipment.

These stocks were the representation of explanatory variables used in this study. Japanese energy sectors used in this study were:

1 coal mining, crude petroleum, and natural gas

2 petroleum refinery products

3 coal products.

The CMR model was employed as an analysis instrument. The LRT method was used in order to test the statistical significance of estimators in the fitted model.

In this study, we used the combination of the variables when conducting the calculations. This study also conducted the hypothesis testing in order to emphasise the results of the test. We then did the deeper analysis, the microscopic analysis, which focused on the analysed sectors. The values of standard deviation, variation coefficients, and correlation were used in order to get the deeper understanding regarding the influences of the variables on these sectors.

The results showed that the combination of the variables, on the analysis period, gave the significant influences on the structural changes of all Japanese energy sectors. The biggest influence was received by the coal products sector while the petroleum refinery products industry had the lowest influence value. Besides, the results also described that, in the microscopic analysis, ICT instruments have strengthened the relationship between analysed and other sectors from 1985–2005. In other words, during the analysis period, the business activities between these industries became more robust because of the improvement of these instruments.

This study could analyse the influences of ICT on the structural changes of Japanese energy sectors from 1985–2005. The area of this study, however, should be broadened.

For example, we can apply the methodology of this study to other sectors, such as manufacture and education sectors, so the influences of ICT can be observed widely. This broader analysis is a suggested further research from this study. Besides, the analysis of the influences of ICT on the structural changes of Japanese industrial sectors which the changes are represented by the dynamics in the capital formation coefficients will also be an interesting further investigation.

The other suggested further research from this study is to extend the period of the analysis in the analysed topic. The comparison between two different periods, for example 'before 2005' and 'after 2005', can be done after conducting this extension. The extension and this comparison will give a broader insight regarding the influences of ICT on the structural changes of Japanese energy sectors.

Finally, conducting the international comparison in this topic is also the suggestion for further research from this study. This comparison will reveal the characteristics of the industrial structural changes of compared countries. Besides, this discussion will also show the similarities and differences of the impacts of ICT on the industrial sectors of analysed countries.

References

Andersson, A.M., Elverhøi, M., Fleten, S-E., Fuss, S., Szolgayová, J. et al. (2014) 'Upgrading hydropower plants with storage: timing and capacity choice', *Energy Systems*, Vol. 5, No. 2, pp.233–252.

Babrowski, S., Heffels, T., Jochem, P. and Fichtner, W. (2014) 'Reducing computing time of energy system models by a myopic approach', *Energy Systems*, Vol. 5, No. 1, pp.65–83.

Barty, K., Bonnans, J.F. and Pfeiffer, L. (2014) 'Sensitivity analysis for the outages of nuclear power plants', *Energy Systems*, Vol. 5, No. 2, pp.371–406.

Bourne, M., Arjomandi, M. and Kurji, R. (2013) 'The economic assessment of micro wind turbines for South Australia', *Energy Systems*, Vol. 4, No. 4, pp.355–377.

Cremer, C., Schlomann, B. and Friedewald, M. (2003) 'The impact of information and communication technologies on electricity consumption in Germany', *Proceeding of the ECEEE 2003 Summer Study*.

Fertig, E., Heggedal, A.M., Doorman, G. and Apt, J. (2014) 'Optimal investment timing and capacity choice for pumped hydropower storage', *Energy Systems*, Vol. 5, No. 2, pp.285–306.

GAMS (n.d.) *Welcome to the GAMS Home Page!* [online] http://www.gams.com/ (accessed 19 May 2014).

Gourtani, A., Pozo, D., Vespucci, M.T. and Xu, H. (2014) 'Medium-term trading strategy of a dominant electricity producer', *Energy Systems*, Vol. 5, No. 2, pp.323–347.

Granado, P.C.D., Wallace, S.W. and Pang, Z. (2014) 'The value of electricity storage in domestic homes: a smart grid perspective', *Energy Systems*, Vol. 5, No. 2, pp.211–232.

Gürbüz, F., Öztürk, C. and Pardalos, P. (2013) 'Prediction of electricity energy consumption of Turkey via artificial bee colony: a case study', *Energy Systems*, Vol. 4, No. 3, pp.289–300.

Japanese Ministry of Internal Affairs and Communications (n.d.a) *2009 White Paper of Information and Communication: Reference* [online] http://www.soumu.go.jp/johotsusintokei/whitepaper/ja/h21/data/html/l6c00000.html (accessed 9 November 2013).

Japanese Ministry of Internal Affairs and Communications (n.d.b) *Input-Output Tables for Japan* [online] http://www.stat.go.jp/english/data/io/ (accessed 26 May 2014).

Khayyat, N.T., Lee, J. and Lee, J-D. (2014) *How ICT Investment Influences Energy Demand in South Korea and Japan* [online] https://mpra.ub.uni-muenchen.de/55454/1/MPRA_paper_55454.pdf (accessed 20 August 2015).

Komala, H.P. and Prasad, A.G.D. (2014) 'Utilization pattern of biomass energy and socioeconomic dimensions associated with Yelandur, Karnataka, India', *International Journal of Energy and Environmental Engineering*, Vol. 5, No. 95, pp.1–7.

Lu, M-J., Chen, S. and Lou, Y. (2013) 'New energy vehicle development in China', *Int. J. Environment and Sustainable Development*, Vol. 12, No. 1, pp.44–59.

Management and Coordination Agency Government of Japan (1989) *1985 Input-Output Tables: Data Report (2)*, National Statistics Agency, Tokyo.

Management and Coordination Agency Government of Japan (1994) *1990 Input-Output Tables: Data Report (2)*, National Statistics Agency, Tokyo.

Miller, R.E. and Blair, P.D. (2009) *Input–Output Analysis: Foundations and Extensions*, 2nd ed., Cambridge University Press, New York.

Ng, K.M., Adam, N.M., Inayatullah, O. and Kadir, M.Z.A. Ab. (2014) 'Assessment of solar radiation on diversely oriented surfaces and optimum tilts for solar absorbers in Malaysian tropical latitude', *International Journal of Energy and Environmental Engineering*, Vol. 5, No. 75, pp.1–13.

Scharff, R., Egerer, J. and Söder, L. (2014) 'A description of the operative decision-making process of a power generating company on the Nordic electricity market', *Energy Systems*, Vol. 5, No. 2, pp.349–369.

Schröder, A. (2014) 'An electricity market model with generation capacity expansion under uncertainty', *Energy Systems*, Vol. 5, No. 2, pp.253–267.

Sireli, A.Y. and Ozan, E. (2013) 'Exploring the possibility of change in the US utilities' market orientation towards more renewable energy', *Int. J. Environment and Sustainable Development*, Vol. 12, No. 1, pp.60–71.

Stallo, C., Sanctis, M.D., Ruggieri, M., Bisio, I. and Marchese, M. (2010) 'ICT applications in green and renewable energy sector', *Proceeding of the 2010 Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises*.

Wu, A-H., Cao, Y.Y. and Liu, B. (2014) 'Energy efficiency evaluation for regions in China: an application of DEA and Malmquist indices', *Energy Efficiency*, Vol. 7, No. 3, pp.429–439.

Zéphyr, L., Lang, P. and Lamond, B. F. (2014) 'Adaptive monitoring of the progressive hedging penalty for reservoir systems management', *Energy Systems*, Vol. 5, No. 2, pp.307–322.

Zuhdi, U. (2014) 'An input-output approach to analyze the ways to increase total output of energy sectors: the case of Japan', *IOP Conference Series: Earth and Environmental Science*, Vol. 19, No. 012015, pp.1–6.

Zuhdi, U. and Mori, S. (2012) 'Analyzing the gross output change of energy sector industry in Indonesia between 1990 and 2005 by decomposition analysis', *Proceeding of the 3rd IAEE Asian Conference*.

Zuhdi, U., Mori, S. and Kamegai, K. (2013) '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', *The Asian Journal of Technology Management*, Vol. 6, No. 2, pp.102–111.

Zuhdi, U., Mori, S. and Kamegai, K. (2014) 'Statistical analysis of influences of ICT on industrial structure changes from 1985 through 2005: the case of Japan', *Journal of Computers*, Vol. 9, No. 6, pp.1291–1299.

Notes

1 Find Appendix 2 for programming info.

Appendices

Appendix 1

Table A1 Japanese industrial sectors (78 sectors)

No.	*Sector name*
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	Beverage
11	Feeds and organic fertiliser, n.e.c.
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 fertiliser
21	Basic industrial inorganic chemicals
22	Basic and intermediate chemical products
23	Synthetic resins
24	Synthetic fibres
25	Final chemical products, n.e.c.
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

Note: n.e.c.: not elsewhere classified.

Source: Zuhdi et al. (2014), with the slight modifications

Table A1 Japanese industrial sectors (78 sectors) (continued)

No.	*Sector name*
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	Office and service industry machineries
46	Electrical appliance
47	Motor vehicles, and the repairement of motor vehicles
48	Ships, and the repairement of ships
49	Other transportation equipment, and the repairement of transportation equipment
50	Precision instruments
51	Miscellaneous manufacturing products
52	Building construction
53	Construction repairement
54	Civil
55	Electricity
56	Gas and heat supply
57	Water supply
58	Waste management services
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 services
69	Services related to the transport

Note: n.e.c.: not elsewhere classified.

Source: Zuhdi et al. (2014), with the slight modifications

Table A1 Japanese industrial sectors (78 sectors) (continued)

No.	*Sector name*
70	Communication
71	Broadcasting
72	Public administration and the activities not elsewhere classified
73	Education
74	Research
75	Medical services, health, and social security
76	Other public services
77	Business services and office supplies
78	Personal services

Note: n.e.c.: not elsewhere classified.

Source: Zuhdi et al. (2014), with the slight modifications

Appendix 2

GAMS programming (syntax)

```
* Multivariate Least Square Analysis for IO coefficients
* 2012 11 16 by S.Mori
* revised -- input data for tables

set T period /1*5/;

* row sectors -- intermediate input and value added
* column sectors -- intermediate input and final demand

set i row sectors       /1*79/;
set j0 column sectors    /1*78/;

set j(j0);

set k0 explanatory variables /1*3/;
set k(k0)       /1*3/;

* Input Data -- using IO_data from 1985 through 2005
```

Table IO_DATA(t,i,j0)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.1	0.0215	0.1078	0.0196	0.0076	0.0000	0.0000	0.0000	0.0000	0.1951	0.1024	0.3293	0.1146	0.0453	0.0028	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000
1.2	0.0066	0.0430	0.0375	0.0034	0.0000	0.0000	0.0000	0.0000	0.0985	0.0002	0.0033	0.0000	0.0244	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
1.3	0.0366	0.0524	0.0000	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.4	0.0006	0.0000	0.0000	0.3550	0.0000	0.0116	0.0001	0.0110	0.0007	0.0000	0.0000	0.0000	0.0001	0.0000	0.3416	0.0007	0.0081	0.0000	0.0000	0.0000
1.5	0.0000	0.0000	0.0000	0.0000	0.0573	0.0000	0.0000	0.0000	0.0810	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.6	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.7	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0038	0.0000	0.0000	0.0155
1.8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0103	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0026	0.0000	0.0000	0.0320
1.9	0.0000	0.0079	0.0000	0.0028	0.0517	0.0000	0.0000	0.0000	0.1780	0.0536	0.3084	0.0001	0.0000	0.0055	0.0005	0.0000	0.0028	0.0000	0.0000	0.0054
1.10	0.0000	0.0006	0.0000	0.0000	0.0038	0.0000	0.0000	0.0000	0.0066	0.0365	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.11	0.0045	0.3810	0.0330	0.0006	0.0117	0.0000	0.0000	0.0000	-0.0004	-0.0012	0.0197	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0079	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.13	0.0005	0.0001	0.0041	0.0078	0.0171	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0003	0.3119	0.3594	0.0003	0.0194	0.0009	0.0022	0.0015	0.0026
1.14	0.0032	0.0008	0.0064	0.0005	0.0061	0.0007	0.0018	0.0024	0.0009	0.0005	0.0004	0.0002	0.0014	0.0204	0.0011	0.0019	0.0006	0.0014	0.0014	0.0020

1.15 0.0000 0.0007 0.0000 0.0028 0.0016 0.0000 0.0013 0.0028 0.0010 0.0015 0.0000 0.0005 0.0004 0.0001 0.1155 0.1419 0.0617 0.0002 0.0001 0.0000
1.16 0.0000 0.0000 0.0071 0.0004 0.0005 0.0009 0.0005 0.0017 0.0003 0.0004 0.0002 0.0012 0.0006 0.0012 0.0003 0.0297 0.0004 0.0005 0.0007 0.0004
1.17 0.0003 0.0000 0.0001 0.0000 0.0000 0.0000 0.0000 0.0000 0.0004 0.0011 0.0000 0.0053 0.0006 0.0003 0.0084 0.0033 0.3463 0.3262 0.1642 0.0000
1.18 0.0129 0.0022 0.0910 0.0000 0.0000 0.0000 0.0000 0.0000 0.0098 0.0328 0.0056 0.0143 0.0074 0.0092 0.0001 0.0182 0.0055 0.0130 0.0043 0.0082
1.19 0.0000 0.0000 0.0086 0.0004 0.0007 0.0023 0.0021 0.0072 0.0024 0.0016 0.0008 0.0018 0.0020 0.0025 0.0010 0.0030 0.0262 0.0980 0.1256 0.0025
1.20 0.0378 0.0027 0.0087 0.0049 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0059 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.2115
1.21 0.0003 0.0000 0.0004 0.0002 0.0005 0.0007 0.0004 0.0000 0.0029 0.0024 0.0000 0.0001 0.0097 0.0000 0.0001 0.0003 0.0204 0.0021 0.0002 0.1065
1.22 0.0000 0.0000 0.0004 0.0000 0.0000 0.0190 0.0001 0.0000 0.0056 0.0090 0.0028 0.0006 0.0145 0.0001 0.0008 0.0008 0.0113 0.0009 0.0006 0.0238
1.23 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0007 0.0000 0.0000 0.0056 0.0005 0.0093 0.0007 0.0000
1.24 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0044 0.0780 0.0043 0.0000 0.0007 0.0009 0.0000 0.0000 0.0000
1.25 0.0361 0.0073 0.0185 0.0102 0.0056 0.0128 0.0065 0.0058 0.0020 0.0002 0.0054 0.0022 0.0126 0.0008 0.0270 0.0235 0.0077 0.0099 0.0288 0.0038
1.26 0.0100 0.0033 0.0236 0.0130 0.0835 0.0129 0.0198 0.0083 0.0056 0.0084 0.0002 0.0025 0.0151 0.0054 0.0017 0.0025 0.0586 0.0060 0.0008 0.0606
1.27 0.0000 0.0000 0.0000 0.0000 0.0000 0.0046 0.0000 -0.0004 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0052
1.28 0.0098 0.0011 0.0025 0.0009 0.0087 0.0014 0.0002 0.0018 0.0156 0.0166 0.0003 0.0015 0.0027 0.0114 0.0025 0.0199 0.0035 0.0241 0.0010 0.0093
1.29 0.0006 0.0006 0.0102 0.0009 0.0005 0.0001 0.0041 0.0036 0.0001 0.0001 0.0000 0.0000 0.0005 0.0014 0.0002 0.0013 0.0001 0.0005 0.0005 0.0007

1.30 0.0001 0.0000 0.0001 0.0003 0.0002 0.0000 0.0021 0.0002 0.0000
0.0000 0.0000 0.0000 0.0001 0.0023 0.0002 0.0004 0.0000 0.0000 0.0000
0.0000
1.31 0.0000 0.0000 0.0000 0.0017 0.0000 0.0000 0.0000 0.0000 0.0021
0.0329 0.0000 0.0000 0.0003 0.0000 0.0002 0.0167 0.0000 0.0000 0.0000
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1.32 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0005 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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1.35 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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0.0000 0.0000 0.0000 0.0000 0.0000 0.0040 0.0123 0.0000 0.0000 0.0000
0.0000
1.37 0.0000 0.0000 0.0000 0.0000 0.0000 0.0044 0.0001 0.0003 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0250 0.0000 0.0000 0.0000
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1.38 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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1.39 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0009
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1.40 0.0000 0.0000 0.0000 0.0000 0.0001 0.0000 0.0000 0.0051 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0006 0.0009 0.0000 0.0000 0.0000
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1.41 0.0013 0.0018 0.0003 0.0049 0.0009 0.0005 0.0139 0.0295 0.0068
0.0582 0.0084 0.0003 0.0004 0.0063 0.0102 0.0547 0.0009 0.0004 0.0003
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1.46 0.0000 0.0004 0.0000 0.0000 0.0011 0.0054 0.0045 0.0069 0.0000
0.0001 0.0000 0.0001 0.0013 0.0000 0.0002 0.0009 0.0000 0.0000 0.0014
0.0040
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0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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1.48 0.0000 0.0000 0.0000 0.0000 0.0257 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
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1.49 0.0000 0.0000 0.0001 0.0000 0.0000 0.0000 0.0001 0.0001 0.0000
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0.0067
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0.0241

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1.62 0.0000
1.63 0.0006 0.0005 0.0007 0.0018 0.0019 0.0075 0.0021 0.0078 0.0022 0.0013 0.0036 0.0011 0.0027 0.0007 0.0024 0.0014 0.0015 0.0023 0.0029 0.0034
1.64 0.0050 0.0463 0.0096 0.0495 0.0080 0.0049 0.0068 0.0071 0.0149 0.0096 0.0388 0.0029 0.0093 0.0067 0.0161 0.0135 0.0324 0.0154 0.0096 0.0183
1.65 0.0129 0.0070 0.0170 0.0190 0.0119 0.0555 0.3223 0.0321 0.0042 0.0026 0.0037 0.0010 0.0027 0.0014 0.0067 0.0033 0.0032 0.0032 0.0049 0.0016
1.66 0.0006 0.0024 0.0006 0.0004 0.0010 0.0006 0.0004 0.0015 0.0012 0.0006 0.0066 0.0002 0.0009 0.0004 0.0106 0.0012 0.0056 0.0014 0.0007 0.0051
1.67 0.0000 0.0000 0.0148 0.0006 0.0006 0.0012 0.0009 0.0011 0.0006 0.0004 0.0006 0.0001 0.0037 0.0011 0.0006 0.0006 0.0008 0.0015 0.0053 0.0006
1.68 0.0008 0.0086 0.0011 0.0002 0.0032 0.0002 0.0002 0.0004 0.0061 0.0018 0.0151 0.0012 0.0012 0.0014 0.0038 0.0014 0.0029 0.0023 0.0013 0.0013
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1.70 0.0000 0.0000 0.0017 0.0013 0.0030 0.0012 0.0027 0.0110 0.0013 0.0026 0.0009 0.0006 0.0022 0.0029 0.0019 0.0035 0.0014 0.0026 0.0051 0.0036
1.71 0.0000
1.72 0.0180 0.0070 0.0030 0.0028 0.0165 0.0061 0.0225 0.0302 0.0055 0.0050 0.0172 0.0275 0.0064 0.0061 0.0088 0.0238 0.0088 0.0098 0.0140 0.0259
1.73 0.0000 0.0000 0.0001 0.0000 0.0000 0.0025 0.0000 0.0000 0.0003 0.0001 0.0001 0.0000 0.0000 0.0003 0.0002 0.0002 0.0004 0.0000 0.0000 0.0002
1.74 0.0003 0.0011 0.0000 0.0000 0.0005 0.0054 0.0000 0.0019 0.0011 0.0028 0.0008 0.0004 0.0020 0.0009 0.0006 0.0034 0.0029 0.0005 0.0007 0.0172

```
1.75   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000
1.76   0.0000 0.0000 0.0000 0.0005 0.0019 0.0013 0.0032 0.0050 0.0013
0.0033 0.0025 0.0011 0.0034 0.0045 0.0010 0.0030 0.0027 0.0029 0.0018
0.0032
1.77   0.0005 0.0008 0.0097 0.0014 0.0081 0.0066 0.0129 0.0185 0.0223
0.0292 0.0115 0.0109 0.0078 0.0163 0.0079 0.0211 0.0055 0.0212 0.0533
0.0132
1.78   0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0017
0.0000
1.79   0.6978 0.2304 0.5068 0.4405 0.5972 0.6457 0.4501 0.5825 0.2289
0.5109 0.1085 0.7721 0.2888 0.3208 0.2940 0.4093 0.2312 0.3429 0.4866
0.2635
;
```

```
* explanatory variable data -- Computer (main parts & accessory) and
      Telecommunication equipment


Table Ex_Var(k0,t)
      1       2       3       4       5
1     2845    6752    7746    10732   15248
2     1788    3825    5304    7969    5159
3     1       1       1       1       1
;

* normalization


parameter IOCHK(t,j0);


IO_DATA(t,i,j0)$(IO_DATA(t,i,j0) le 0.0)=0.0;


IOCHK(t,j0)=sum(i, IO_DATA(t,i,j0));
IO_DATA(t,i,j0)=IO_DATA(t,i,j0)/IOCHK(t,j0);


parameter IO_DATC(t,i,j0);
IO_DATC(t,i,j0)=IO_DATA(t,i,j0);
```

```
IO_DATC(t,i,j0)$(IO_DATA(t,i,j0) le 1.0e-4)=1.0;

IO_DATC(t,i,j0)=1.0;

Parameters OBJ_LR(j0);

positive variables
  IO_DATR(t,i,j0)
;

variable
  RGR_EST(j0,i,k)
  IO_ERR(t,i,j0)
  OBJ
;

Equations
  IO_DATR_DEF(t,i,j0)
  IO_ERR_DEF(t,i,j0)
  IO_CNST_DEF(t,j0)
  OBJ_DEF
;


  IO_DATR_DEF(t,i,j)..
IO_DATR(t,i,j)=E= sum(k, RGR_EST(j,i,k)*Ex_Var(k,t));
* IO_ERR(t,i,j) relative error

IO_ERR_DEF(t,i,j)..
IO_ERR(t,i,j)=E=(IO_DATA(t,i,j)-IO_DATR(t,i,j))/IO_DATC(t,i,j);

IO_CNST_DEF(t,j).. sum(i, IO_DATR(t,i,j) )=E=1.0;
```

```
OBJ_DEF.. OBJ=E=sum(j, sum(i, sum(t, IO_ERR(t,i,j)*IO_ERR(t,i,j))));

Model MulVR /all/;

FILE FSAVE /Trial 6 (1x3).CSV/;
PUT FSAVE;
FSAVE.PC=5;

loop(j0,
  j(j0)=no;
);

loop(j0,
  j(j0)=yes;

  Solve MulVR minimizing OBJ using nlp;

  OBJ_LR(j)=OBJ.L;

  j(j0)=no;

);

loop(j0,
  j(j0)=yes;
);

Put "Estimators"/;
Loop(j,
  Put "",j.TL,"column sector"/;
  Put "","",""; loop(k, put k.tl); put /;
  Loop(i,
```

```
    Put "","",i.tl;
    Loop(k, Put RGR_EST.L(j,i,k):15:6);
    Put /;
  );
  Put "",OBJ_LR(j)/;
  Put //;
);

Put "Original IO coeff. data"/;
Loop(j,
  Put "",j.TL,"column sector"/;
  Put "","","";loop(t, put t.tl);put /;
  Loop(i,
    Put "","",i.tl;
    Loop(t, Put IO_DATA(t,i,j):15:6);
    Put /;
  );
  Put //;
);

Put "Estimated IO coeff. data"/;
Loop(j,
  Put "",j.TL,"column sector"/;
  Put "","","";loop(t, put t.tl);put /;
  Loop(i,
    Put "","",i.tl;
    Loop(t, Put IO_DATR.L(t,i,j):15:6);
    Put /;
  );
  Put //;
);
```

```
Put "Comparison -- Historical and Estimated"/;
Loop(j,
  Put "",j.TL,"column sector"/;
  Put "","","";loop(t, put t.tl); put /;
  Loop(i,
    Put "","",i.tl;
    Loop(t, Put IO_DATA(t,i,j):15:6); put /;

    Put "","","estimated";
    Loop(t, Put IO_DATR.L(t,i,j):15:6); put //;
  );
  Put /;
);
```