Productive Efficiency and Production-factor Redundancy on Each Industry of Regional Economies in Japan

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on Each Industry of Regional Economies in Japan*

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ABSTRACT : We consider the tasks on the Japanese economy in details. First, we estimate the production function of each industry with prefectural panel data. Then, we select "Data Envelopment Analysis (DEA)" model from the Returns-to-scale of each industry by this estimation results. Finally, we implement DEA to evaluate the productive efficiency by industry and prefecture in the economic center areas. The empirical results show that all economic activities with high added value have concentrated in Tokyo only; because of the estimated redundancy reaching around 8-9% of total input amount, it seems to be highly probable that we have to reform regional economies.

Keywords: DEA, Production Function, Returns-to-scale, Productive Efficiency, Production-factor redundancy.
JEL Classification Numbers: P47, R30.

1. Introduction

Today, Japan has recovered from the redundant problems on employment, equipment and debt, which Japan had faced since the burst of the bubble economy in early 1990's, and Japan is generally considered to have achieved internal reform and returned to an economic growth path (bottomed in January in 2002) if not with dynamism.

In order to confirm this current status of the Japanese economy, we review year-on -year growth rates of important economic variables as follows. First, the real GDP has made a positive growth since 2000, and its growth rate in 2006 has reached 2.2%. So has the nominal GDP since 2004, and its growth rate in 2004 has reached 1.3%. Next, the total unemployment rate in 2006 has improved to 4.1% over the worst of 5.4% in 2002. Finally, the mining and manufacturing capital utilization rate in 2006 has recovered to 101.2 over the

worst of 94.7 in 2001 and 2002 (objective average: 2002=100).

As clearly shown above, we can say that the Japanese economy has returned to a calm growth path nationwide. However, can we say the same about each region in Japan?

In order to address the concern above, we provide the following indexes on each region as shown in Table 1: the average value of year-on-year growth rate of nominal GRP since 2000, that of total unemployment ratio since 2000, and the prefectural transition ratio of the proportion of the nominal GRP to the nominal GDP in 1975-2004.

Table 1 Economic status of each region

No.	Regions	Average of year-on-year growth rate on nominal GRP 2000-2006(%)	Average of toatal unemployment rate 2000-2006(%)	Transition ratio of proportion of nominal GRP to GDP 1975-2004(%)	Proportion of nominal GRP to GDP 1975(%)	Proportion of nominal GRP to GDP 2006(%)
1	Hokkaido	-0.62	5.8	-7.93	4.20	3.87
2	Tohoku	-0.93	5.2	-8.99	6.76	6.49
3	Southern-Kanto	0.14	4.7	9.80	28.78	31.54
4	Northern-Kanto,Koshin	-0.44	4.0	9.58	6.80	7.46
5	Hokuriku	-0.45	3.7	-4.65	4.46	4.26
6	Tokai	0.41	3.7	6. 4	12 03	12.86
7	Kinki	-0.68	5.9	-10.77	17.70	15.79
8	Chugoku	-0.22	4.0	-12.85	6.55	5.71
9	Shikoku	-0.34	4.6	-12.49	3.04	2.66
10	Kyusyu	-0.05	5.5	-3.61	9.72	9.38
	Japan	-0.17	4.8	—	—	—

Sources: Japan National Ecomomic Accounting (Cabinet Office, Japan), Prefectural Economic Accounting (each prefecture), Labor Force Servey (Ministry of Internal affair and Communications, Government of Japan).

The first index shows that the economic growth of Minami-Kanto, Tokai and Kyushu surpasses the national total. Especially, the growth in Tokai is outstanding. However, those of Hokkaido, Tohoku, Kita-Kanto, Koshin, Hokuriku, and Kinki have fallen below the national total. Especially in Hok-kaido and Kinki, the economic recovery is very slow. Next, the second index shows that the employment environment of Minami-Kanto, Kita-Kanto, Koshin, Tokai, Tyugoku, and Shikoku is better than the national total. Especially, the condition in Hokuriku and Tokai is outstanding. Meanwhile, those of Hokkaido, Tohoku, Kinki, and Kyushu have fallen below the national total. Especially, the condition in Hokkaido and Kinki is so severe. Finally, the third index shows that Minami-Kanto, Kita-Kanto, Koshin, and Tokai have made an increase in each proportion to GDP, while the other regions have decreased.

As shown above, if we look at the economic status by region, we can perceive

the difference in economic situation among regions: especially, noticeable is the outstanding situation in Tokai and Minami-Kanto versus the poor situation in Hokkaido and Kinki. Moreover, Kanto (including Minami-Kanto, Kita-Kanto, and Koshin) and Tokai have increased their own importance to GDP in 20 years from 1975 to 2004, while all other regions have decreased. Above all, the poor economic situation and the degradation of Hokkaido and west Japan including Kinki[1], which had once an economic strength, are highlighted.

Therefore, we present the method to analyze the economic state not nationwide but by region in this study. Then, we implement the above method and suggest the improvement measures on each regional economy. Moreover, we intend to show the difficulties which each regional economy are facing. Here, let us account for our objectives in the analysis. In order to acquire more detailed and concrete results, we adopt not districts as in Table 1 but prefectures as our objectives.

We consider the above-mentioned problems through the analysis of the "production technique[2]" on each industry. In the basic theory of production in Economics, the production factors, which produce economic added values, are "labor" as human resource and "capital equipment" as material one. In the theory, it is assumed that each production factor produces the maximum economic added valued on an efficient production technique. However, is this assumption true in the real world? In order to answer this question and find concrete measures to improve each industrial activity in each prefecture, we use Econometrics and Data Envelopment Analysis (DEA): this method was developed by Mr. A. Charnes and W. W. Cooper to implement an efficiency analysis of exchanging process from inputs to outputs (see Charnes *et al.* (1978)).

Moreover, we implement this analysis on each industry (see Section 3 for the details of industries) based on major divisions of the Japan Standard Industry Classification (JSIC). The reason for this is the following: if we analyze the regional economy as a whole, we cannot appropriately evaluate the efficiency of the regional economy and, therefore, being not able to present concrete and meaningful measures to improve the economy in each region.

The rest of the paper is organized as follows. In Section 2, we explain the basic concept of DEA, its examples of utilization, and models. In Section 3, we explain 12 industries dealt herein and data on labor, capital equipment, GRP

and so on. In Section 4, we select the DEA model among the CCR model, the DRS model, and the IRS model (see Section 2), in order to implement DEA in Section 6. This model selection depends on the assumption on "Re-turns-to-scale (RTS)" between inputs and outputs of each industry we adopt among "Constant returns-to-scale (CRS)", "Decreasing returns-to-scale (DRS)", and "Increasing returns-to-scale (IRS)". This model selection is extremely important because it affects the result of DEA. However, it is not possible to determine which relationship is to be assumed statistically. Therefore, many preceding researches by DEA had been concurrently conducted under each assumption (see e. g., Miyara and Fukushige (2002a, b); Nozao (2007)). But in this case, it will be difficult and unclear to interpret the results of DEA. Therefore, in order to remove this nuisance, we estimate the production function on each industry with panel data, and, from the results, determine the state of RTS, namely the DEA model by industry. DEA is an analytical method implemented through comparing performances between different decision making units (DMUs). Therefore, it is considered that the comparison between DMUs, which have extremely different characteristics, may not produce meaningful results. Taking into account of this fact, we divide 47 prefectures as DEA objects into four clusters having similar regional characteristics. In Section 5, we explain the clustering adopted herein. In Section 6, we implement DEA by industry and cluster, explain the results of DEA, and discuss the difficulties that each prefectural economy has. In Section 7, we summarize the empirical results and show the direction for the policy design based on our study and the future work.

1. Explanation of DEA model

1.1. Basic concept and utilization examples of DEA

At the beginning, we explain the basic concept of DEA as follows.

If there are several DMUs having similar inputs and outputs, first, we compare the efficiency among DMUs by the ratio scale of each DMU. The ratio scale is defined "weighted sum of outputs / weighted sum of inputs[3]", under the assumption that the activities of the DMUs, which yield larger output with less input, are more efficient. Second, we link the activities of the most efficient

DMUs to introduce the "efficient frontier". Based on the efficient frontier, the performances of other DMUs are evaluated. This is the basic principle of DEA. Therefore, parametric analyses are based on an average image of objectives, while DEA is a non-parametric analysis based on better DMUs. Then, DEA brings out two analysis results on DMUs using the efficient frontier. One is the efficiency[4] (we call it D-efficiency value) on the activity of each DMU, and the other is the improvement measures for the activity of each DMU.

Next, we explain the merits and demerits of DEA, as shown in Okuda and Take (2006) and Viton(1996). We begin with the former. DEA can assess activities of several outputs in the output phase as well as in the input phase. DEA does not demand researchers to specify the function form between inputs and outputs in advance, not like other parametric analyses. Therefore, the arbitrariness in this point can be avoided. Also, DEA has no statistical process, so researchers can do their analysis without many samples. We continue to explain the latter. DEA does not predict observational errors of samples, so, if inappropriate samples are mixed in, the analysis results can be largely distorted. Additionally, there is also the risk of selecting input and output variables that are inappropriate theoretically and statistically, because it does not assume the relationship between input and output variables theoretically or test them statistically[5].

Finally, we explain the preceding analyses by DEA. Despite of the imperfection of DEA as described above, it has been used to evaluate various DMUs, which ranging from private enterprises to public institutions, due to the following analytical characteristic: DEA can deterministically evaluate the efficiency of each DMU and show improvement measures for the DMU. Then, we can quote the following analyses as examples of DEA. Ferrier and Lovell (1990) implement DEA on 575 financial institutes of America in 1984; Viton (1996): on 217 bus services (both private and public) in 1990; Chalos and Cherian (1995) : on 207 elementary school districts of Illinois in America between 1987 and 1989; Drake and Simper (2000): on the English and Welsh police forces between 1992 and 1996; Ueda (2006): on Japanese paper manufacturing companies between 1990 and 2004; Miyara and Fukushige (2002a): on 48 public bus services in Japan in 1999; Miyara and Fukushige (2002b): on police of 47 prefectures in Japan between 1975 and 1999; Terada(2003) : on 166 sewerage works of Japan in 1997; Nozao (2007): on 606 regional public

hospitals of Japan in 2001. In addition, XU (2005) implement DEA to measure TFP (total factor productivity), technical changes, and efficiency changes of manufacture between 1993 and 2002 in 25 prefectures in China.

2.2. DEA model used in this study

2.2.1. CCR model (input-oriented model)

The CCR model[6] is a basic model of DEA assuming CRS on RTS. If we are concerned about DMU "O", we can denote this model as the following two-phase linear programming problem.

$$\text{First objective function} \quad \min \quad \theta \tag{1}$$

$$\text{second objective function} \quad \min \quad -\mathbf{es}_x - \mathbf{es}_y \tag{2}$$

$$s.t. \quad \theta \mathbf{x}_o = \mathbf{X}\lambda + \mathbf{s}_x, \tag{3}$$

$$\mathbf{y}_o = \mathbf{Y}\lambda - \mathbf{s}_y, \tag{4}$$

$$\theta \geq 0, \tag{5}$$

$$\lambda \geq 0, \tag{6}$$

$$0 \leq \mathbf{e}\lambda \leq \infty, \tag{7}$$

$$\mathbf{s}_x \geq 0, \tag{8}$$

$$\mathbf{s}_y \geq 0, \tag{9}$$

where $\mathbf{e} = (1,\ldots,1)$: a vector of ones: the dimensions of $\mathbf{e}s$ are m (the number of inputs), s (the number of outputs) , and n (the number of DMUs) in order of appearance; $\mathbf{s}_x = (s_x^1,\cdots,s_x^m)^T$: an input "slack" vector of which every element shows the excess on every input; $\mathbf{s}_y = (s_y^1,\cdots,s_y^s)^T$: an output "slack" vector of which every element shows the shortfall on every output; $\theta \in [0,1]$ is a variable

showing the D-efficiency value of DMU O: lesser θ means lesser efficiency; $\mathbf{x}_o = (x_o^1, \cdots, x_o^m)^T$: the input vector of DMU O; and X is a $m \times n$ matrix composed of the input vectors of all DMUs; $\lambda = (\lambda_1, \cdots, \lambda_n)^T$: a non-negative vector for creating a non-negative linear combination of activities of the referred DMUs; $\mathbf{y}_o = (y_o^1, \cdots, y_o^s)^T$: the output vector of DMU O; Y is a $s \times n$ matrix composed of the output vectors of all DMUs.

The Solution of CCR model relating to DMU O is $(\theta^*, \lambda^*, s_x^*, s_y^*)$ obtained by solving the above-mentioned problem. If $\theta^* = 1$ and slack less ($s_x^* = 0, s_y^* = 0$), we say that such DMU is efficient; otherwise it is inefficient.

If DMU O is inefficient,

$$E_o = \{ j \mid \lambda_j > 0, j = 1, \ldots, n \} \tag{10}$$

is said to be the reference set for it.

In addition, as a result of solving the above-mentioned problem, an improvement measure for DMU O is finally as follows:

$$\mathbf{x}_o \Rightarrow \theta^* \mathbf{x}_o - \mathbf{s}_x^*, \tag{11}$$

$$\mathbf{y}_o \Rightarrow \mathbf{y}_o + \mathbf{s}_y^*. \tag{12}$$

2.2.2. Decreasing returns-to-scale model (DRS model) and increasing returns-to-scale model (IRS model) [7]

The CCR model is a model assuming CRS on RTS. However, it can be assumed that the activity environment of DMUs is not CRS depending on the production function of DMUs or the form of the production possibility set. Therefore, we introduce the DRS model assuming DRS and the IRS model assuming IRS, as options except for the CCR model.

First, we explain the DRS model. In this model, Equations (7) in CCR model is changed as the following:

$$0 \leq \mathbf{e\lambda} \leq 1, \tag{13}$$

where, $\mathbf{e} = (1, \ldots, 1)$: a n dimensional vector of ones. Since the upper bound in

this equation is 1, expansion of the activity of each DMU is not allowed in the production possibility set assumed in this model. However, reduction to scale is free.

Next, we explain the IRS model. In this model, Equations (7) in CCR model is changed as the following:

$$1 \leq \mathbf{e}\lambda \leq \infty , \tag{14}$$

where $\mathbf{e}$ is the same one as in Equation (13). Since the lower bound in this equation is 1, reduction of the activity of each DMU is not allowed. However, expansion to scale is free.

2.2.3. Measurement of change of efficiency in time-series —Window Analysis---[8]

The above-mentioned models deal with the efficiency analysis of DMUs at one point in time. However, if there is time-series data of each DMU, we can implement the Window Analysis. In this analysis, we regard each DMU at each point in time as an independent activity, and measure the efficiency-change in time-series to observe its time-scale change. The analytical method is explained as follows.

The number of DMUs is n, the number of periods is t, the length of window is p, the index of period is k. However, $p \leq t$. At this time, we implement DEA intended for each adjacent period p to obtain D-efficiency value by DMU and period. Then, generalized efficiency values are as follows:

$$\theta^o_{k,k}, \theta^o_{k,k+1}, \cdots, \theta^o_{k,k+p-1} \quad \text{for } o = 1,\ldots,n,\, k = 1,\ldots,t-p+1. \tag{15}$$

Moreover, we calculate the average D-efficiency value of adjacent period in Equation (15) as follows:

$$\overline{\theta^o_k} = \sum\nolimits_{l=k}^{k+p-1} \theta^o_{k,l} \Big/ p \quad \text{for } o = 1,\ldots,n,\, k = 1,\ldots,t-p+1. \tag{16}$$

Then, seeing $\overline{\theta^o_k}$ in Equation (16) as an index, we can observe the time-series change of efficiency of DMU O.

2.3. Productive efficiency dealt in this study

Taking account of unit cost of each production factor (each input) and cost for manufacturing, as Farell (1957), Viton (1996), and Drake and Simper (2000) show, we can disintegrate the productive efficiency as follows:

$$PE = AE \times TE = AE \times [SE \times PTE],$$

where PE, AE, TE, SE, and PTE mean productive efficiency, allocative efficiency, technical efficiency, scale efficiency, and pure technical efficiency, respectively.

Certainly, if DMUs concerned are enterprises, they cannot ignore AE to realize the minimization of their production cost[9]. However, we analyze the efficiency of the technique producing macro output (economic added value: see Section 3) from inputs (labor, capital equipment: see Section 3) in each industry (12 industries: see Section 3) in each prefecture. Therefore, we define TE in the above equation as the productive efficiency in this study. [10]

3. Industry divisions and data used for analysis

3.1. Industry divisions

The industry divisions in our analysis are as follows. We use "12 industries" based on the major divisions of JSIC (Ministry of Internal Affair and Communication, Government of Japan: ex-Management and Coordination Agency) as instructed in Table 2 (except for "Public service (Pub.): not classifiable to other category" and "Others: not-classifiable") in order to analyze real economy inclusively.

Table 2 12 industries

No.	Industries	No.	Industries
1	Agriculture (Agri.)	8	Transportation & Communication (TC)
2	Forestry (Fore.)	9	Commerce (Com.)
3	Fishery (Fish.)	10	Finance & Insurance (FI)
4	Mining (Min.)	11	Real Estate (Est.)
5	Construction (Const.)	12	Servises (Serv.)
6	Manufacturing (Manu.)		All Industries (All)
7	Electricity,Gas & Water (EGW)		

3.2. Data for analysis

For the analysis of productive efficiency by prefecture and industry, we assume that "the amount of labor (AL)" and "the amount of capital equipment (ACEQ)" of each prefecture and industry are inputs and "Gross Value Added (GVA)" is output.

However, data representing AL and ACEQ do not actually exist. Therefore, we make some data processing on the existing data, preparing "the number of employees (NE)" and "the amount of compensation of employee (ACEM)" as a proxy for AL and "the amount of depreciation of fixed capital (ADFC)" as a proxy for ACEQ. The reasons we use these proxies are as follows.

First is the explanation on NE and ACEM. We think that NE adequately denotes the real labor scale in the industries where not much capability difference exists among employees; meanwhile, we think that ACEM is more accurate than NE in the industries where the above-mentioned difference strongly exists. However, the actual selection between NE and ACEM is implemented in Section 4.

Next is the explanation on ADFC. As for data relating to ACEQ, we can list only the followings: private capital stock data by industry in "Annually Report of Private Enterprise Stock" (Cabinet Office, Government of Japan); 14 key social capitals (such as roads, ports and so on) by prefecture in "Social Capital in Japan" (in 1988, Economic Planning Agency, Government of Japan); data of administrative investment by work purpose (such as living infrastructure, industrial infrastructure) in "Government Investment" (Institute of Local Finance). But, we cannot find stock data of capital equipment by industry and prefecture from any material. Therefore, we have decided to use ADFC, which

is not ACEQ itself, because we considered that ADFC has a close relationship with ACEQ and shifts therewith.

Then, we show the sources of data for our analysis in Table 3. However, note that we use the data shown in Table 3 after doing necessary processing as footnote 11 shows[11].

<div align="center">Table 3 Sources of the variables</div>

Variables	Proxy Variables	Unit	Sources
AL	NE	1000 person	Employment Status Survey (in 1992,1997,and 2002, Bureau of Statistic, MIAC)
	ACEM (nominal)	1 million yen	
ACEQ	ADFC (nominal)	1 million yen	Iuput-Output Tables of Each Prefecture (in 1990,1995, and 2000, each prefecture)"
GVA (nominal)	—	1 million yen	

Note: MIAC denotes Ministry of Internal Affairs and Communication: ex-Management and Coordination Agency, Government of Japan.

4. Selection of DEA mode—Estimation of production function with panel data—

4.1. Estimation method for production function

The selection of DEA models depends on which relationship is assumed among CRS, DRS, and IRS on RTS between inputs and output. This selection is extremely important because it affects the results of DEA. However, we cannot determine which relationship is statistically adequate in DEA. Then, many preceding researches using DEA had been concurrently conducted under each assumption (see, e. g., Miyara and Fukushige (2002-a, b); Nozao (2007)). But, in this case, it will be unclear under which assumption efficiency and their improvement measures of DMUs are to be considered. Moreover, as pointed out in Okuda and Take (2006), the significance of input variables cannot be statistically tested, so there is the risk of selecting variables having a theoretical problem.

Therefore, in order to remove these problems above, in this section, we estimate the production function in each industry and determine the state of RTS to select the adequate model among CCR, DRS, and IRS, obeying the

following process.

[1] A regression model A is analyzed with panel analysis, using NE (or ACEM) and ADFC as independent variables that represent production factors and GVA as a dependent variable. However, if the significance of NE is rejected at 10% significant level, we shall adopt ACEM, which includes the difference of abilities among employees, as an alternative.

[2] A regression model B is analyzed with panel analysis, using ADFC divided by NE (or ACEM) as an independent variable and GVA divided by NE (or ACEM) as a dependent variable.

[3] Using residual sum of squares (RSS) obtained as the results of [1] and [2], homogeneity of degree one (namely, CRS) of each production function is tested with F statistics.

[4] If homogeneity of degree one is accepted in [3], we adopt CRS on RTS. Conversely, if it is rejected, we shall determine RTS using the sum of coefficient estimates on NE (or ACEM) and ADFC.

4.2. Regression model

Here is the explanation of the two regression models above. First, we start with the regression model A. We assume the following Cobb-Douglas production function as the production function for each industry,

$$Y_t^{ji} = A^j \left(L_t^{ji}\right)^{\alpha} \left(K_t^{ji}\right)^{\beta_K} \text{ for } j = 1,\ldots,12, i = 1,\ldots,47, \tag{17}$$

where Y denotes GAV, L is AL, K is ACEQ, and A is the level of technology, respectively. In addition, j, i, and t denote the industry index, the prefecture index, and year, respectively. Then, using ADFC (D) as a proxy variable of ACEQ (K), we obtain the following Equation (18),

$$Y_t^{ji} = A^j \left(L_t^{ji}\right)^{\alpha} \left(D_t^{ji}\right)^{\beta} \text{ for } j = 1,\ldots,12, i = 1,\ldots,47. \tag{18}$$

In addition, carrying out logarithmic conversion of Equation (18), we obtain the following as the final form of the production function,

$$\log Y_t^{ji} = \log A^j + \alpha \log L_t^{ji} + \beta \log D_t^{ji}. \tag{19}$$

Consequently, we can obtain the regression model A from this equation. For obtaining the regression model A, we relax the assumption in Equation (19) as follows. In Equation (19), the first term of the right-hand side is assumed to be common among all prefectures. However, in reality, Equation (19) has the part depending on every prefecture in the term above. Therefore, we obtain the following regression model A based on Equation (19):

$$\log Y_t^{ji} = C^j + \alpha \log L_t^{ji} + \beta \log D_t^{ji} + \varepsilon_t^{ji}$$
$$= C^j + \alpha \log L_t^{ji} + \beta \log D_t^{ji} + v^{ji} + u_t^{ji}, \tag{20}$$

where C is the common part for all prefectures in the terms above, being able to be treated as a constant term, ε is an error term before separating indi-vidual effect, v is the particular part for each prefecture, being able to be treated as the individual effect in this regression model, and u denotes an error term satisfying the assumption[12] of the standard linear regression model after separating v from ε. In addition, if $E(v^{ji} \mid \log L_t^{ji}, \log D_t^{ji}) = 0$, this model is the random effect model; if $E(v^{ji} \mid \log L_t^{ji}, \log D_t^{ji}) \neq 0$, this model is the fixed effect model.

Next, we explain the regression model B. The regression model B assumes "$\alpha + \beta = 1$" in Equation (18). Under this assumption, dividing both sides of Equation (18) by L and implementing the same arrangement to the said Equation as we did to Equation (18), we obtain,

$$\log(Y_t^{ji} / L_t^{ji}) = C^j + \beta \log(D_t^{ji} / L_t^{ji}) + v^{ji} + u_t^{ji}. \tag{21}$$

In addition, even in this model, if $E(v^{ji} \mid \log(D_t^{ji} / L_t^{ji})) = 0$, this model is the ran-dom effect model; if $E(v^{ji} \mid \log(D_t^{ji} / L_t^{ji})) \neq 0$, this model is the fixed effect model.

4.3. Data used for estimation of production functions

Data for the estimation of production functions are prefectural panel data which are divided into 12 industries (see Section 3) over three time points: 1990 - 1995 - 2000.

The contents of the provided data are GVA as Y of Equation (20) and (21), NE

and ACEM as L, ADFC as D (see Section 3 for details of each data). In addition, Table 4 shows descriptive statistics on each data in 2000.

Table 4 Descriptive statistics of the variables (in 2000)

Industries	Variables	Number of samples	Average	Standard deviation	Minimum Value	Maximum Value
1. Agri.	GVA	47	119.3	104.7	31.5	691.2
	NE	47	62.6	32.2	20.0	143.1
	ACEM	47	14.4	9.7	4.0	56.3
	ADFC	47	28.0	28.4	2.3	185.7
2. Fore.	GVA	47	18.0	29.7	0.4	208.4
	NE	47	1.4	1.2	0.1	8.0
	ACEM	47	5.3	8.5	0.2	59.7
	ADFC	47	1.1	1.3	0.0	7.4
3. Fish.	GVA	47	24.6	32.5	0.5	206.2
	NE	47	6.1	6.3	0.2	53.6
	ACEM	47	8.0	10.3	0.2	62.3
	ADFC	47	4.0	4.9	0.0	29.5
4. Min.	GVA	47	15.2	13.1	1.8	70.4
	NE	47	1.0	0.7	0.0	4.0
	ACEM	47	5.7	5.4	0.6	36.0
	ADFC	47	2.9	3.1	0.2	17.7
5. Const.	GVA	47	788.4	815.9	197.9	5,117.9
	NE	47	136.5	112.7	35.6	512.4
	ACEM	47	569.8	616.1	123.5	3,844.0
	ADFC	47	83.9	84.3	17.1	503.7
6. Manu.	GVA	47	2,384.1	2,364.5	251.6	10,667.0
	NE	47	279.0	268.0	34.4	1,121.0
	ACEM	47	1,178.1	1,270.6	94.4	5,752.5
	ADFC	47	341.9	350.0	11.2	1,900.5
7. EGW	GVA	47	311.4	328.0	37.4	1,791.9
	NE	47	8.1	7.2	1.1	32.5
	ACEM	47	73.7	108.7	9.8	707.3
	ADFC	47	106.0	108.0	12.1	474.1
8. TC	GVA	47	762.0	1,022.4	114.8	6,157.2
	NE	47	100.6	127.6	15.4	674.6
	ACEM	47	429.3	576.8	66.6	3,454.2
	ADFC	47	144.3	219.6	20.0	1,346.0
9. Com.	GVA	47	1,677.6	2,856.5	294.1	17,852.2
	NE	47	248.4	249.3	50.6	1,221.7
	ACEM	47	1,128.5	1,920.9	165.2	11,853.1
	ADFC	47	124.5	204.2	18.5	1,257.3
10. FI	GVA	47	636.1	1,412.5	97.7	9,722.5
	NE	47	39.6	47.1	9.0	256.2
	ACEM	47	288.4	589.6	52.6	4,031.3
	ADFC	47	84.8	180.7	10.1	1,205.5
11. Est.	GVA	47	1,225.4	1,639.4	217.9	9,754.6
	NE	47	18.6	31.8	1.4	181.4
	ACEM	47	59.6	139.0	4.9	920.7
	ADFC	47	441.2	579.5	79.8	3,315.7
12. Serv.	GVA	47	2,813.8	4,478.6	491.9	29,488.8
	NE	47	437.1	442.2	96.9	2,405.3
	ACEM	47	1,827.9	2,592.9	335.7	16,614.2
	ADFC	47	429.1	846.2	68.4	5,720.8
All	GVA	47	11,340.4	14,880.9	2,239.6	93,626.2
	NE	47	1,402.6	1,328.8	321.3	6,663.5
	ACEM	47	5,955.5	8,014.2	1,190.2	50,186.4
	ADFC	47	1,957.4	2,488.6	393.0	15,336.7

Notes: (1) The unit for GVA, ACEM, and ADFC is1 billion yen. The unit for NE is 1000 person.
(2) Amount data is modified in the base year: 2000.
(3) The sum of 12 industries does not correspond with the sum of all industries because of analytical exception of Pub. and Others.

4.4. Estimation results

Table 5-1-1, Table 5-1-2, and Table 5-2 show the estimation results. The followings [1] to [4] explain how to read the results.

[1] The fixed effect and the random effect models were implemented by industry and regression model. In addition, the within-group estimator model was implemented as the fixed effect model.[13] After this analysis, the Hausman test[14] on the difference between both models was implemented at 5% significant level to determine which model to be adopted. In the tables above, we denote the adopted model as either "fixed" or "random".

[2] When there was not the significance of NE as L of Equations (20) and (21) even at 10% significant level, we used ACEM instead of NE. Table 5-1-1 shows the results of industries with NE being L, while Table 5-1-2 shows those with ACEM being L.

[3] From the value of F statistic[15], which were obtained from the sum of squared residual (SSR) and the degree of freedom (DF) on each regression model: A, B, homogeneity of degree one ("$\alpha + \beta = 1$" in Equation (18)), namely, CRS on each industry was tested at 5% significant level. Table 5-2 shows the results.

[4] On industry not indicating homogeneity of degree one in [3], we determined its RTS from the sum of the estimated coefficients on L and D : its DEA model was selected .

Table 5-1-1, Table 5-1-2, and Table 5-2 show that ACEM is adopted as a variable representing AL in "5: Const.", "6: Manu.", "8: TC", "9: Com.", "10: FI", and "11: Est."; CRS on RTS is recognized and CCR model is adopted in "1: Agri.", "7: EGW", "8: TC", "10: FI", "12: Serv.", and "All"; DRS is recognized and DRS model is adopted in "2: Fore.", "3: Fish.", "4: Min.", "5: Const.", "6: Manu. ", "9: Com.", and "11: Est.".

Table 5-1-1 Estimation results by industry (L is NE.)

	No.	1	2	3	4	7	12	
	Indusries	Agri.	Fore.	Fish.	Min.	EGW	Serv.	All
ModelA (unrestricted)	Hausman test	15.659	64.428	101.240	26.073	5.045	8.283	16.159
	P-value	[0.000]	[0.000]	[0.000]	[0.000]	[0.080]	[0.016]	[0.000]
	Fixed or random effect	fixed	fixed	fixed	fixed	random	fixed	fixed
Log of NE	Estimated coefficents	0.653	-0.318	0.114	0.150	0.097	0.666	0.507
	Standard error	0.063	0.136	0.068	0.047	0.043	0.281	0.178
	P-value	[0.000]	[0.022]	[0.078]	[0.002]	[0.025]	[0.020]	[0.005]
Log of ADFC	Estimated coefficents	0.263	0.230	0.390	0.560	0.855	0.465	0.384
	Standard error	0.049	0.080	0.043	0.043	0.035	0.058	0.021
	P-value	[0.000]	[0.005]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Constant	Estimated coefficents	—	—	—	—	2.821	—	—
	Standard error	—	—	—	—	0.296	—	—
	P-value	—	—	—	—	[0.000]	—	—
SSRu		0.836	8.660	1.804	2.192	6.661	0.466	0.237
DF (1)		92	92	92	92	138	92	92
Adjusted-R^2		0.980	0.910	0.988	0.962	0.940	0.993	0.996
ModelB (restricted)	Hausman test	14.572	12.315	13.876	12.566	0.324	9.087	23.049
	P-value	[0.000]	[0.000]	[0.000]	[0.000]	[0.596]	[0.003]	[0.000]
	Fixed or random effect	fixed	fixed	fixed	fixed	random	fixed	fixed
Log of (ADFC/NE)	Estimated coefficents	0.289	0.312	0.538	0.684	0.865	0.492	0.386
	Standard error	0.058	0.102	0.067	0.059	0.035	0.030	0.022
	P-value	[0.000]	[0.003]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Constant	Estimated coefficents	—	—	—	—	2.052	—	—
	Standard error	—	—	—	—	0.245	—	—
	P-value	—	—	—	—	[0.000]	—	—
SSRr		0.852	14.986	4.24472	2.983	6.764	0.472	0.238
DF (2)		93	93	93	93	139	93	93
Adjusted-R^2		0.853	0.748	0.840	0.933	0.848	0.853	0.924

Note: DF denotes degree of freedom.

Table 5-1-2 Estimation results by industry (L is ACEM.)

	No.	5	6	8	9	10	11
	Indusries	Const.	Manu.	TC	Com.	FI	Est.
ModelA (unrestricted)	Hausman test	82.353	66.308	5.941	17.835	5.908	8.126
	P-value	[0.000]	[0.000]	[0.051]	[0.000]	[0.0521]	[0.017]
	Fixed or random effect	random*	fixed	fixed*	fixed	random	fixed
Log of ACEM	Estimated coefficients	0.672	0.449	0.451	0.506	0.732	0.225
	Standard error	0.059	0.091	0.092	0.102	0.023	0.038
	P-value	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Log of ADFC	Estimated coefficients	0.202	0.071	0.600	0.350	0.270	0.626
	Standard error	0.059	0.037	0.084	0.069	0.019	0.026
	P-value	[0.001]	[0.060]	[0.000]	[0.000]	[0.000]	[0.000]
Constant	Estimated coefficients	2.459	—	—	—	1.024	—
	Standard error	0.265	—	—	—	0.142	—
	P-value	[0.000]	—	—	—	[0.000]	—
SSRu		3.293	0.470	0.543	0.457	1.468	0.674
DF (1)		138	92	92	92	138	92
Adjusted-R^2		0.962	0.994	0.993	0.995	0.987	0.991
ModelB (restricted)	Hausman test	0.442	7.375	5.087	0.328	1.726	15.864
	P-value	[0.506]	[0.007]	[0.024]	[0.570]	[0.189]	[0.000]
	Fixed or random effect	random	fixed	fixed	fixed*	random	fixed
Log of (ADFC/ACEM)	Estimated coefficients	0.239	0.101	0.591	0.392	0.269	0.680
	Standard error	0.065	0.038	0.082	0.077	0.019	0.018
	P-value	[0.000]	[0.010]	[0.000]	[0.000]	[0.000]	[0.000]
Constant	Estimated coefficients	0.909	—	—	—	1.041	—
	Standard error	0.124	—	—	—	0.034	—
	P-value	[0.000]	—	—	—	[0.000]	—
SSRr		3.496	0.839	0.548	0.559	1.469	0.729
DF (2)		139	93	93	93	139	93
Adjusted-R^2		0.071	0.671	0.763	0.555	0.554	0.960

Notes: (1) DF denotes degree of freedom.
(2) * in Fixed or random effect term indicates that the selection obeys that of another model.

Table 5-2 Estimation results by industry (2)

(the state of RTS: model selection on DEA)

No.	Indusries	Fstatics	Degree of nume. (2)-(1)	Degree of deno. (1)	Reject or not	Sum of estemated coefficients of modelA	RTS (model selection on DEA)		
							IRS (IRS)	CRS (CCR)	DRS (DRS)
1	Agri.	1.773	1	92	not	0.915		O	
2	Fore.	67.205	1	92	reject	-0.089			O
3	Fish.	124.521	1	92	reject	0.504			O
4	Min.	33.188	1	92	reject	0.709			O
5	Const.	8.498	1	138	reject	0.874			O
6	Manu.	72.067	1	92	reject	0.520			O
7	EGW	2.130	1	138	not	0.951	O		
8	TC	0.694	1	92	not	1.051	O		
9	Com.	20.491	1	92	reject	0.856			O
10	FI	0.049	1	138	not	1.001	O		
11	Est.	7.518	1	92	reject	0.851			O
12	Serv.	1.142	1	92	not	1.131	O		
	All	0.701	1	92	not	0.891	O		

Notes: (1) F statistics are used to judge "homogeneous of degree one".

(2) "nume." and "deno." denotes numerator and denomerator of F stasitic, respectively.

5. Clustering of 47 prefectures

In this Section, we divided 47 prefectures into clusters having similar regional characteristics to implement DEA with similar DMUs[16].

This reason is that as pointed out in Okuda and Take (2006), DEA is an analytical method implemented by comparing performance of each DMU, so comparing DMUs with extremely different characteristics cannot bear meaningful analytical results. The significance of this classification is clearly shown in the comparison, for example, between Tokyo and Tottori: the former has the largest proportion of its nominal GRP to GDP (17.62% as of 2004), while the latter has the smallest one (0.40%).

Then, Yoshida (2007) divided 47 prefectures into four clusters with their regional characteristics. So, we adopt his clustering because it corresponds with our aim.

Now, according to Yoshida (2007), we explain his method as follows[17]:

1. First, he selected six observed variables shown in Table 6 as indexes

presenting regional characters.

2. Next, he implemented the factor analysis to obtain three factor scores (on each prefecture) used in the following cluster analysis.

3. Finally, he implemented the cluster analysis with the factor scores above. And he decided four clusters shown in Table 7 by the Ward method as a clustering method and the Euclid distance as a distance measurement. Moreover, he named the four clusters, in the order of numbering, as follows: "the small-sized industrial cluster", "the middle cluster", "the heavy-agriculture, forestry, and fishery cluster", "the economic-activity-base cluster".

Table 6 List of observed variables

Observed variables	Unit	Year	Source
Farming Output	100 million yen	FY2002	
Material (Raw Wood) Output	1000 m³	FY2002	
Fishery Output	100 million yen	FY2002	Comprehensive List of Regional Economy 2005 (TOYO KEIZAI, INC.)
Product Shipment Value	100 million yen	FY2002	
Annual Retailing Sales	100 million yen	FY2002	
Night-Day Population Ratio	%	FY2000	Statistical Observations of Municipality (SBMIAC)

Note: SBMIAC denotes Statistics Bureau of Ministry of Internal Affairs and Communication, Government of Japan.

Table 7 Prefectures in each cluster

First Cluster (11 prefectures)		Second Cluster (13 prefectures)		Third Cluster (14 prefectures)		Fourth Cluster (9 Prefectures)	
Toyama	Tokushima	Yamagata	Shiga	Hokkaido	Ehime	Ibaraki	Osaka
Ishikawa	Kagawa	Tochigi	Kyoto	Aomori	Kochi	Saitama	Hyogo
Fukui	Saga	Gumma	Nara	Iwate	Nagasaki	Chiba	
Yamanashi	Okinawa	Niigata	Okayama	Miyagi	Kumamoto	Tokyo	
Wakayama		Nagano	Hiroshima	Akita	Oita	Kanagawa	
Tottori		Gifu-ken	Fukuoka	Fukushima	Miyazaki	Shizuoka	
Yamaguchi		Mie		Shimane	Kagoshima	Aichi	

6. Implementation of DEA and the results

6.1. The objective cluster of DEA

In this Section, we implemented DEA by industry in the fourth cluster: the

economic-activity-base cluster (see Section 5). The reasons we concentrated our investigation in this cluster are as follows[18]:

1. This cluster is the center of the Japanese economy: especially on the secondary and the tertiary industries.
2. This cluster includes the main prefectures in Kanto, Tokai, and Kinki district. And the proportion of GRP of these districts to GDP is about 68% in 2004.
3. That is to say, the concentration informs us about the detailed status on the regions which carry the major part of the Japanese economy.

6.2. Kinds of DEA implemented

We implemented the following DEA[19].

[1] The CCR and DRS models (input-oriented): 12 industries+"All" (in 2000, the fourth cluster)
[2] The Window Analysis (input-oriented): 12 industries+"All"(during 1990-1995-2000, the fourth cluster)

Note that the selection between the CCR and the DRS models is based on Section 4 as well as the selection between NE and ACEM as the input AL. In addition, Table 8 shows descriptive statistics of each data on the fourth cluster in 2000.

Table 8 Descriptive statistics of the variables (the fourth cluster: 2000)

Indusries	Variables	Number of samples	Average	Standard deviation	Minimum Value	Maximum Value
1. Agri.	GVA	9	136.0	87.5	31.5	287.9
	NE	9	81.2	38.1	26.9	126.4
	ADFC	9	25.8	17.1	3.7	55.5
2. Fore.	GVA	9	6.6	5.4	0.4	17.1
	NE	9	1.4	0.6	0.5	2.5
	ADFC	9	0.5	0.3	0.1	1.1
3. Fish.	GVA	9	18.6	12.2	1.2	39.5
	NE	9	4.3	3.4	0.6	10.2
	ADFC	9	2.9	2.0	0.1	6.0
4. Min.	GVA	9	16.1	10.0	3.7	34.6
	NE	9	1.1	0.3	0.5	1.6
	ADFC	9	2.6	2.0	0.4	7.2
5. Const.	GVA	9	1,941.2	1,183.1	842.1	5,117.9
	ACEM	9	1,425.8	910.7	449.2	3,844.0
	ADFC	9	206.6	112.1	94.4	503.7
6. Manu.	GVA	9	6,489.9	2,303.0	4,081.2	10,667.0
	ACEM	9	3,318.9	1,400.1	1,697.7	5,752.5
	ADFC	9	929.8	367.7	630.7	1,900.5
7. EGW	GVA	9	730.9	407.5	373.5	1,791.9
	NE	9	19.9	7.2	9.1	32.5
	ADFC	9	245.9	101.0	134.6	474.1
8. TC	GVA	9	2,233.8	1,533.3	804.4	6,157.2
	ACEM	9	1,237.4	873.1	359.5	3,454.2
	ADFC	9	457.3	345.7	121.8	1,346.0
9. Com.	GVA	9	5,225.6	5,010.0	1,266.0	17,852.2
	ACEM	9	3,539.9	3,349.2	711.1	11,853.1
	ADFC	9	391.6	346.4	100.8	1,257.3
10. FI	GVA	9	2,038.1	2,772.6	398.7	9,722.5
	ACEM	9	910.0	1,136.8	211.1	4,031.3
	ADFC	9	264.7	341.5	53.6	1,205.5
11. Est.	GVA	9	3,696.2	2,406.4	1,033.3	9,754.6
	ACEM	9	219.5	259.0	30.7	920.7
	ADFC	9	1,344.1	812.3	388.8	3,315.7
12. Serv.	GVA	9	8,404.1	7,832.7	2,646.8	29,488.8
	NE	9	1,133.5	542.2	448.3	2,405.3
	ADFC	9	1,383.2	1,586.6	305.7	5,720.8
All	GVA	9	32,296.8	23,400.1	12,419.2	93,626.2
	NE	9	3,619.7	1,428.7	1,573.2	6,663.5
	ADFC	9	5,633.7	3,732.4	2,108.7	15,336.7

Note: See Notes of Table 4.

6.3. Productive efficiency by industry and prefecture

Table 9 shows the results of the CCR and the DRS models. Then, the main findings are as follows:

1. Tokyo has the highest efficiency on all industries except for "2: Fore." and "8: TC".
2. Aichi has the highest efficiency on "6: Manu.", "9: Com.", and "10: FI." However, it does not show the prominent strength on other industries. Considering these facts and the amount level of ADFC of "6: Manu." simultaneously, we can guess that the strength of Aichi economy is based on "6: Manu.".
3. Osaka is generally considered the least efficient through all industries except for "5: Const.", "9: Com.", and "12: Serv.".
4. Kanagawa next to Tokyo has the strength on "6: Manu." and "11: Est.". Then, it is generally efficient through all industries.
5. Saitama and Chiba next to Tokyo are generally less efficient through all industries. It is probably reflected on the fact that these regions are the commuter towns of Tokyo.
6. Ibaraki has the strength on "5: Const.", "6: Manu.", "8: TC", "9: Com.", and "12: Serv.". Then, it is relatively efficient through all industries.
7. Hyogo does not have the strength on "5: Const.", "6: Manu.", "8: TC", "9: Com.", and "12: Serv." against Ibaraki. Then, it is relatively less efficient through all industries.

Table 9 Productive efficiency of each Industry: CCR, DRS model
(the fourth cluster: 2000)

No.	1		2		3		4		5	
Industries	Agri.		Fore.		Fish.		Min.		Const.	
DEA model	CCR		DRS		DRS		DRS		DRS	
Input as AL	NE		NE		NE		NE		ACEM	
Prefecture	θ	Rank	θ	Rank	θ	Rank	θ	Rank	θ	Rank
Ibaraki	0.941	4	0.250	8	1.000	1	0.481	4	1.000	1
Saitama	0.843	7	0.346	7	1.000	1	0.298	9	0.929	7
Chiba	1.000	1	0.553	4	0.867	7	0.531	3	0.876	9
Tokyo	1.000	1	0.687	3	1.000	1	1.000	1	1.000	1
Kanagawa	0.861	6	0.351	6	0.953	5	0.440	6	0.962	4
Shizuoka	0.917	5	1.000	1	1.000	1	0.449	5	0.967	3
Aichi	0.994	3	0.472	5	0.680	8	0.361	7	0.934	6
Osaka	0.801	9	0.180	9	0.574	9	0.348	8	0.961	5
Hyogo	0.817	8	1.000	1	0.907	6	1.000	1	0.909	8

No.	6		7		8		9		10	
Industries	Manu.		EGW		TC		Com.		FI	
DEA model	DRS		CCR		CCR		DRS		CCR	
Input as AL	ACEM		NE		ACEM		ACEM		ACEM	
Prefecture	θ	Rank	θ	Rank	θ	Rank	θ	Rank	θ	Rank
Ibaraki	1.000	1	0.734	6	1.000	1	1.000	1	0.923	5
Saitama	0.746	8	0.812	3	0.834	4	0.899	8	0.918	6
Chiba	0.952	5	0.684	9	0.800	7	0.878	9	0.885	9
Tokyo	1.000	1	1.000	1	0.797	8	1.000	1	1.000	1
Kanagawa	1.000	1	0.732	7	0.814	5	0.904	6	0.917	7
Shizuoka	0.794	7	0.894	2	0.845	3	0.919	5	0.927	4
Aichi	1.000	1	0.738	5	0.855	2	1.000	1	1.000	1
Osaka	0.731	9	0.715	8	0.790	9	0.963	4	0.889	8
Hyogo	0.834	6	0.753	4	0.807	6	0.904	7	0.931	3

No.	11		12			
Industries	Eat.		Serv.		All	
DEA model	DRS		CCR		CCR	
Input as AL	ACEM		NE		NE	
Prefecture	θ	Rank	θ	Rank	θ	Rank
Ibaraki	0.966	6	1.000	1	0.965	2
Saitama	1.000	1	0.805	9	0.847	8
Chiba	0.933	8	0.811	8	0.823	9
Tokyo	1.000	1	1.000	1	1.000	1
Kanagawa	1.000	1	0.916	5	0.952	3
Shizuoka	1.000	1	0.890	7	0.900	7
Aichi	0.964	7	0.941	4	0.934	5
Osaka	0.868	9	0.963	3	0.946	4
Hyogo	0.989	5	0.899	6	0.902	6

Note: θ and Rank denote D-efficiency value and ranking on θ in the cluster, respectively.

6.4. Secular efficiency changes by industry and prefecture

Table 10 shows the results of the Window Analysis. Then, the main findings are as follows:

1. Tokyo had been generally efficient through 1990 - 2000.
2. Though Aichi economy generally seems to be strong, it had reduced the efficiency level on all industries except for "6: Com." and "10: FI" in 1990 - 2000.
3. Osaka economy generally seems to be weak. Actually, it had reduced the efficiency level on all industries except for "1: Agri.", "5: Const.", and "12: Serv." in 1990 - 2000.
4. From the macro view, we can point out the following on this cluster. Any prefecture is less efficient than Tokyo, that is, all economic activities, which can bear high added value, have concentrated in Tokyo only.

Table 10 Results of Window Analysis (input-oriented)
(the fourth cluster: 1990-1995-2000)

No.	1			2			3			4		
Industries	Agri.			Fore.			Fish.			Min.		
Term	Former	Latter	△	Former	Latter	△	Former	Latter	△	Former	Latter	△
Ibaraki	0.901	0.918	1.8	0.354	0.282	-20.4	1.000	1.000	0.0	0.607	0.445	-26.7
Saitama	0.807	0.741	-8.2	0.437	0.346	-21.0	0.595	0.772	29.8	0.520	0.315	-39.4
Chiba	0.983	1.000	1.7	0.498	0.456	-8.4	0.672	0.833	24.0	1.000	0.765	-23.5
Tokyo	0.985	0.979	-0.6	0.685	0.616	-10.0	0.842	0.802	-4.8	0.950	1.000	5.3
Kanagawa	0.806	0.828	2.7	0.482	0.284	-41.1	0.699	0.798	14.2	0.399	0.403	1.0
Shizuoka	0.811	0.833	2.7	0.986	0.889	-9.9	1.000	1.000	0.0	0.612	0.459	-25.0
Aichi	0.949	0.880	-7.3	0.492	0.429	-12.8	0.803	0.636	-20.8	0.547	0.430	-21.4
Osaka	0.710	0.739	4.0	0.489	0.211	-56.8	0.760	0.566	-25.5	0.548	0.372	-32.2
Hyogo	0.915	0.820	-10.3	0.876	1.000	14.1	0.729	0.798	9.5	1.000	0.956	-4.4
Average	0.874	0.860	-1.7	0.589	0.501	-14.9	0.789	0.801	1.5	0.687	0.572	-16.8

No.	5			6			7			8		
Industries	Const.			Manu.			EGW			TC		
Term	Former	Latter	△	Former	Latter	△	former	latter	△	Former	Latter	△
Ibaraki	0.786	0.926	17.8	0.885	0.955	7.9	0.918	0.867	-5.5	0.934	1.000	7.1
Saitama	0.828	0.820	-0.9	0.772	0.768	-0.5	0.868	0.766	-11.7	0.812	0.832	2.4
Chiba	0.829	0.876	5.7	0.930	0.942	1.2	0.707	0.710	0.4	0.827	0.838	1.3
Tokyo	1.000	0.978	-2.2	0.963	0.992	3.0	1.000	0.966	-3.4	0.798	0.782	-2.1
Kanagawa	0.839	0.882	5.1	0.888	0.970	9.2	0.613	0.660	7.6	0.791	0.795	0.5
Shizuoka	0.857	0.873	1.9	0.837	0.812	-3.1	0.951	0.836	-12.1	0.809	0.816	0.9
Aichi	0.976	0.924	-5.4	0.957	0.938	-2.0	0.779	0.728	-6.6	0.839	0.823	-1.9
Osaka	0.812	0.885	8.9	0.824	0.779	-5.5	0.708	0.695	-1.9	0.796	0.783	-1.6
Hyogo	0.777	0.778	0.1	0.845	0.856	1.3	0.557	0.604	8.4	0.787	0.805	2.3
Average	0.856	0.882	3.1	0.878	0.890	1.4	0.789	0.759	-3.8	0.821	0.830	1.1

No.	9			10			11			12		
Industries	Com.			FI			Est.			Serv.		
Term	Former	Latter	△	Former	Latter	△	Former	Latter	△	Former	Latter	△
Ibaraki	0.922	0.959	4.0	0.896	0.779	-13.1	0.954	0.982	2.9	0.967	1.000	3.4
Saitama	0.881	0.916	4.0	0.961	0.816	-15.1	0.976	0.988	0.7	0.908	0.888	-2.2
Chiba	0.911	0.938	3.0	0.916	0.834	-8.9	0.953	0.889	-6.7	0.961	0.895	-6.9
Tokyo	1.000	1.000	0.0	0.939	0.904	-3.8	0.996	1.000	0.4	0.980	1.000	2.1
Kanagawa	0.940	0.931	-0.9	0.931	0.807	-13.4	0.958	1.000	4.3	0.904	0.914	1.0
Shizuoka	0.936	0.925	-1.2	0.928	0.865	-6.7	0.997	0.982	-1.6	0.930	0.910	-2.2
Aichi	0.975	1.000	2.5	1.000	1.000	0.0	1.000	0.923	-7.7	0.971	0.938	-3.3
Osaka	0.990	0.967	-2.8	0.982	0.811	-17.4	0.921	0.795	-13.7	0.884	0.887	0.8
Hyogo	0.874	0.904	3.5	0.944	0.798	-15.4	0.829	0.813	-1.9	0.883	0.866	-1.9
Average	0.937	0.949	1.3	0.944	0.846	-10.4	0.954	0.930	-2.5	0.932	0.922	-1.1

Industries	All		
Term	Former	Latter	△
Ibaraki	0.825	0.789	-4.3
Saitama	0.761	0.720	-5.4
Chiba	0.767	0.738	-3.8
Tokyo	1.000	1.000	0.0
Kanagawa	0.750	0.745	-0.6
Shizuoka	0.900	0.819	-9.0
Aichi	0.973	0.871	-10.5
Osaka	0.877	0.809	-7.7
Hyogo	0.752	0.710	-5.5
Average	0.845	0.800	-5.3

Note: Former, Latter, and △ denote average D-efficiency value of 1990-1995, that of 1995-2000, and the growth
rate (%) of Latter to Former, respectively.

6.5. Improvement measures and production-factor redundancy

Table 11 shows the "Difference" between the "Data" and the "Projection". Here, the "Data" denotes actual used quantity and amount in total by input and prefecture. Then, the "Projection" denotes efficient quantity and amount in total by input and by prefecture. Therefore, the "Difference" denotes the redundancy in total on each input in the prefecture. Here, note the following. We obtained the "Difference", the "Data", and the "Projection" by industry and prefecture, however we intend to discuss the problem in macro. Hence we show figures in total by prefecture in this table.

In view of cost reduction, the social planners of each prefecture and the Japan government can downsize NE, ACEM, and ADFC by the "Difference" of each input. In other words, Table 11 indicates the improvement measures on each prefectural economy.

On the other hand, in view of social security, the social planners must perceive the following fact. The "Difference" of each input denotes the redundancy, that is, it may denote that the private (production) sector instead of public sector substantially redistributes income. Therefore, it seems to be highly probable that the public sector has to redistribute income much more than it actually does.

Table 11 indicates that the estimated redundancy is very severe. According to this table, the redundancy of NE comes up to 9.1%, that of ACEM is 7.9%, and that of ADFC is 8.1%, respectively, in the fourth cluster total. Successively, let us observe this table by input and prefecture. First, regarding NE, the estimated redundancy of Saitama, Chiba, Shizuoka, and Hyogo is especially severe. Next, regarding ACEM, so is that of Saitama, Chiba, Shizuoka, and Osaka. Finally, regarding to ADFC, so is that of Chiba, Shizuoka, Osaka, and Hyogo. Meanwhile, Ibaraki, Tokyo, Kanagawa, and Aichi display good performance through all items of input. These results seem to explain that Saitama, Chiba, Shizuoka, Osaka, and Hyogo in this cluster face the strong pressure to reform their own economies and the potential demand to implement more sufficient social security policies not through private sector but by public sector.

Table 11 Improvement measures for production activities in macro (2000)

	Inputs & output	Data	Projection	Difference	Difference %
Ibaraki	NE	590.4	576.3	-14.1	-2.4%
	ACEM	3,459.3	3,412.5	-46.8	-1.4%
	ADFC	1,682.6	1,624.7	-57.9	-8.1%
	GVA	11,733.6	11,733.6	0.0	0.0%
Saitama	NE	1,199.8	872.4	-327.4	-27.3%
	ACEM	6,842.0	5,642.0	-1,199.9	-17.5%
	ADFC	3,633.3	3,191.3	-442.0	-12.2%
	GVA	19,750.8	19,750.8	0.0	0.0%
Chiba	NE	1,142.5	942.0	-200.5	-17.5%
	ACEM	5,981.4	5,304.0	-677.4	-11.3%
	ADFC	3,691.8	3,152.4	-539.4	-14.6%
	GVA	19,102.8	19,102.8	0.0	0.0%
Tokyo	NE	2,470.7	2,470.6	-0.2	0.0%
	ACEM	29,855.8	29,153.7	-702.1	-2.4%
	ADFC	14,642.9	14,229.1	-413.8	-2.8%
	GVA	89,632.9	89,632.9	0.0	0.0%
Kanagawa	NE	1,504.7	1,365.2	-139.5	-9.3%
	ACEM	9,299.2	8,660.2	-638.9	-6.9%
	ADFC	5,161.6	4,774.6	-387.0	-7.5%
	GVA	30,827.2	30,827.2	0.0	0.0%
Shizuoka	NE	697.4	623.8	-73.7	-10.6%
	ACEM	5,858.2	5,021.3	-836.9	-14.3%
	ADFC	2,704.5	2,317.3	-387.3	-14.3%
	GVA	15,591.9	15,591.9	0.0	0.0%
Aichi	NE	1,217.0	1,141.4	-75.6	-6.2%
	ACEM	12,698.4	12,365.2	-333.2	-2.6%
	ADFC	5,686.7	5,438.0	-248.8	-4.4%
	GVA	33,616.6	33,616.6	0.0	0.0%
Osaka	NE	1,418.4	1,347.0	-71.4	-5.0%
	ACEM	15,269.7	13,019.2	-2,250.5	-14.7%
	ADFC	6,621.5	5,627.5	-994.0	-15.0%
	GVA	39,224.8	39,224.8	0.0	0.0%
Hyogo	NE	930.8	821.6	-109.2	-11.7%
	ACEM	6,600.7	5,699.2	-901.4	-13.7%
	ADFC	3,267.9	2,913.6	-354.4	-10.8%
	GVA	18,952.4	18,952.4	0.0	0.0%
Cluster total	NE	11,171.6	10,160.2	-1,011.5	-9.1%
	ACEM	95,864.6	88,277.3	-7,587.3	-7.9%
	ADFC	47,292.8	43,468.4	-3,824.4	-8.1%
	GVA	278,433.0	278,438.0	0.0	0.0%

Note: The unit for NE is 1000 person, and that of ACEM, ADFC, and GVA is 1 billion yen.

7. Concluding remarks

In this study, first, we analyzed the state of RTS between inputs (labor and fixed capital) and output (GRP) through the estimation of production function on each industry[20] with prefectural panel data. Then, the results are summed up as follows: NE is adopted as a variable representing labor in "1: Agri.", "2: Fore.", "3: Fish.", "4: Min.", "7: EGW", "12: Serv. ", and "All"; meanwhile, ACEM, which includes the difference on ability among employees, is adopted in "5: Const.", "6: Manu.", "8: TC", "9: Com.", "10: FI", and "11: Est."; CRS on RTS of production is recognized in "1: Agri.", "7: EGW", "8: TC", "10: FI", "12: Serv.", and "All"; meanwhile, DRS is recognized in "2: Fore.", "3: Fish.", "4: Min.", "5: Const.", "6: Manu. ", "9: Com.", and "11: Est.". Moreover, from these results of RTS, we decided to adopt the CCR model of DEA on industries having CRS technology and the DRS model on industries having DRS technology.

Next, we implemented DEA on each industry in the prefectures which belong to the fourth cluster: the economic-activity-base cluster. Then, the results are summed up as follows: Tokyo has the highest efficiency on all industries except for "2: Fore." and "8: TC"; Aichi has the highest efficiency on "6: Manu.", "9: Com.", and "10: FI"; Osaka economy is generally the least efficient through all industries except for "5: Const.", "9: Com.", and "12: Serv."; from the results of the Window Analysis, any prefecture is less efficient than Tokyo, that is, all economic activities with high added value have concentrated in Tokyo only; the redundancy of NE comes up to 9.1%, that of ACEM is 7.9%, that of ADFC is 8.1% in this cluster total; there are more severe redundancy in prefectures such as Saitama, Chiba, Shizuoka, Osaka, and Hyogo.

Then, from the last two facts that DEA results indicate above, we can understand the situation that regional economies, especially, Saitama, Chiba, Shizuoka, Osaka, and Hyogo, are facing the strong pressure to reform their economy and the potential demand to implement more sufficient social security by public sector.

Finally, we indicate the future task that we will have to tackle. In this study, in order to investigate the real economy inclusively, we implemented DEA on 12 industries based on the major divisions of JSIC. However, if we analyzed on more detailed categories such as middle division, minor division in JSIC[21], DEA would enable us to obtain more detailed information because of its

analytical characteristics. Therefore, in order to acquire more elaborated improvement measures and plan more elaborated economic and social security policies, it is desirable to implement DEA with the above detailed categories by the method we presented in this paper.

NOTES

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1 The Osaka economy, the center of Kinki economy, is in difficulties as follows: on the average value of the total unemployment rate since 2000, it holds 7.1%, which is the second highest after Okinawa; on the proportion of nominal GRP to GDP, it has reduced the proportion by 15.64 points in 1975–2004, while Tokyo has increased by 4.73 points, Aichi by 7.79 points; on the financial status of the public sector, Osaka prefecture was the only one to have a budget deficit among all prefectures in FY2006.

2 Note that we regard the "production technique" as one including all production and management activities: from preparing production factors to sales of goods and service.

3 In DEA, the set of weights can be variable with each DMU, applying most favorable one to such DMU. It is acceptable to apply larger weight to the items the DMU is good at and less weight to ones it is not good at. However, the ratio scales of the other DMUs should be calculated by the same weight. After that, the efficiency of each DMU is relatively evaluated with the results.

4 We can quote "Stochastic Frontier Analysis" as a parametric analysis to evaluate the efficiency of each object. For reference, see Aigner *et al.*(1977), Battese and Coeli(1995) and etc.

5 Chalos and Cherian (1995) implement a regression analysis between input and output variables and confirm the relationship statistically before implementing DEA.

6   See Cooper *et al.* (1978), Cooper *et al.* (2000) ch.2, 3 Tone (1993) ch.2, 3 and etc. for the details of this model.

7   See Cooper *et al.* (2000) ch.4 and 5, Tone (1993) ch.4, Banker *et al.*(1984) and etc. for the details of these models and BCC model: the base of these.

8   See Cooper *et al.* (2000 ch.9 and Tone (1993) ch.6 and etc. for the details of this analysis.

9   See Tone (1993) ch.8 for the DEA model dealing with minimization of production cost.

10   In addition, in this paper, DEA is implemented with specifying RTS (see Section 4) by industry. Therefore, we assume that the scale efficiency is 1; $TE = 1 \times PTE$.

11   First, regarding NE. The source of NE is "The Basic Survey of Employment Structure" (in 1992, 1997, and 2002, Ministry of Health, Labor and Welfare, Government of Japan). However, we took the following process to obtain the necessary data from this survey. We recounted the data from it according to the divisions instructed in Table 2. However, its divisions are partially different from those of Table 2, so we divided the necessary part of the data using the portion between divisions with the data in the closest year. Successively, we made the data of 1990-1995-2000 with a method of linear interpolation from the data of 1992, 1997 and 2002.

     Next, regarding ACEM, ADFC, and GVA. The source of these data is "Input-Output Tables" (1990-1995-2000, each prefecture), but we had to take the following process to obtain the necessary data from these tables. First, item units in these tables vary depending on prefectures, so we needed to modify these differences and implement necessary conversion. Second, classification methods also vary depending on prefecture, so we needed to integrate divisions according to 12 divisions in Table 2. Third, the data are nominal, so we deflated the data with GDP deflator: base year = 2000.

12   The assumption is the following: $E(u_i^t) = 0, E((u_i^t)^2) = (\sigma_u^t)^2, E(u_i^t u_i^s) = 0$ *for* $i \neq l, t \neq s$.

13   See Greene (1997) ch.14, Wooldridge (2002) ch.10, and others for the details of the fixed effect model and the random effect model

14   See Green (1997) ch.9, Wooldridge (2002) ch.10, and others for the details of the Hausman test.

15   See Green (1997) ch.6 and others for the details of the F static and F test.

16 DEA with Categorical DMUs exists as the DEA considering the environment DMUs faced (See Cooper *et al.* (2000) ch.7 for the details of this). But this DEA deals just one environment, and we consider a plural of indexes on regional characters. So, we cannot use this model.

17 See Yoshida (2007) ch.3 for the detailed of his method.

18 Moreover, because of space limitation, we cannot show the results on all 47 prefectures.

19 Because of space limitation, unit of the number of employees is 1000 person and that of amount is 1 billion yen in Table 8 and 11. However, when we implemented DEA, the former was 100 person and the latter was 100 million yen.

20 See Section 3 for the details of industries.

21 In fact, the result of "All" item loses detailed information. Compare this result with that of other items in Table 9, 10.

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