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Using the DEA-R model in the hospital industry to study the pseudo-inefficiency problem

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ABSTRACT

Because of the unreasonable and unnecessary weight restriction assumption, a barely noticeable deficiency in pseudo-inefficiency occurs at times when applying a CCR model. The CCR was the first model designed for Data Envelopment Analysis (DEA); it remains its most popular model. To detect this type of unobvious deficiency, this study compared the following: the efficiency score and optimal weight set of an input oriented CCR model (CCR-I); the model with a weight restriction assumption; an input-oriented ratio-based DEA model (DEA-R-I); and the model without it. In this case study of hospitals, pseudo-inefficiency was discovered and the reason behind it determined. Further, this study proved that the DEA-R-I is a valid model. Because DEA-R-I is valid and without a weight restriction assumption, this study puts forward the DEA-R-I as a capable substitutive model for CCR-I in order to avoid pseudo-inefficiency.

1. Introduction

Improving efficiency is an important goal for all companies. Before improving efficiency, it is necessary to determine a suitable method for its measure. One of the most well-known methods, DEA, applies the concept of efficient frontier; it identifies the efficient frontier and calculates efficiency scores in order to measure efficiency. Efficient frontier is a set of efficient Decision Making Units (DMU). The DMU, derived from the efficient frontier, is referred to as the inefficient DMU. The efficient DMU, on the efficient frontier, can function as the benchmark for the progression of inefficient DMU into efficient DMU. The concept of efficient frontier is based on the non-dominated condition, as proposed by Italian economist Pareto in 1927. Koopmans applied the concept of non-dominated condition to measure efficiency in the manufacturing industry in 1951 while Farrell defined the productivity index in 1957 (Cooper, Seiford, & Tone, 2002). Charnes, Cooper, and Rhodes (1978) developed a method as well, applying linear programming to measure an efficiency score. This kind of methodology is called Data Envelopment Analysis (DEA). One of most popular DEA models is CCR, so titled as an acronym of three authors' names. DEA has been used as the representative method to calculate efficiency in many studies (Cummins & Zi, 1998; Hjalmarsson, Kumbhakar, & Heshmati, 1996; Olesen, Petersen, & Lovell, 1996; Sharma, Leung, & Zaleski, 1997). Over the past two decades, DEA has been established as a robust and valuable methodology for estimating efficient frontier (Chen & Ali, 2002).

The majority of DEA models, like CCR, are based on $(\sum vx)/(\sum uy)$ or $(\sum uy)/(\sum vx)$. These kinds of DEA models cause two kinds of deficiency: weak efficiency and pseudo-inefficiency. Weak efficiency is the misclassification of inefficient DMU as efficient DMU. This deficiency is solved by the two-phase method (Cooper et al., 2002) or SBM (Tone, 2001). At present, pseudo-inefficiency, that identifies efficient DMU as inefficient DMU, remains neglected. In practice, pseudo-inefficiency may result in some mistakes. An efficient hospital, after using CCR to evaluate its efficiency, may implement unnecessary policies or lose sight of its own strengths. Since pseudo-inefficiency is a theoretical deficiency that results in practical effects, this study attempted to determine pseudo-inefficiency, track its source, and avoid it.

The first goal of this study was to determine pseudo-inefficiency by comparing the efficiency scores of both CCR and DEA-R-I in real cases. The idea of comparing two models to determine pseudo-inefficiency was inspired by our study, which proved that the efficient score of DEA-R-I is always larger than that of the CCR-I. As well, that study showed that the weight restriction assumption is the source of the difference. Using that study, it can be inferred that the cause of the pseudo-inefficiency is also the weight restriction assumption. The weight restriction assumption concludes that the models, which are based on $(\sum vx)/(\sum uy)$, implicitly assume input and contribute equally to each output. A hospital was used

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as an example to elaborate the assumption. With regard to overall output (outpatient, hospitalization, and surgery), the relative importance of the first input (number of physicians) compared to the second input (number of sickbeds) was A:B. With regard to outpatient, hospitalization, and surgery, the actual relative importance of the first input compared the second input was C:D, E:F, and G:H, respectively. However, the assumption constrained the relative importance of physicians and sickbeds to the first, the second output, and the third output are A:B. This assumption is not only redundant but also unreasonable. While many studies have focused on the issue of weight restrictions such as assurance regions (Liu & Chuang, 2009), none of them have focused on the weight restriction assumption. This study contained the hypothesis that the assumption lead to pseudo-inefficiency in the CCR-I model. If the hypothesis holds, a valid model without a weight restriction assumption can be applied to prevent pseudo-inefficiency. Therefore, the second and third goals of this study were to validate the hypothesis and prove that the DEA-R-I model without the weight restriction assumption is valid.

This article consists of five sections to study the pseudo-inefficiency issue. In the first section, the structure of this article is introduced along with the issue of pseudo-inefficiency. Because pseudo-inefficiency is not obvious, a comparison between the CCR-I and the DEA-R-I is necessary. The two models are introduced in Section 2 and the results of the two models compared to reveal the phenomenon in Section 3. The fourth section describes the attempts to determine the model which best avoids pseudo-inefficiency. It is known that DEA-R-I does not include the assumption; however the accuracy of the DEA-R-I is not yet verified. Mathematical proof that the DEA-R-I is valid is shown in order to make the claim that DEA-R-I can provide the solution to the pseudo-inefficiency challenge. Finally, in Section 5, the study discusses the issue of pseudo-inefficiency and concludes.

2. Method

To show less than obvious pseudo-inefficiency, it is necessary to compare two kinds of models: models with and without the assumption. As a result, this study introduced CCR-I as the model with assumption and the DEA-R-I as the model without assumption, and compared their efficiency scores and optimal weight sets. In 1978, Charnes et al. developed a non-parametric method to identify efficient frontier. This method is called DEA while the first model of DEA is called CCR. The CCR-I is expressed as follows:

$$\max \quad u_1 \times y_{1o} \tag{1}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} v_i \times x_{ij} \geqslant u_1 \times y_{1j} \quad j = 1, \ldots, n \tag{2}$$

$$\sum_{i=1}^{m} v_i \times x_{io} = 1 \tag{3}$$

$$v_i, u_1 \geqslant \varepsilon > 0 \tag{4}$$

To solve the problem of weight restriction, the DEA-R-I model was developed. It is without the weight restriction assumption and, by combining DEA with the concept of ratio DEA-R-I, is expressed as Eqs. (5)–(8).

$$\max \quad \theta_o \tag{5}$$

$$\text{s.t.} \quad \sum_{i=1}^{m} \sum_{r=1}^{s} W_{ir} \frac{(X_{ij}/Y_{rj})}{(X_{io}/Y_{ro})} \geqslant \theta_o \quad j = 1, \ldots, n \tag{6}$$

$$\sum_{i=1}^{m} \sum_{r=1}^{s} W_{ir} = 1 \tag{7}$$

$$W_{ir} \geqslant 0, \quad \theta_o \geqslant 0 \tag{8}$$

It was indicated that the efficiency score of the DEA-R-I was equal or larger than the efficiency score of the CCR-I and is proof that this equation always stands. From that proof, the fact that pseudo-inefficiency occurs at times was easily inferred. For example, the efficiency score of the CCR-I was 0.9. From that proof, the DEA-R-I efficiency score of this DMU may be determined as 0.9, 0.95, or 1. When the efficiency score is 0.9 or 0.95, the DMU is still identified as inefficient DMU. However, when the efficiency score is 1, the DMU is identified as efficient DMU. In the latter situation, pseudo-inefficiency occurs, in which the CCR identifies efficient DMU as inefficient DMU. The next section describes how this study applied these two models to real cases and compare the results in order to observe and search for the cause of pseudo-inefficiency.

3. The comparison of two models

This section will illustrate how this study evaluated the performance of Taiwan medical centers in 2005 by its use of CCR-I and DEA-R-I models. Like other studies (Ballestero & Maldonado, 2004; Katharaki, 2008), this study chose the hospital industry as its example. The first reason for using the hospital industry as a case is because the results of the evaluation can be well interpreted into practice. The more important reason however, is because hospitals in Taiwan must improve their efficiency; their budgets are controlled by the government both to remain competitive and to avoid the waste of limited resources. The data shown in Table 1 was collected by the Department of Health. All 21 medical centers, at the highest levels of the hospital industry, were selected as the DMUs for evaluation. These medical centers include 7 public hospitals (33%) and 14 private hospitals (67%). Two inputs and three outputs were chosen. The input items were the number of beds and the number of physicians. Output items were the number of outpatients (ten thousand/year), the number of inpatient days (ten thousand/year), and the number of surgeries (thousand/year). Take DMU 4 for an example: in 2005, DMU 4 used 2,902 sickbeds and employed 973 physicians to service 2,596,143 outpatients, 855,467 inpatients, and 75,348 surgeries. The correlation between input and output variables is provided in Table 2. The correlation between input and output variables is not smaller than 0.7 while the numbers for both input and output are less than half the number of DMU. Drawing from experience, the selection of variables was not difficult.

3.1. Efficiency score of medical centers

To observe the pseudo-inefficiency of CCR, the efficiency scores of each medical center were compared. DEA-Solver software was used to calculate the efficiency score of CCR and Excel was used to determine the efficiency score of DEA-R. Due to budget limitations in Taiwan, this study applied the input orientations of models to assist DMU in developing both strategies. The results were shown in Table 3. If an efficiency score of DMU is less than 1, the DMU is not efficient and reducing input can help this DMU become efficient. The new input, after reduction, is equal to the original input × the efficiency score of DMU. Take DMU 4 for example. By using the CCR-I model, the efficiency score of DMU 4 was 0.998. So, the CCR-I suggested that DMU 4 reduce sickbeds from 2902 to 2896 (.196) and physicians from 973 to 971 (.054). The efficiency score of DMU 4 provided by DEA-R-I was 1. This means that DMU 4 was efficient and did not require an improvement strategy. This result was evidence of the possibility of pseudo-inefficiency. To further explain the cause of pseudo-inefficiency in CCR, the optimal weight sets of two models were compared.

Table 1
The input and output variables of Taiwan medical centers in 2005.

DMU	Sickbed	Physician	Outpatient	Inpatient	Surgeries	DMU	Sickbed	Physician	Outpatient	Inpatient	Surgeries
01	2618	1106	2,029,864	680,136	38,714	11	920	316	334,090	268,723	15,130
02	1212	473	1,003,707	297,719	18,575	12	3236	1023	1,954,775	920,215	56,167
03	1721	531	1,592,960	408,556	36,658	13	495	130	332,741	136,351	23,423
04	2902	973	2,596,143	855,467	75,348	14	1759	491	1,465,374	430,407	35,599
05	1389	447	1,116,161	337,523	23,803	15	1357	390	1,277,752	368,174	36,006
06	1500	547	1,476,282	378,658	22,503	16	2468	675	1,825,332	668,467	32,275
07	340	145	1,300,016	55,003	5614	17	962	316	550,700	247,961	15,618
08	571	305	1,052,992	199,780	26,026	18	745	272	1,277,899	217,371	11,671
09	1168	369	1,849,711	326,109	30,967	19	1662	590	1,916,888	418,205	21,551
10	921	372	1,089,975	209,323	23,847	20	898	275	698,945	209,134	11,748
						21	1708	537	1,702,676	470,437	32,218

Table 2
Correlation of input and output variables.

	I-1	I-2	O-1	O-2	O-3
I-1	1.000	0.956	0.774	0.990	0.828
I-2	0.956	1.000	0.775	0.945	0.781
O-1	0.774	0.775	1.000	0.769	0.719
O-2	0.990	0.945	0.769	1.000	0.863
O-3	0.828	0.781	0.719	0.863	1.000

Table 3
Efficiency of medical centers.

DMU	CCR-I	DEA-R-I	DMU	CCR-I	DEA-R-I
01	0.814	0.814	11	0.981	0.981
02	0.791	0.792	12	0.980	0.980
03	0.835	0.843	13	1.000	1.000
04	0.998	1.000	14	0.884	0.908
05	0.835	0.842	15	0.972	0.986
06	0.835	0.842	16	0.975	0.980
07	1.000	1.000	17	0.878	0.878
08	1.000	1.000	18	1.000	1.000
09	1.000	1.000	19	0.850	0.855
10	0.736	0.746	20	0.815	0.822
			21	0.959	0.968
			Avg.	0.911	0.916

3.2. Optimal weight set of medical centers

To reveal the source of pseudo-inefficiency in CCR, the optimal weight sets of two models were compared. These weight sets are shown in Table 4. There were many reasons to make distinctions between CCR-I and DEA-R-I. First, the weight which DEA-R-I can choose is more than the weight which CRR-I can choose. In this case, CCR could choose an optimal weight set from five different weights ($v1$ is the weight of Sickbed, $v2$ is the weight of physician, $u1$ is the weight of Inpatient, $u2$ is the weight of Outpatient, $u3$ is the weight of Surgery) while DEA-R-I could choose an optimal weight set from six different weights (w_{11} is the weight of the ratio of Sickbed/Inpatient, w_{12} is the weight of the ratio of Sickbed/Outpatient, w_{13} is the weight of the ratio of Sickbed/Surgery, w_{21} is the weight of the ratio of Physician/Inpatient, w_{22} is the weight of the ratio of Physician/Outpatient, w_{23} is the weight of the ratio of Physician/Surgery); in other words, the area of research for DEA-R-I is broader than that of CCR-I. This is the first reason why the efficiency score of DEA-R-I is larger than that of CCR-I. Although more weight requires a longer time to compute, the DMU and variable is not too large in most cases; both CCR-I and DEA-R-I are linear models. Therefore, this study concludes that the DEA-R-I model is a suitable model for avoiding pseudo-inefficiency.

Table 4
The weight of efficient DMU which CCR cannot identify.

	v_1x_1	v_2x_2		u_1y_1	u_2y_2	u_3y_3
CCR-I	0.689	0.311		0.000	0.998	0.000
	w_{11}	w_{12}	w_{13}	w_{21}	w_{22}	w_{23}
DEA-R-I	0.064	0.571	0.000	0.000	0.365	0.000

In cases which have two inputs and two outputs or only one input or output, the efficiency score of DEA-R-I is also bigger than that of CCR-I. For example, because all the weights of Surgery are 0 for DMU 4, they could be considered as two inputs and two output cases. In this situation, the weights for which DEA-R-I could choose were equal to the weights for which CRR-I could choose; however the efficiency score of DEA-R-I was still bigger than that of the CCR-I. For this kind of case, a different identification may be associated with the second reason. The results of this study inferred that the second reason for pseudo-inefficiency is the redundant weight restriction assumption in CCR. Take the Data of Table to illustrate this assumption. The optimal weight set of DEA-R-I showed that sickbed for outpatient, sickbed for inpatient, and physician to provide inpatient care, were advantages of for DMU 4. This weight set showed that there were no constraints between w_{11}:w_{12} and w_{21}:w_{22}. But in CCR, the advantages of DMU 4 were found only in sickbed, physician, and inpatient. This means that sickbed for inpatient, and physician to provide inpatient were advantages of DMU 4 but not sickbed for outpatient. In other words, the CCR set constraint that the advantage of sickbed to provide outpatient must equal sickbed to provide inpatient. In a word, the weight set of CCR showed that there were constraints between w_{11}:w_{12} and w_{21}:w_{22}. This caused not only pseudo-inefficiency but also the interpretation of weight in practice. This problem of weight restriction is well described in our study. This study not only revealed pseudo-inefficiency by comparing efficiency scores but it also detected the reasons for pseudo-inefficiency by analyzing the optimal weight set.

4. The efficient frontier of DEA-R-I

After revealing the pseudo-inefficiency and the reason for pseudo-inefficiency in the CCR model, the next step was to look for a suitable model to avoid pseudo-inefficiency. If this is not done, someone may challenge the validation of the DEA-R-I and claim its classification is wrong and that the pseudo-inefficiency did not occur. So, in this section, DEA-R-I is validated both to answer the challenge and assert that DEA-R-I is a solution for pseudo- inefficiency. To show that the DEA-R-I model is valid, this study determined that the efficient frontier, which is identified by DEA-R-I, is the same as the efficient frontier identified by the graph method. The proof indicates that the efficient frontier derived from DEA-R-I can be drawn in the real world and that the identification of efficient DMU using DEA-R-I is accurate. The first part of this section demonstrates how to identify the efficient frontier using the graphic method. Subsequently, it will be proved that the efficient frontier derived by using DEA-R-I is the same as the efficient frontier derived by using the graphic method.

4.1. Efficient frontier derived by graphic method

There are three steps to deriving efficiency frontier using the graphic method. The steps are: (1) Plot DMU into an input orient ratio base coordinate system; (2) Derive the production possibilities; (3) Derive the efficient frontier according to definition. After deriving the efficient frontier, the efficiency score can also be derived using the graphic method.

Step 1: Plot DMU into an input orient ratio base coordinate system
The 'input-oriented ratio-based coordinate system' takes X_i/Y_r as AXIS_{ir}. Taking the data of Table 5 as an example, the ratio X_1/Y_1 of DMU A is 1/4 and the ratio X_1/Y_2 of DMU A is 1/3. If we take X_1/Y_1 as the horizontal axis and X_1/Y_1 as the vertical axis, we can plot DMU A (1/4, 1/3) into an input-oriented ratio-based coordinate system as shown in Fig. 1. It is the same for DMU B, C, and D. The result is shown in Fig. 1.

Step 2: Derive the production possibilities
Before deriving the efficient frontier, introducing the concept of production possibilities is necessary. Production possibilities are the set that includes all points, which linearly combine by any known points. For example, A′(5/23, 20/69) of Fig. 1, which is one of the combinations of point C and D, is a production possibility. According to the definition, all points inside the quadrilateral of *ABCD* in Fig. 1 are production possibilities. It must be confirmed on the piecewise linear production possibility set assumption in order to derive production possibilities. A more detailed explanation of assumption can be found in Cooper et al. (2002).

Table 5
One input two output data.

DMU	Input		Output	
	X_1	X_2	Y_1	Y_2
1(A)	2.0	–	4.0	3.0
2(B)	2.0	–	3.0	5.0
3(C)	2.0	–	4.2	4.2
4(D)	2.0	–	5.0	3.0

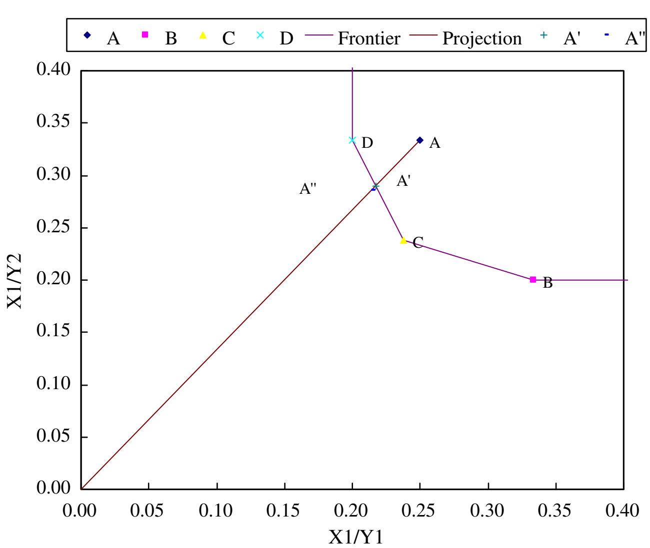

Fig. 1. Efficient frontier derived by graphic method in input-oriented ratio-based coordinate system.

Step 3: Derive the efficient frontier
Because input-oriented ratios X_i/Y_r were taken as AXIS_{ir}, the closer point to the origin point of every angle is more efficient. So, the efficient frontier in an input-oriented ratio based coordinate system, abbreviated to frontier-R-I, is defined as the set of the **closest** production possibilities to the origin point in every angle. For example, for Angle A, the closest point of the production possibilities to the origin point is point A. According to the definition, the derived broken-line $\overline{BCD}$ in Fig. 1 is the frontier-R-I of data in Table 5.

4.2. Mathematic proof: efficient frontier derived by DEA-R-I is the same as graphical method

To ensure the identification of efficient DMU using DEA-R-I is accurate and that DEA-R-I is a valid model, this study aspired to prove that the efficient frontier derived from the DEA-R-I model is the same as the efficient frontier derived from using the graphic method. This proof indicates that the efficient frontier of DEA-R-I exits in the real world. Frontier-R-I is the efficient frontier derived using the graphic method. E_j is the plane formed by reference set $(j', j'' \ldots)$ of *object*. The L_I is the line that includes the *object* $[(X_{1o}/Y_{1o}), \ldots, (X_{io}/Y_{ro})]$ and origin. The *object*′ is the intersection of the planeE_j and the lineL_I. And, *projection* is the projection for which DEA-R-I suggests DMU improve to. To show the consistency between frontier-R-I and frontier derived by using DEA-R-I, proving that *object*′ and *projection* are the same point is necessary. In other words, this study wants to prove *projection* in on E_j and L_I.

Proof 1. It is known that when j' is one DMU of a reference set, $\sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir}\left(X_{ij'}/Y_{rj'}\right)/(X_{io}/Y_{ro})$ is equal to θ_o in Eq. (6). Then, any two reference DMUs can be combined to obtain: $\sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir}\left(X_{ij'}/Y_{rj'}\right)/(X_{io}/Y_{ro}) = \theta_o = \sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir}\left(X_{ij''}/Y_{rj''}\right)/(X_{io}/Y_{ro})$. After transposition, Eq. (9) would be obtained.

$$\sum_{i=1}^{m}\sum_{r=1}^{s}\frac{W_{ir}}{(X_{io}/Y_{ro})}\left(\frac{X_{ij'}}{Y_{rj'}}-\frac{X''_{ij}}{Y''_{rj}}\right)=0 \tag{9}$$

Eq. (9) signifies that $[W_{11}/(X_{1o}/Y_{1o}), \ldots, W_{ir}/(X_{io}/Y_{ro})]$ is the normal vector of the plane having points $j'\lfloor X_{1j'}/Y_{1j'}, \ldots, X_{ij'}/Y_{rj'}\rfloor$ and $j''\lfloor X_{1j''}/Y_{1j''}, \ldots, X_{ij''}/Y_{rj''}\rfloor$, It is easy to analogize this progression for all reference points and get all reference points are in the same plane, which has point j' and normal vector $[W_{11}/(X_{1o}/Y_{1o}), \ldots, W_{ir}/(X_{io}/Y_{ro})]$:

Subsequently, by multiplying both sides of Eq. (7) $\sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir} = 1$ by θ_o, we obtain: $\theta_o \sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir} = \theta_o = \sum_{i=1}^{m}\sum_{r=1}^{s} W_{ir}\left(X_{ij'}/Y_{rj'}\right)/(X_{io}/Y_{ro})$. After transposition, we get Eq. (10).

$$\sum_{i=1}^{m}\sum_{r=1}^{s}\frac{W_{ir}}{(X_{io}/Y_{ro})}\left[\frac{X_{ij'}}{Y_{rj'}}-\theta_o\frac{X_{io}}{Y_{ro}}\right]=0 \tag{10}$$

Eq. (10) means that the point *projection* is included in the planeE_j, which has point j' and normal vector $[W_{11}/(X_{1o}/Y_{1o}), \ldots, W_{ir}/(X_{io}/Y_{ro})]$. From the mean of Eqs. (9) and (10), we know reference set $(j', j'' \ldots)$, and *projection* are on the same plane E_j.

Furthermore: $\frac{\theta_o(X_{1o}/Y_{1o})-0}{X_{1o}/Y_{1o}-0} = \cdots = \frac{\theta_o(X_{io}/Y_{ro})-0}{X_{io}/Y_{ro}-0} = \theta_o$; the line L_I, which has the *object* $[(X_{1o}/Y_{1o}), \ldots, (X_{io}/Y_{ro})]$ and origin, has *projection* $[\theta_o(X_{1o}/Y_{1o}), \ldots, \theta_o(X_{io}/Y_{ro})]$.

As a result, this study proved that the *projection* was on the Frontier-R-I and that *projection* is the same as *object*′. It was also derived from this proof that the efficiency score of DEA-R-I was equal to the efficiency score of Frontier-R-I, which was $\overline{oO'}/\overline{oO}$ (o is origin) = θ_o. According to the above proof, DEA-R-I is a valid model.

In Section 3, this study stated the weight choice of DEA-R-I was broader and more flexible than CCR-I. Combining the descriptions in Sections 3 and 4, this study claims that the DEA-R-I is a suitable model for avoiding pseudo-inefficiency. □

5. Conclusion

There were three main idea presented in this article. First, by reference to other studies on the subject of weight restriction, it can be concluded that CCR not only underestimates the efficiency score of inefficient DMU, but also identifies efficient DMU as inefficient. Because this mistake, referred to as pseudo-inefficiency, was not obvious, this study compared CCR-I with DEA-R-I. DEA-R-I does not include a weight restriction assumption to detect pseudo-inefficiency. When this study applied DEA-R-I and CCR-I models to evaluate the performance of medical centers in Taiwan, the pseudo-inefficiency was discovered. Second, this study determined the reason for pseudo-inefficiency by comparing the optimal weight sets of two models. The data indicated that the cause of pseudo-inefficiency is the number of weight as well as the weight restriction assumption. Third, this study validated the DEA-R-I model and claimed that it can be a substitutive model for CCR-I in order to avoid pseudo-inefficiency.

Finally, this study depicted some influences of pseudo-inefficiency in practice and defined the future issues surrounding pseudo-inefficiency. Take the health industry in Taiwan for example. To control expenditures, the Bureau of National Health Insurance in Taiwan not only applies the total budget system but also demotes inefficient hospitals. Because the payment of each patient decreases after demotion, hospitals take demotion seriously. Hospitals not only face a decrease in total income but they also need to change strategy after a demotion. Take the medical center studied in Section 3 as an example of strategy change. Because the payment for each patient decreased and doctors were required to spend more time on outpatient service, doctors could not spend as much time on research; the hospital strategy required a shift from research to the servicing of more patients. Because the influence of demotion looms so large, the accuracy of evaluation, especially inefficiency, is highly important and pseudo-inefficiency does not allow for occurrence. Another example is in the electric industry. After the global financial crisis of 2008 and the decrease in demand for electricity, the government wanted DRAM companies to merge in order to improve efficiency and competence. However, no efficient company wants to be identified as an inefficient unit and be sold at a low price. So, the deficiency of CCR, like pseudo-inefficiency, can not be sneezed at; the problem of pseudo-inefficiency must be studied and solved. Two future issues can be derived from this article. The first concerns super efficiency. The differences between CCR and DEA-R-I had already been discussed when the DMU was identified as inefficient by CCR. However, the differences between CCR and DEA-R-I were not discussed when the DMU was identified as efficient DMU by CCR. So, the concept of super efficiency can be introduced to study the differences between CCR and DEA-R-I. This study can help companies understand the areas of advantage and the degree with which they can be so. Moreover, the concept of two phases of SBM can be applied to DEA-R-I to simultaneously avoid weak efficiency and pseudo-inefficiency.

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