

Medical Care System Evaluation Based On DEA Of Prefectures In Japan

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Abstract— In order to reveal disparity and its cause in medical care among Japanese prefectures, this paper describes how DEA works as follows: (1) DEA/BCC model estimates the disparity between prefectures, (2) “RM-DEA using Cone-Ratio approach” estimates the cause of the disparity, and (3) Improved MF-DEA (Multi-Frontier based DEA) model estimates the disparity between eastern and western Japan. This paper also illustrates three numerical experiments.

Keywords: Data Envelopment Analysis, Medical Service.

I. INTRODUCTION

Nowadays the shortage of medical employees connects with the regional and medical disparity, and it becomes a bigger problem. Especially the shortage of medical doctor is reported by Ministry of Health [1], and that of nurse is done by Japan Medical Association [2]. As these countermeasures, the analysis is done in Japan Medical Association Research Institute [3] (JMARI), and the committee relating to the medical employees is held also by the organization in the Japan[4]. Thus, the concern about the shortage of medical employees is higher and higher.

However, not only the number of employees but also the enhancement of equipment is critical to offer the better medical service. Therefore, the above-mentioned evaluation by only employee's data is insufficient in order to consider “anytime, anywhere, anyone, equally [5]” which is the medical ideal in Japan. And the regional and medical disparity should be considered by data including employees' and equipment's information. There is a similar analysis in JMARI, while the analysis is not carried out by the overall evaluation used multiple data items, and which item is prime cause of the disparity is not investigated. Then this paper intends to examine these disparity and its cause by using the multiple data, the number of medical employees and that of medical equipment. In this case, a relative evaluation method corresponding to the multiple inputs and outputs is necessary.

Recent years, in order to examine the efficiency of medical and other public services, a nonparametric method, Data Envelopment Analysis (DEA), is often used [5]. DEA is a method that can relatively compare ratios of the input and the output. This relative comparison and the comparative evaluation are basis in DEA.

Then the purpose of this paper is to evaluate the medical care system of prefecture in Japan and to reveal the regional and medical disparity by BCC (Banker-Charnes-Cooper) model. And “Restricted Multipliers DEA model using Cone-Ratio approach (RM-DEA) [6]” is applied in order to find out the weakness and the strength of prefecture. In addition, the medical disparity between western and eastern Japan is examined by the improved Multi-Frontier based DEA (MF-DEA) [7].

II. THE PROBLEM OF MEDICAL CARE SYSTEM EVALUATION IN CONVENTIONAL METHOD

Medical care system is evaluated by one ratio in a lot of researches. And most researches use the ratio to the number of patients. Hereafter, this method is regarded as the conventional method. Now, there are the following six data items: the number of doctors, nurses, high priced medical equipment, beds, ICU beds, and hospitals in inhabitable area (Hospital density). Then doctor and nurse items indicate medical employees. Bed, ICU bed, and high priced medical equipment item indicate equipment. The data item of hospital density shows geographical factor. For example, this factor indicates time to go to hospital. Here, prefectures can be evaluated in each data compared with the ratio value.

TABLE I. EXAMPLE:THE RATIO OF EACH ITEM

Prefecture	Ratio value per 100,000 patients		
	Doctor	Nurse	Bed
Hokkaido	208.8	947.4	1830.7
Aomori	150.2	709.2	1286.6
Iwate	185.2	735.1	1382.3
Miyagi	190.8	661.1	1162.1
Akita	187.6	728.7	1394.1
Yamagata	179.2	718.6	1161.1
:	:	:	:

However, there is not evaluation reached by all six items. Medical service can not be evaluated by one data item such as the number of doctors. The number of the doctors and nurses may be the most important in the hospital management but no medical employees can work in the place where there are no

medical facilities. Conversely, even if there are some medical employees, a necessary medical service cannot be offered without the necessary equipment. Therefore, medical service should be evaluated by multiple data items which show the number of medical employees and the enhancement of medical facilities equipment.

TABLE II. DATA SET

Data items	Data sources
The number of doctors	Hospital Report
The number of nurses	Hospital Report
The number of expensive equipments	Survey of Medical Institutions
The number of beds	Survey of Medical Institutions
The number of Icu beds	Survey of Medical Institutions
The number of hospitals	Survey of Medical Institutions
Inhabitable area	Social life statistics index
The number of patients	Survey of Medical Institutions

III. OUTLINE OF DATA ENVELOPMENT ANALYSIS

DEA was proposed by A. Charnes et al. in 1978 as a method for management analysis. It is applied in various fields such as data mining, prospect for bankruptcy or so.

Evaluated objects, namely DMUs (Decision Making Units) are hospital, bank, electricity company or prefecture, for example. And each DMU is characterized by multi-inputs and multi-outputs. Then DMU which have smaller inputs and larger outputs is regarded as more efficient. Management efficiency is evaluated by efficiency value. Then efficient DMU has efficiency value as 1, inefficient DMU has it as less than 1. Efficiency value is calculated based on line called efficiency frontier which is formed by efficient DMUs [8, 9].

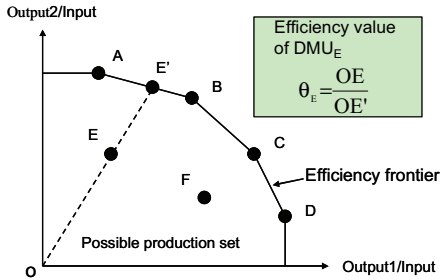


Fig. 1. Efficiency frontier and efficiency value of DMU_E

Here, Fig. 1 is prepared to signify how to evaluate DMU. Each axis indicates outputs divided by input. Therefore, DMU which is far from origin is more efficient. Four DMU_{A,B,C,D} have no difference of superiority or inferiority, and they are equally efficient. The efficient frontier is formed with these efficient DMUs. Moreover, four DMU_{A,B,C,D} get efficiency value 1 since they are located on the efficiency frontier. And other DMU DMU_{E,F} is judged to be inefficient, their efficiency values are calculated at ratio of distance to the efficient frontier. As an example, the way to calculate the efficiency value of inefficient DMU_E is described. This time, the efficiency value of DMU_E is calculated by distance to efficiency frontier. In a word, the efficiency value is calculated from OE / OE' by ratio of the distance from origin to Point E' and origin to point E .

Here, E' shows ideal state that DMU_E can reach by improvement of production activity.

IV. ANALYSIS METHODS

A. BCC Model

There are some models in DEA as the analytic model. And there are two analytic types called input-oriented type and output-oriented type. Here, output-oriented BCC model is explained since it is utilized in this paper. BCC model assumes the harvest variable of the scale. Moreover, the output-oriented type premises the current input, and obtains maximum output which is expected.

Assuming that there are n DMUs ($DMU_1, DMU_2, \dots, DMU_k, \dots, DMU_n$), and DMU_k is characterized by m inputs and s outputs. Then DMU_k has input expressed as $x_{1k}, \dots, x_{mk}$ and output expressed as $y_{1k}, \dots, y_{sk}$. Here the efficiency value is shown by calculating following linear algorithm.

$$\begin{aligned}
 & \max \quad \theta_k \\
 & s.t. \quad \sum_{j=1}^n x_{ij} \lambda_{jk} \leq x_{ik} \quad (i = 1, 2, \dots, m) \\
 & \quad - \sum_{j=1}^n y_{rj} \lambda_{jk} + \theta_k y_{rk} \leq 0 \quad (r = 1, 2, \dots, s) \\
 & \quad \sum_{j=1}^n \lambda_{jk} = 1 \\
 & \quad \lambda_{jk} \geq 0, \quad \theta_k : \text{free}, \quad j = 1, 2, \dots, n
 \end{aligned}$$

About the optimal solution θ_k^* calculated by the formula (1), there is $\theta_k^* \geq 1$ and an efficiency value is expressed as $1/\theta_k^*$ at this time. When $1/\theta_k^* = 1$, DMU_k is evaluated to be efficient. And when $\theta_k^* \leq 1$, DMU_k is evaluated to be inefficient.

B. RM-DEA model using Cone-Ratio approach

RM-DEA limits input and output items in an evaluation axis by restricting the variable weights, then the method can include subjective information. However, this method has the problem that the optimal solution cannot be obtained when the restricting condition is strong.

Therefore, in order to avoid this problem in the previous study, the evaluation method which gives distortion in the search direction by using a valuing level $0 < \alpha_r \leq 1$ ($r=1,2,\dots,s$) is proposed.

At this time, the formula is shown below. And α_r is any number decided by the evaluator and shows valuing level to the r -th output item.

$$\begin{aligned}
 & \max \quad \theta_k \\
 & s.t. \quad \sum_{j=1}^n x_{ij} \lambda_{jk} \leq x_{ik} \quad (i = 1, 2, \dots, m) \\
 & \quad - \sum_{j=1}^n \frac{1}{\alpha_r} y_{rj} \lambda_{jk} + \theta_k y_{rk} \leq 0 \quad (r = 1, 2, \dots, s) \\
 & \quad \sum_{j=1}^n \lambda_{jk} = 1 \\
 & \quad \lambda_{jk} \geq 0, \quad \theta_k : \text{free}, \quad j = 1, 2, \dots, n
 \end{aligned}$$

The r -th output item is evaluated most at $\alpha_r = 1$, and the more α_r approaches 0, the more the r -th output item is disregarded. Therefore, the efficiency value can be calculated when α of the item that the evaluator wants to value is set as 1 and α of other items is set as any value in the range of 0 and 1. As a result in the previous study, the items which are the strength and weakness in DMU are able to be found by the change of the efficiency value when valuing level of the item is changed.

Next, Above-mentioned way to find is concretely explained by using 5 as sample data. When valuing level is given to the output item y_3 , Table 3 shows the results. And the strength and weakness of each DMU are found.

TABLE III. RESULT IN VALUING y_3

DMU	Efficiency value			
	$\alpha=1.0$	$\alpha=0.8$	$\alpha=0.5$	$\alpha=0.3$
1	0.86	0.73	0.70	0.70
2	0.92	0.74	0.46	0.39
3	1.00	0.95	0.91	0.91
4	1.00	1.00	1.00	1.00
5	1.00	0.94	0.93	0.93

Table 3 shows efficiency value when the valuing level of y_3 is set to 1, and the valuing level of other output items is set as 1, 0.8, 0.5, and 0.3. At this time the valuing level of the output item other than y_3 is α in this table.

In Table 3, DMU₄ did not show a decrease in the efficiency value even if the valuing level of the output item other than y_3 becomes small. The output item y_3 is the strength of DMU₄.

On the other hand, DMU₂ show a great decrease in the efficiency value, when the valuing level of the output item other than y_3 becomes small. Therefore, the output item y_3 is the extreme weakness of DMU₂.

Thus this paper finds out the strong and weak items in each prefecture by the change of the efficiency value when valuing level of the item is changed.

C. Improved MF-DEA

The previous study proposed MF-DEA which assigns frontier to each group, and gathering evaluation based on each frontier leads to multi-evaluation. Moreover, position in the group or relation with other groups can be considered if multiple efficiency values are compared. Fig. 2 shows the frontier formed by MF-DEA in the case of two groups.

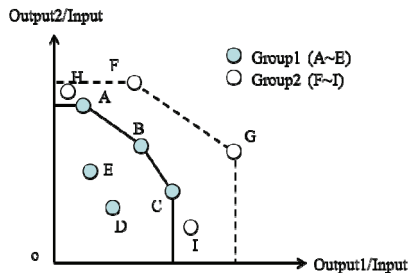


Fig. 2. Frontier formed by MF-DEA

Next, the formula of MF-DEA is described. There are p groups here. Group1 consists of α DMUs chosen optionally, group2 consists of β DMUs chosen optionally, and group p consists of γ DMUs.

$$\begin{aligned}
 \min \quad & \theta_k \\
 \text{s.t.} \quad & \theta_k x_{ik} \geq \sum_{a=1}^{\alpha} x_{ia} \lambda_a^1 + \sum_{b=1}^{\beta} x_{ib} \lambda_b^2 + \cdots + \sum_{p=1}^{\gamma} x_{ip} \lambda_p^p \quad (i = 1, 2, \dots, m) \\
 & y_{rk} \leq \sum_{a=1}^{\alpha} y_{ra} \lambda_a^1 + \sum_{b=1}^{\beta} y_{rb} \lambda_b^2 + \cdots + \sum_{p=1}^{\gamma} y_{rp} \lambda_p^p \quad (r = 1, 2, \dots, s) \\
 & \theta_k = \theta_k^1 + \theta_k^2 + \cdots + \theta_k^p \\
 & \theta_k^a x_{ik} \geq \sum_{a=1}^{\alpha} x_{ia} \lambda_a^1 \quad \theta_k^b x_{ik} \geq \sum_{b=1}^{\beta} x_{ib} \lambda_b^2 \quad \cdots \quad \theta_k^p x_{ik} \geq \sum_{p=1}^{\gamma} x_{ip} \lambda_p^p \\
 & y_{rk} \leq \sum_{a=1}^{\alpha} y_{ra} \lambda_a^1 \quad y_{rk} \leq \sum_{b=1}^{\beta} y_{rb} \lambda_b^2 \quad \cdots \quad y_{rk} \leq \sum_{p=1}^{\gamma} y_{rp} \lambda_p^p \\
 & \sum_{a=1}^{\alpha} \lambda_a^1 = \sum_{b=1}^{\beta} \lambda_b^2 = \cdots = \sum_{p=1}^{\gamma} \lambda_p^p = 1 \\
 & \theta : \text{free} \quad \lambda_a^1 \geq 0 \quad \lambda_b^2 \geq 0 \quad \cdots \quad \lambda_p^p \geq 0
 \end{aligned}$$

Here, θ_k^p indicates efficiency value based on group p , and then DMU _{k} is evaluated from p viewpoints. Objective function θ_k which is sum of the efficiency value based on each viewpoint does not have any particular meaning. Here, efficiency value based on each group is shown in Table 4 by 9 DMUs data in Fig. 2.

TABLE IV. RESULT IN MF-DEA

Group	DMU	Efficiency value based on each frontier	
		Group1	Group2
1	A	1	0.85
	B	1	0.8
	C	1	0.7
	D	0.55	0.4
	E	0.7	0.45
2	F	1.2	1
	G	1.3	1
	H	1.05	0.9
	I	1.1	0.7

Then all group1's efficiency value based on group2 and all group2's efficiency value based on group1 are remarkable. The former values are less than 1 and the latter values are over 1. This means that DMUs in group1 exists outside the frontier of group 2 and DMUs in group2 exists inside the frontier of group1. In other words, the frontier of group2 covers that of group1. The relation between frontiers can also be considered by an efficiency value in Table 4. When the former and latter values are various, they have relation as union of set. This means that these frontiers cross.

However, relation between frontiers cannot completely be considered by efficiency values. As an example, there are six DMUs which have one input and two outputs. And Table 5 shows the result. Then, all group1's efficiency value based on group2 and all group2's efficiency value based on group1 are remarkable. Because the former and latter values are various, they have relation as union of set. Therefore these frontiers cross. However, the figure cannot be uniquely determined because there are two possible cases shown in Fig. 3 and Fig. 4.

The relation between frontiers can be almost considered by only efficiency values of efficient DMUs in belonging group. However, in the case of Table 5, the relation between frontiers cannot be uniquely determined due to different interpretations on inefficient DMU_D.

TABLE V. EXAMPLE:RESULT IN MF-DEA

Group	DMU	Efficiency value based	
		Group1	Group2
1	A	1	1.1
	B	1	1.25
	C	1	1.5
	D	0.6	0.8
2	E	1.2	1
	F	1.3	1

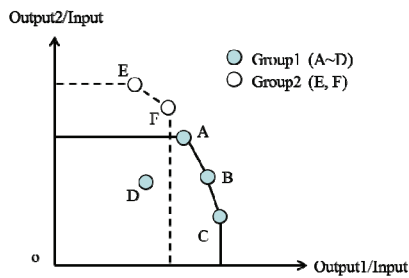


Fig. 3. Case1

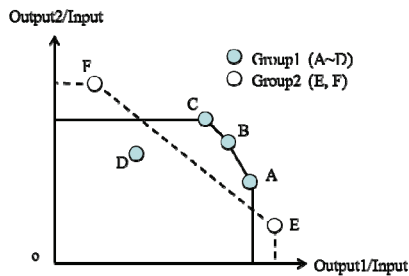


Fig. 4. Case2

Then, this paper pushes up inefficient DMUs to the frontier of its own group intentionally in order to solve this problem. Now, DMU_D moves to the frontier and then the arrival point is regarded as point D'. Here, the correction data is shown below. θ_k^* is the optimal solution calculated by BCC model.

$$\begin{aligned} x_{ik}^+ &= x_{ik} \quad (i = 1, 2, \dots, m) \\ y_{rk}^+ &= \theta_k^* y_{rk} \quad (r = 1, 2, \dots, s) \end{aligned}$$

And when MF-DEA is applied to these correction data in Fig. 5, Table 6 shows the result. Hereafter, improved MF-DEA indicates what MF-DEA is applied to these correction data.

DMU_D's efficiency value based on group2 is remarkable, and then this value is more than 1. DMU_{D'} in group 1 exists outside the frontier of group2. Therefore the relation between frontiers is shown as Fig. 5. Finally, the figure can be uniquely determined from Table 5.

TABLE VI. EXAMPLE:RESULT IN IMPROVED MF-DEA

Group	DMU	Efficiency value based	
		Group1	Group2
1	A	1	1.1
	B	1	1.25
	C	1	1.5
	D'	1	1.2
2	E	1.2	1
	F	1.3	1

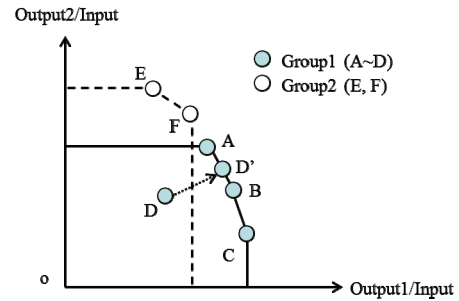


Fig. 5. Relation between frontiers in TABLE V

Thus this paper examines the relation between frontiers by using improved MF-DEA. This time position in the group is not considered. The frontier is regarded as the characteristics of its own group, and the difference between groups is described from the relation.

V. NUMERICAL EXPERIMENTS

A. Experimental conditions

Then this paper evaluates the medical care system by the following three experiments:

I. Experiment1 evaluates the medical care system based on the efficiency value, which is calculated by DEA. This time, BCC model is applied in order to notice output items. Finally, the result in this experiment compares with that in the conventional method.

II. “RM-DEA using Cone-Ratio approach” is able to find out data items which show strength and weakness. For that, there are the following three patterns in the previous study:

- The valuing level α of one output item is set as 1, and those of other output items are set as 0.8.
- The valuing level α of one output item is set as 1, and those of other output items are set as 0.5.
- The valuing level α of one output item is set as 1, and those of other output items are set as 0.3.

Experiment2 applies these patterns to every six output items and especially examines the cause of medical disparity. Here, the cause indicates data items which show the weakness of prefecture. conventional method.

III. Experiment3 makes the analysis by improved MF-DEA in order to examine medical disparity between two big regions named western and eastern Japan. Eastern Japan has total 18 prefectures including Hokkaido, Tohoku region, Kanto region and four prefectures (Niigata, Yamanashi, Nagano and Shizuoka). Western Japan has 29 prefectures of the rest. Moreover, the result in MF-DEA is not placed due to the limitation of the page space. Therefore, the comparison between the result in MF-DEA and improved MF-DEA is performed in this paper.

B. Experimental data

Data set (Table 2) in II is used. The number of DMUs is forty-seven, and each DMU has the following two inputs and six outputs:

◆Inputs

Input1 : The number of patients

Input2 : The amount of investment

◆Output

Output1 : The number of doctors

Output2 : The number of nurses

Output3 : The number of expensive equipment

Output4 : The number of beds

Output5 : The number of ICU beds

Output6 : Hospital density.

C. Experimental Result

1) Experiment 1

Table 7 shows the result in BCC model and the conventional method. Here, “The ranking of rate per 100,000 patients” indicates the results in the conventional method, and the value indicates ranking in each item. Then “score” indicates the efficiency value in BCC model, “rank” indicates the ranking in “score”.

TABLE VII. RESULT IN EXPERIMENT1

DMU	Ranking of rate value per 100,000 patients						BCC model	
	Doctor	Nurse	Bed	ICU	Equip	Density	score	rank
Hokkaido	25	8	4	9	6	47	1.000	1
Aomori	47	32	30	22	20	42	0.779	45
Iwate	43	27	25	45	12	42	0.850	35
Miyagi	39	39	38	10	30	39	0.795	43
Akita	41	28	24	37	37	39	0.839	39
Yamagata	45	31	39	33	43	34	0.689	47
Fukushima	42	22	23	14	24	45	0.850	36
Ibaraki	30	35	28	29	16	42	0.861	32
Tochigi	18	37	34	33	28	33	0.853	34
Gunma	16	20	26	43	22	25	0.883	29
Saitama	32	45	41	27	40	32	0.826	41
Chiba	23	44	43	21	39	41	0.847	37
Tokyo	1	47	47	7	46	10	1.000	1
Kanagawa	7	46	45	12	47	15	0.942	24
Niigata	46	30	37	44	30	46	0.744	46
Toyama	20	14	11	47	6	23	0.976	20
Ishikawa	8	4	7	29	1	15	1.000	1
Fukui	22	17	16	5	8	9	1.000	1
Yamanashi	19	33	22	39	34	3	0.926	26
Nagano	21	21	33	7	19	37	0.908	28
Gifu	44	43	44	14	27	28	0.792	44
Shizuoka	26	38	32	3	26	30	0.931	25
Aichi	31	40	46	33	45	37	0.878	30
Mie	40	42	40	25	36	24	0.812	42
Shiga	13	24	36	25	44	14	0.839	38
Kyoto	3	23	20	23	35	4	1.000	1
Oosaka	5	34	35	4	41	8	1.000	1
Hyogo	24	41	42	16	41	29	0.853	33
Nara	4	25	21	37	15	1	1.000	1
Wakayama	14	36	29	18	10	5	0.970	21
Tottori	11	15	19	24	23	2	1.000	1
Shimane	9	12	15	41	37	7	0.990	19
Okayama	6	18	18	2	17	26	1.000	1
Hiroshima	35	29	31	36	32	26	0.828	40
Yamaguchi	34	13	12	40	17	20	1.000	1
Tokushima	17	16	8	18	4	6	1.000	1
Kagawa	33	26	27	10	9	10	1.000	1
Ehime	38	19	17	17	21	20	0.910	27
Kochi	12	2	1	20	2	13	1.000	1
Fukuoka	10	10	13	5	32	31	1.000	1
Saga	37	11	14	32	28	18	0.868	31
Nagasaki	27	9	9	27	24	17	0.951	22
Kumamoto	29	7	6	46	14	34	1.000	1
Oita	15	5	5	31	2	19	1.000	1
Miyazaki	35	6	10	41	11	22	0.951	23
Kagoshima	28	3	2	13	5	34	1.000	1
Okinawa	2	1	3	1	13	10	1.000	1

2) Experiment 2

Table 8 shows only the result when doctor item is given valuing level due to the limitation of the page space. Table 9 extracts “Change from BCC” in the time when each item is given valuing level. Symbol (Δ) indicates the increase from efficiency value at BCC, and symbol (∇) indicates decrease. And the value beside a symbol indicates the degree of the change.

TABLE VIII. RESULT IN EXPERIMENT2

DMU	BCC($\alpha=1$)		$\alpha=0.8$		$\alpha=0.5$		$\alpha=0.3$		Change from BCC	
	score	rank	score	rank	score	rank	score	rank	$\pm$ score	$\pm$ rank
Hokkaido	1.000	1	0.909	18	0.779	29	0.779	29	$\nabla 0.22$	$\nabla 28$
Aomori	0.779	45	0.628	46	0.525	47	0.525	47	$\nabla 0.253$	$\nabla 2$
Iwate	0.850	35	0.730	40	0.660	42	0.660	42	$\nabla 0.189$	$\nabla 7$
Miyagi	0.795	43	0.724	42	0.667	40	0.667	40	$\nabla 0.128$	$\Delta 3$
Akita	0.839	39	0.783	35	0.779	30	0.779	30	$\nabla 0.059$	$\Delta 9$
Yamagata	0.689	47	0.628	46	0.621	45	0.621	45	$\nabla 0.068$	$\Delta 2$
Fukushima	0.850	36	0.724	42	0.657	43	0.657	43	$\nabla 0.192$	$\nabla 7$
Ibaraki	0.861	32	0.785	34	0.712	37	0.712	37	$\nabla 0.148$	$\nabla 5$
Totigi	0.853	34	0.797	29	0.797	26	0.797	26	$\nabla 0.055$	$\Delta 8$
Gunma	0.883	29	0.815	27	0.807	24	0.807	24	$\nabla 0.075$	$\Delta 5$
Saitama	0.826	41	0.766	38	0.748	32	0.748	32	$\nabla 0.077$	$\Delta 9$
Chiba	0.847	37	0.788	33	0.774	31	0.774	31	$\nabla 0.073$	$\Delta 6$
Toukyou	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Kanagawa	0.942	24	0.942	15	0.942	14	0.942	14	0.000	$\Delta 10$
Niigata	0.744	46	0.673	45	0.601	46	0.601	46	$\nabla 0.143$	0
Toyama	0.976	20	0.935	16	0.921	15	0.921	15	$\nabla 0.054$	$\Delta 5$
Ishikawa	1.000	1	0.972	11	0.950	11	0.950	11	$\nabla 0.049$	$\nabla 10$
Fukui	1.000	1	0.956	13	0.946	12	0.946	12	$\nabla 0.054$	$\nabla 11$
Yamanashi	0.926	26	0.877	21	0.875	18	0.875	18	$\nabla 0.05$	$\Delta 8$
Nagano	0.908	28	0.828	25	0.794	27	0.794	27	$\nabla 0.113$	$\Delta 1$
Gifu	0.792	44	0.695	44	0.638	44	0.638	44	$\nabla 0.153$	0
Shizuoka	0.931	25	0.789	32	0.723	35	0.723	35	$\nabla 0.208$	$\nabla 10$
Aichi	0.878	30	0.821	26	0.821	22	0.821	22	$\nabla 0.057$	$\Delta 8$
Mie	0.812	42	0.804	28	0.804	25	0.804	25	$\nabla 0.008$	$\Delta 17$
Shiga	0.839	38	0.839	23	0.839	21	0.839	21	0.000	$\Delta 17$
Kyouto	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Oosaka	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Hyougo	0.853	33	0.793	30	0.792	28	0.792	28	$\nabla 0.061$	$\Delta 5$
Nara	1.000	1	0.973	10	0.945	13	0.945	13	$\nabla 0.055$	$\nabla 12$
Wakayama	0.970	21	0.839	23	0.821	23	0.821	23	$\nabla 0.149$	$\nabla 2$
Tottori	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Shimane	0.990	19	0.975	9	0.975	9	0.975	9	$\nabla 0.014$	$\Delta 10$
Okayama	1.000	1	1.000	1	1.000	1	1.000	8	0.000	$\nabla 7$
Hiroshima	0.828	40	0.726	41	0.666	41	0.666	41	$\nabla 0.162$	$\nabla 1$
Yamaguchi	1.000	1	0.972	11	0.966	10	0.966	10	$\nabla 0.033$	$\nabla 9$
Tokushima	1.000	1	0.910	17	0.886	17	0.886	17	$\nabla 0.113$	$\nabla 16$
Kagawa	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Aiti	0.910	27	0.769	37	0.737	33	0.737	33	$\nabla 0.173$	$\nabla 6$
Kouchi	1.000	1	0.945	14	0.903	16	0.903	16	$\nabla 0.097$	$\nabla 15$
Fukuoka	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0
Saga	0.868	31	0.747	39	0.726	34	0.726	34	$\nabla 0.141$	$\nabla 3$
Nagasaki	0.951	22	0.792	31	0.721	36	0.721	36	$\nabla 0.23$	$\nabla 14$
Kumamoto	1.000	1	0.903	19	0.863	19	0.863	19	$\nabla 0.137$	$\nabla 18$
Ooita	1.000	1	0.885	20	0.850	20	0.850	20	$\nabla 0.149$	$\nabla 19$
Miyazaki	0.951	23	0.776	36	0.709	37	0.709	37	$\nabla 0.241$	$\nabla 14$
Kagoshima	1.000	1	0.857	22	0.709	39	0.709	39	$\nabla 0.29$	$\nabla 38$
Okinawa	1.000	1	1.000	1	1.000	1	1.000	1	0.000	0

TABLE IX. CHANGE OF RANKING IN EACH ITEM

DMU	Change of ranking					
	Doctor	Nurse	Bed	ICU	Equip	Denisty
Hokkaido	$\nabla 28$	0	0	$\nabla 9$	0	$\nabla 35$
Aomori	$\nabla 2$	$\Delta 7$	$\Delta 8$	$\Delta 18$	$\Delta 16$	0
Iwate	$\nabla 7$	$\Delta 2$	$\Delta 7$	$\nabla 11$	$\Delta 16$	$\nabla 8$
Miyagi	$\Delta 3$	$\Delta 2$	$\Delta 1$	$\Delta 30$	$\Delta 8$	$\Delta 3$
Akita	$\Delta 9$	$\Delta 16$	$\Delta 16$	$\Delta 8$	$\nabla 6$	$\nabla 3$
Yamagata	$\Delta 2$	$\Delta 4$	$\Delta 1$	$\Delta 6$	$\Delta 1$	0
Fukushima	$\nabla 7$	$\Delta 10$	$\Delta 13$	$\Delta 16$	$\Delta 9$	$\nabla 8$
Ibaraki	$\nabla 5$	$\nabla 3$	$\Delta 5$	$\Delta 2$	$\Delta 8$	$\nabla 6$
Totigi	$\Delta 8$	$\nabla 8$	$\nabla 6$	$\nabla 6$	$\nabla 6$	$\nabla 7$
Gunma	$\Delta 5$	$\Delta 1$	0	$\nabla 15$	$\nabla 1$	$\nabla 1$
Saitama	$\Delta 9$	$\nabla 4$	$\Delta 3$	$\Delta 18$	$\nabla 1$	$\Delta 10$
Chiba	$\Delta 6$	$\nabla 7$	$\nabla 6$	$\Delta 21$	$\nabla 7$	$\nabla 2$
Toukyou	0	0	0	0	0	0
Kanagawa	$\Delta 10$	$\nabla 6$	$\nabla 8$	$\Delta 13$	$\nabla 14$	$\Delta 13$
Niigata	0	$\Delta 14$	$\Delta 2$	$\nabla 1$	$\Delta 5$	0
Toyama	$\Delta 5$	$\Delta 3$	$\Delta 5$	$\nabla 25$	$\Delta 5$	$\nabla 5$
Ishikawa	$\nabla 10$	0	$\nabla 12$	$\nabla 25$	0	$\nabla 14$
Fukui	$\nabla 11$	$\nabla 14$	$\nabla 10$	0	0	$\nabla 9$
Yamanashi	$\Delta 8$	$\nabla 5$	0	$\nabla 12$	$\nabla 5$	$\Delta 18$
Nagano	$\Delta 1$	$\Delta 1$	$\nabla 7$	$\Delta 15$	$\Delta 5$	$\nabla 9$
Gifu	0	$\nabla 3$	$\nabla 3$	$\Delta 23$	$\Delta 9$	$\Delta 9$
Shizuoka	$\nabla 10$	$\nabla 14$	$\nabla 9$	$\Delta 16$	$\nabla 7$	$\nabla 9$
Aichi	$\Delta 8$	$\Delta 8$	0	$\Delta 6$	$\Delta 8$	$\nabla 2$
Mie	$\Delta 17$	$\Delta 5$	$\Delta 6$	$\Delta 17$	$\Delta 15$	$\Delta 22$
Shiga	$\Delta 17$	$\Delta 4$	$\nabla 7$	$\Delta 2$	$\nabla 9$	$\Delta 21$
Kyouto	0	$\nabla 24$	$\nabla 20$	$\nabla 21$	$\nabla 25$	0
Oosaka	0	0	0	0	$\nabla 13$	0
Hyougo	$\Delta 5$	$\nabla 3$	$\nabla 6$	$\Delta 21$	$\nabla 4$	$\Delta 5$
Nara	$\nabla 12$	$\nabla 39$	$\nabla 30$	$\nabla 38$	$\nabla 24$	0
Wakayama	$\nabla 2$	$\nabla 25$	$\nabla 20$	$\nabla 7$	$\Delta 3$	$\Delta 9$
Tottori	0	0	0	0	0	0
Shimane	$\Delta 10$	$\Delta 3$	$\Delta 5$	$\nabla 14$	$\nabla 15$	$\Delta 10$
Okayama	$\nabla 7$	$\nabla 19$	$\nabla 19$	0	$\nabla 15$	$\nabla 22$
Hiroshima	$\nabla 1$	$\Delta 11$	$\Delta 7$	$\Delta 3$	$\Delta 1$	$\Delta 13$
Yamaguchi	$\nabla 9$	0	0	$\nabla 28$	$\nabla 11$	$\nabla 12$
Tokushima	$\nabla 16$	$\nabla 22$	$\nabla 18$	$\nabla 14$	$\nabla 10$	$\nabla 6$
Kagawa	0	0	0	0	0	0
Aiti	$\nabla 6$	$\Delta 6$	$\Delta 5$	$\Delta 8$	$\Delta 6$	$\Delta 8$
Kouchi	$\nabla 15$	0	0	$\nabla 16$	0	$\nabla 15$
Fukuoka	0	0	0	0	0	$\nabla 21$
Saga	$\nabla 3$	$\Delta 12$	$\Delta 6$	$\nabla 1$	$\nabla 12$	$\Delta 13$
Nagasaki	$\nabla 14$	$\Delta 4$	$\Delta 5$	$\nabla 13$	$\nabla 11$	$\Delta 1$
Kumamoto	$\nabla 18$	0	0	$\nabla 41$	0	$\nabla 28$
Ooita	$\nabla 19$	$\nabla 12$	$\nabla 11$	$\nabla 33$	$\nabla 9$	$\nabla 23$
Miyazaki	$\nabla 14$	$\Delta 9$	$\Delta 5$	$\nabla 20$	$\Delta 6$	$\nabla 3$
Kagoshima	$\nabla 38$	0	0	$\nabla 17$	$\nabla 12$	$\nabla 32$
Okinawa	0	0	$\nabla 15$	0	$\nabla 19$	$\nabla 13$

3) Experiment 3

The tracery in Table 10 indicates the efficiency value based on belonging group, other parts indicate the efficiency value based on each group. The marking parts (*) indicate the result in CCR model as a reference because the efficiency value is not able to be calculated by cancellation error through calculation process.

TABLE X. RESULT IN EXPERIMENT3

Group	DMU	Efficiency value based on each criterion		
		Eastern Japan	Western Japan	All Japan
Eastern Japan	Hokkaido	1.000	1.388	1.000
	Aomori	1.000	0.893	0.870
	Iwate	1.000	0.868	0.850
	Miyagi	1.000	0.936	0.906
	Akita	1.000	0.839	0.839
	Yamagata	1.000	0.878	0.876
	Fukushima	1.000	0.864	0.850
	Ibaraki	1.000	0.988	0.933
	Totigi	1.000	0.903	0.886
	Gunma	1.000	0.910	0.883
	Saitama	1.000	1.053	0.949
	Chiba	1.000	1.017	0.955
	Toukyou	1.000	1.755	1.000
	Kanagawa	1.000	0.970	0.942
	Niigata	1.000	1.030	0.947
	Yamanashi	1.000	0.926	0.926
	Nagano	1.000	0.923	0.908
	Shizuoka	1.000	0.963	0.931
Western Japan	Toyama	*1.961	1.000	1.000
	Ishikawa	*1.704	1.000	1.000
	Fukui	*1.844	1.000	1.000
	Gihu	1.185	1.000	0.995
	Aichi	1.702	1.000	1.000
	Mie	2.674	1.000	1.000
	Shiga	1.778	1.000	1.000
	Kyouto	2.936	1.000	1.000
	Oosaka	1.593	1.000	1.000
	Hyougo	1.422	1.000	1.000
	Nara	1.975	1.000	1.000
	Wakayama	2.096	1.000	1.000
	Tottori	1.754	1.000	1.000
	Shimane	*1.738	1.000	1.000
	Okayama	*2.249	1.000	1.000
	Hiroshima	1.159	1.000	1.000
	Yamaguchi	*2.505	1.000	1.000
	Tokushima	*1.938	1.000	1.000
	Kagawa	3.833	1.000	1.000
	Aiti	2.063	1.000	1.000
	Kouchi	*1.505	1.000	1.000
	Fukuoka	1.895	1.000	1.000
	Saga	1.648	1.000	1.000
	Nagasaki	1.237	1.000	1.000
	Kumamoto	1.746	1.000	1.000
	Ooita	1.460	1.000	1.000
	Miyazaki	1.394	1.000	1.000
	Kagoshima	1.191	1.000	1.000
	Okinawa	2.480	1.000	1.000

D. Discussion

1) Experiment 1

BCC model and conventional method evaluate the medical care system. And these results are compared. As mentioned in II, it is difficult to apply superiority or inferiority to prefectures in consideration of plural items. For example, Kagawa and Toyama of “Ranking of rate value per 100,000 patients” in Table 7 are remarkable. Toyama’s ranking in items other than the hospital density and ICU bed item is higher place than Kagawa’s ranking. However, Toyama’s ranking is the lowest place in ICU beds item. Then, superiority or inferiority between these prefectures is not able to be evaluated. Thus, the difference between prefectures cannot be examined because there are no absolute standards in medical fields. Then according to score in Table 7, 18 prefectures are judged to be efficient because these efficiency values are 1. Therefore, these prefectures have the better medical care system.

Next, efficient prefectures are shown by using the map of Japan as Fig 6. At this time, the tracery indicates efficient prefectures. Then, because there are a lot of efficient prefectures in Kyushu and Shikoku region, these regions have the better medical care system in the whole region.



Fig. 6. Result in BCC model

On the other hand, Table 7 shows that Tohoku region has a lot of prefectures, such as Yamagata, Aomori, Miyagi, Akita, Fukushima, and Iwate whose efficiency value is low. In Fig. 6, while the other regions have at least one efficient prefecture, there is no efficient prefecture in Tohoku region. Therefore, the medical care system in Tohoku region is inferior to that in other region.

2) Experiment 2

When “valuing level α ” is given to each item, the efficiency value almost is changed. If a DMU shows great decrease in the efficiency value when the valuing level of an output item is given, the output item is the weakness. However, this great decrease is clearly not defined. Therefore, this paper evaluates the weakness from “Change of ranking” in table 9. Here, “Change of ranking” indicates “ $\pm$ rank” of “Change from BCC” in table 8. Moreover, the strength is evaluated by “change of ranking”, too.

In Table 9, let us focus on Tokyo, Tottori, and Kagawa. These prefectures did not show a decrease in the ranking, if the valuing level is given to every six output items. Here it is said that the medical care system is offered to the patient because these three prefectures do not have the weakness in any output item.

Next, Hokkaido prefecture is remarkable. When ICU bed item and hospital density item are strongly valued, these ranking decreased. Especially, 28 places are dropped in doctor item and 35 places are dropped in the hospital density item. This means that these items are weakness in this prefecture compared with other prefectures. Therefore, firstly hospital density item should be improved from the degree of ranking drop and secondly doctor item should be improved. Conversely, there was no change from 1st place when nurse, bed, and the high priced medical equipment item are strongly valued. This means that these items are the strength in this prefecture compared with other prefectures. In this way, while experiment1 is not able to find out the weakness and the strength, experiment2 is able to do those.

Miyagi is remarkable. In this case, the up of ranking happens in all items. In these ranking up, the degree of the up is the smallest in bed item. Subsequently, the degree is the second in nurse item. This means that there are a lot of prefectures where these two items are the strength compared with other items. In other word, these items are the weakness of Miyagi. Therefore, firstly bed item should be improved from the degree of ranking up and then nurse item should be improved.

3) Experiment 3

The medical disparity between western and eastern Japan is described by the relation between frontiers. Let us denote efficiency value based on each criterion as follows to simplify the discussion.

Efficiency value based on All Japan : θ

Efficiency value based on Eastern Japan : θ^E

Efficiency value based on Western Japan: θ^W

In Table 10, all prefectures in western Japan are remarkable, then θ^E is higher than θ^W . From this result, the prefectures in western Japan exist outside the frontier of eastern Japan. Therefore, the frontier of western Japan exists outside that of eastern Japan.

Next, all prefectures in eastern Japan are remarkable. θ^W is higher than θ^E in most prefectures, while θ^E is higher than θ^W in the following five prefectures: Hokkaido, Saitama, Chiba, Tokyo and Niigata prefectures. This result shows that most prefectures in western Japan exist outside the frontier of eastern Japan, these five prefectures exist outside the frontier of western Japan and these frontiers cross here.

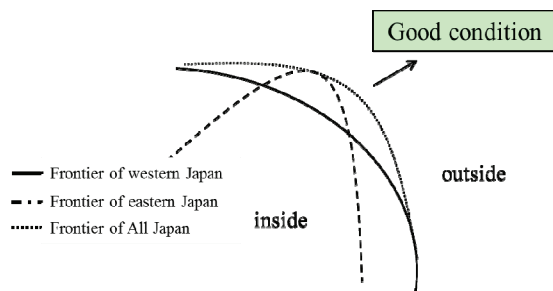


Fig. 7. Image of frontiers

As the result, the relation among frontiers is shown as Fig. 7. Therefore, western Japan has better medical care system than eastern Japan because the frontier of western Japan almost covers that of eastern Japan except for a part. Conversely, the medical care system of eastern Japan almost is inferior to that of western Japan, and there are few efficient prefectures in eastern Japan as shown Table 7. That is why, it is necessary to improve the medical care system in the entire eastern Japan.

VI. CONCLUSION

In order to evaluate the medical care system and to reveal the regional and medical disparity, this paper has applied three kinds of methods to the data published by Ministry of Health. The conventional method, ratio-comparison per 100,000 patients, could not evaluate the medical care system in each prefecture. However, the medical disparity between prefectures can have been examined by BCC model this time. And its cause has been found out by "Restricted Multipliers DEA model using Cone-Ratio approach". In addition, the regional relation between western and eastern Japan has been examined by the improved MF-DEA.

As future works, it is necessary to examine the medical disparity in a smaller region, secondary medical region, than prefecture and to reveal the disparity in a prefecture. In addition, the selection of input and output items needs to be rethought because there are a lot of data which show medical employees and equipment else.

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