An Explanation for the Paradox Phenomenon in Taiwan's Bank Performances

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Abstract

A traditional DEA (data envelopment analysis) model is useful for estimating the best performances for a successful and a more efficiency DMU (decision-making unit). This study uses a traditional DEA model to estimate the efficiency score of bank z in Taiwan and get a good efficiency score based on the 2006 data, however the bank z was taken over by the government in early 2007. In illustrating this paradox phenomenon, the study reconsiders the tradition DEA model by contributing a worst-practice frontier under a traditional DEA model. Findings: the bank z is located on the intersection of the worst-practice frontier and the traditional DEA model frontier. This study provides a critical determinant of a bank's failure that a bank has a location such as the bank z.

Keywords: performance, efficiency, worst-practice frontier, bank's failure

1. Introduction

Measuring the efficiency of a decision making unit (DMU) is one of the major objectives of data envelopment analysis (DEA). Farrell (1957) builds a DEA methodology to estimate the ratio efficiency of a DMU through some specific mathematical programming models. Following Charnes et al. (1978) and Banker et al. (1984), the operations research and management science (OR/MS) researchers, economists, and experts apply the DEA methodology into their respective disciplines (Førsund and Sarafoglou, 2002, 2005). DEA can estimate the relative efficiency of bank without assuming a prior production function (Chebat et al., 1994), and provides a single efficiency score for each estimated bank based on multiple input and/or multiple output variables (Bauer et al., 1998).

In the DEA framework, excesses in inputs and shortfalls in outputs are called as slacks. Charnes et al. (1985) create an additive DEA model in which the slacks are used to calculate the efficiency value of DMU. The literature that attempts to define inefficiency based on the slacks includes Russell (1985), Pastor (1996), Lovell and Pastor (1995), Torgersen et al. (1996), Cooper and Tone (1997), and Sueyoshi and Goto (2011). Meanwhile, some studies turn the ratio efficiency and the slacks into a scalar measure (Tone, 1993).

Harris and Ogbonna (2001) use efficiency and effectiveness to be a criterion for estimating the DMU's performance. All DEA papers above are to indentify the DMU performances in the most favorable scenario in which the best efficient DMU construct a best-practice frontier as "best-practice frontier" DEA, i.e., BPF-DEA or call as the traditional frontier (Liu and Chen, 2009). The main contribution in the paper of Liu and Chen (2009) is to define the bad performances such as bankrupt firms in the most unfavorable scenario in which the worst efficient DMUs construct a worst-practice frontier as "worst-practice frontier" DEA, i.e., WPF-DEA. The journal papers basing on the DEA approaches to estimate the performance in the worst efficiency only include Paradi et al. (2004) and Liu and Chen (2009). The past literature has a lack of the discussion in the issue of WPF-DEA, but this study can provide a theoretical example and an empirical example to illustrate the importance of the issue of WPF-DEA. Table 1 provides a theoretical example comes.

Table 1. A theoretical example

Index	Notation	DMU							
		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
Input 1	x_1	4	7	8	4	1	4	6	3
Input 2	x_2	3	3	1	2	5	6	3	5
Output	y	1	1	1	1	1	1	1	1

Source: Liu and Chen (2009)

Figure 1 includes the locations of all DMUs. DMUs *C*, *D*, and *E* are located on the best-practice frontier. In the BPF-DEA model, they are evaluated as efficient DMUs, and the other DMUs, i.e., *A*, *B*, *F*, *G*, and *H*, are less efficient DMUs which are far from the best-practice frontier. In the WPF-DEA model, DMUs *B*, *C*, and *F* are estimated as the worst efficient DMUs which are located on the worst-practice frontier. The other DMUs, i.e., *A*, *D*, *E*, *G*, and *H*, are far from the worst-practice frontier, thus they are more efficient in comparison with the worst efficient DMUs.

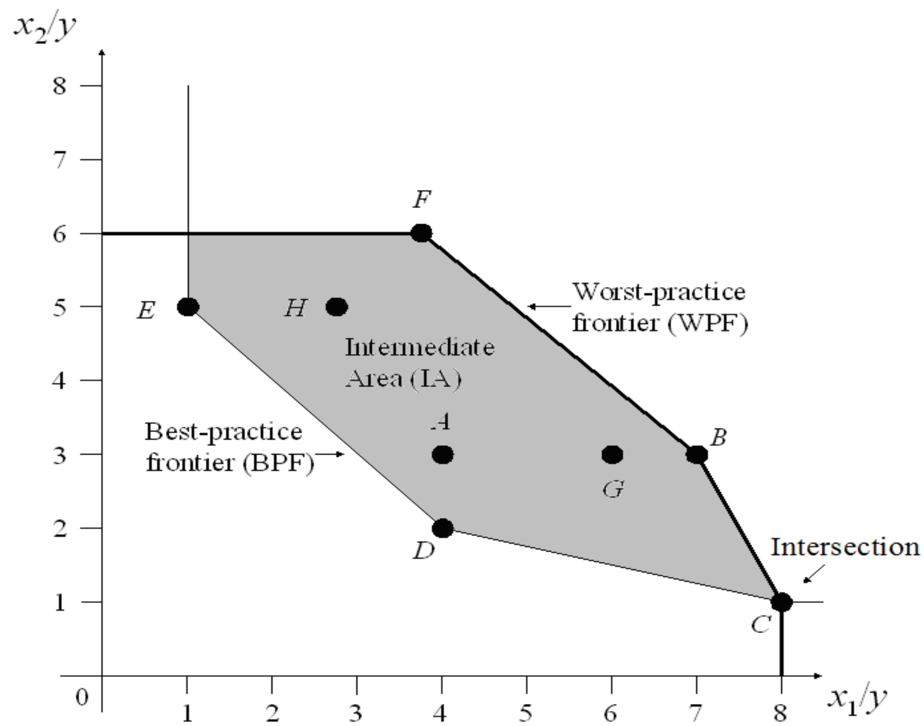

Figure 1. The best-practice frontier and the worst-practice frontier

In Figure 1, DMU *C* is not only located on the best-practice frontier but also on the worst-practice frontier. Hence, we wonder whether DMU *C* is an efficient DMU or the worst efficient DMU.

To answer this question, we use a local bank in Taiwan as example. Bank *z* in Taiwan has a good performance in 2006 (as viewable in Table 5); however, this bank was taken over by the government in early 2007 since the bank suffered from a bank-run. Based on this situation, bank *z* is not only located on the best-practice frontier but also on the worst-practice frontier such as DMU *C* in Figure 1. Many past studies have concluded that the bank failure has been related to the profit performance of the banks (Akhigbe and Madura, 2001; Cannella et al., 1995; Chen, 1999; Miller, 1996; Thomson, 1991), but there are only two studies investigate the relationship between efficiency and bank failure (Siems, 1992; Luo, 2003). Siems (1992) suggests that profitability efficiency or management quality is a critical determinant of a bank's failure. Luo (2003) finds that the overall technical efficiency of the profitability performance can predict the likelihood of bank's failure. The purpose of our study is to suggest another viewpoint of estimating the likelihood of bank's failure by applying the WPF-DEA model.

The remaining structure of this study has the following structure. Section 2 describes the traditional DEA model provided by Banker et al. (1984) called as BCC model. On the other hand, the WPF-BCC model is also provided.

Section 3 presents the data set and the variables utilized. Section 4 discusses the results of the BCC model and the WPF-BCC model. Section 5 concludes with a summary of the empirical results.

2. Methodology

The traditional DEA model such as BCC model provided by Banker et al. (1984) is a linear programming model that formulates the best-practice frontier which consists of efficient DMU. The efficiency score reflects the ability of DMU to generate the maximum outputs under a given level of inputs. On the contrary, a worst efficiency score for a DMU generates the minimum outputs under a given level of inputs.

2.1 BCC Model

DMU_i stands an evaluated entity which efforts to create a maximum output under a given level of inputs. The efficiency score of each DMU_i (θ_i) metric comes from the ratio of all outputs over all inputs. BCC model proposed by Banker et al. (1984) is as follows:

$$\text{Max } \theta_i = \frac{\sum_{t=1}^{T} u_t y_i^t - u_0}{\sum_{s=1}^{S} v_s x_i^s}$$

$$\text{s.t. } \frac{\sum_{t=1}^{T} u_t y_j^t - u_0}{\sum_{s=1}^{S} v_s x_j^s} \le 1,\ j = 1,\dots, N,$$

$$v_s,\ u_t \ge 0,\ s = 1,\dots, S,\ t = 1,\dots, T,$$

$$u_0 \in R. \tag{1}$$

The variables x_j^s, y_j^t stand for the sth input and the tth output that are used and produced by the jth DMU. The total DMU number, total input number, and total output number are N, S, and T, respectively. The variables v_s and u_t are the weights of sth input and tth output, respectively. The variable u_0 is an interception term that $u_0 > 0$, $u_0 = 0$, and $u_0 < 0$ represent that the efficiency frontier is the decreasing returns to scale (DRS), constant returns to scale (CRS), and increasing returns to scale (IRS), respectively. The sign of u_0 captures the main character of BCC model that its efficient frontier belongs to variable returns to scale (VRS).

The number of optimal solution combination on the weights of input and output (v_s^*, u_t^*) in Equation (1) is infinite. For obtaining the only one optimal solution in BCC model, we impose the constraint $\sum_{s=1}^{S} v_s x_i^s = 1$ in Equation (1), which provides:

$$\text{Max } \theta_i = \sum_{t=1}^{T} u_t y_i^t - u_0$$

$$\text{s.t. } \sum_{s=1}^{S} v_s x_i^s = 1$$

$$\sum_{s=1}^{S} v_s x_j^s - \sum_{t=1}^{T} u_t y_j^t + u_0 \ge 0,\ j = 1,\dots, N,$$

$$v_s,\ u_t \ge 0,\ s = 1,\dots, S,\ t = 1,\dots, T,$$

$$u_0 \in R. \tag{2}$$

The duality solution of BCC model is used to measure the efficiency score θ_i for DMU_i is shown as:

$$1/\theta_i = \text{Min } \phi_i$$

$$\text{s.t. } \sum_{j=1}^{N} \lambda_j x_j^s - \phi_i x_i^s \ge 0,\ s = 1,\dots, S,$$

$$\sum_{j=1}^{N} \lambda_j y_j^t - y_i^t \le 0,\ t = 1,\dots, T,$$

$$\sum_{j=1}^{N} \lambda_j = 1, \text{ for } \forall\ \lambda_j \ge 0. \tag{3}$$

The variable ϕ_i is an inverse efficiency score of DMU$_i$; in other words, the efficiency score θ_i of DMU$_i$ is $1/\phi_i$.

2.2 WPF-BCC Model

The purpose of the WPF-BCC model is different with BCC model since the former is to examine how bad a DUM's performance could possibility be in a worst scenario. Hence, the objective function in WPF-BCC model is to minimize the efficiency score of DMU. In WPF-BCC model, the DMUs with the worst efficiency are located on the worst-practice frontier and the DMUs with more efficient are far from the worst-practice frontier. For establishing a worst-practice frontier, we formulate WPF-BCC model below:

$$\text{Min } h_i = \frac{\sum_{t=1}^{T} u_t y_i^t - u_0}{\sum_{s=1}^{S} v_s x_i^s}$$

$$\text{s.t. } \frac{\sum_{t=1}^{T} u_t y_j^t - u_0}{\sum_{s=1}^{S} v_s x_j^s} \geq 1,\ j = 1,\ldots, N,$$

$$v_s, u_t \geq 0,\ s = 1,\ldots, S,\ t = 1,\ldots, T,$$

$$u_0 \in R. \tag{4}$$

The two main difference between BCC model and WPF-BCC model are (i) WPF-BCC model is to minimize the objective function; (ii) the constraint for the ratio scales of the weighted sum of the outputs to that of the inputs in WPF-BCC model should larger than or equal to 1.

We translate the fractional programming in Equation (4) into the following linear programming as follows:

$$\text{Min } h_i = \sum_{t=1}^{T} u_t y_i^t - u_0$$

$$\text{s.t. } \sum_{s=1}^{S} v_s x_i^s = 1$$

$$\sum_{s=1}^{S} v_s x_j^s - \sum_{t=1}^{T} u_t y_j^t + u_0 \leq 0,\ j = 1,\ldots, N,$$

$$v_s, u_t \geq 0,\ s = 1,\ldots, S,\ t = 1,\ldots, T,$$

$$u_0 \in R. \tag{5}$$

The duality solution of WPF-BCC model is used to measure the efficiency score θ_i for DMU$_i$ is shown as:

$$1/h_i = \text{Max } \varphi_i$$

$$\text{s.t. } \sum_{j=1}^{N} \lambda_j x_j^s - \varphi_i x_i^s \geq 0,\ s = 1,\ldots, S,$$

$$\sum_{j=1}^{N} \lambda_j y_j^t - y_i^t \leq 0,\ t = 1,\ldots, T,$$

$$\sum_{j=1}^{N} \lambda_j = 1,\ \text{for } \forall\ \lambda_j \geq 0. \tag{6}$$

In the WPF-BCC model, the optimal efficiency score φ_i^* of DMU*i* is not less than 1. And the more efficient the DMU is, the higher the efficiency score will be. $\phi_i^* = 1$ represents that the DMU*i* is the worst efficient.

2.3 Variables and Data

This study follows the article of Kao and Liu (2004) to consider three output factors – total loans, interest income, and non-interest income; and three input factors – total deposits, interest expenses, and non-interest expenses. We referred to the 2006 data which includes 28 commercial banks in Taiwan. All variable data are obtained from Taiwan Economic Journal Co. Ltd and were showed in Table 2.

Table 2. Data set

Bank	Total Loans	Interest Income	Non-interest Income	Total Deposits	Interest Expenses	Non-interest Expenses
1	9949004	247094	57537	1021949	129793	126519
2	10733523	299098	46383	1218813	165739	204737
3	11376596	317947	47193	1281473	172087	242758
4	10095851	293450	72272	1054245	190943	150572
5	1527592	30928	6437	165924	14379	28008
6	2204190	55127	6422	239796	21830	65743
7	9666212	366101	156522	1127463	152548	998044
8	7646072	267069	114931	882230	104155	321723
9	6913189	272629	172493	775743	149105	379949
10	1519886	70254	7961	145462	24160	100526
11	8547871	181819	101324	794951	100612	213067
12	1201077	26293	8112	118756	13716	24931
13	1794348	99880	15788	191087	28109	141984
14	4117899	140932	170728	755549	93019	299625
15	4818838	129076	106027	518957	67726	328514
16	2692910	70302	20792	267418	31813	94650
17	6291581	273542	557203	620027	90728	1434310
18	2616682	75107	23138	250095	40195	132705
19	2717238	86090	16669	252352	36675	223148
20	2444741	73371	59035	222111	34419	137765
21	895137	43286	12741	106456	18329	64969
22	2508675	76992	17204	286922	29008	111257
23	2040497	46270	4646	212951	21744	38255
24	2190725	73661	48895	200233	28390	197716
25	821664	17087	2245	85686	7318	15615
26	18270859	357268	69672	1822979	228439	207890
27	1690972	36878	16112	156530	18221	41848
28	2758271	88112	35233	354848	43122	56825

1. Unit: One hundred thousand New Taiwan dollars
2. Data sources: Taiwan Economic Journal Co. Ltd (http://www.finasia.biz/ensite/Default.aspx?TabId=121)

The descriptive statistics for six variables are shown in Table 3.

Table 3. Descriptive statistics table

Variables	Average	Max	Min	Standard deviation
Outputs				
Total loans	5001861	18270859	821664	4304131
Interest income	146988	366101	17087	114221
Non-interest income	70490	557203	2245	108321
Inputs				
Total deposits	540393	1822979	85686	458606
Interest expenses	73440	228439	7318	64293
Non-interest expenses	227988	1434310	15615	302175

The standard deviation of the total loans for 28 commercial banks in Taiwan is larger than that of the total deposits. This result implies that there is a large difference between the size of total loans and the size of total deposits among the samples. The standard deviation of the interest expense is small. This result implies that the bank's cost in interest expenses is seriously controlled.

3. Empirical Results

This section uses the BCC model and WPF-BCC model to analyze the real data of the 28 commercial banks in Taiwan and then to illustrate a phenomenon that bank *z* in Taiwan has a good efficiency score in 2006, but the bank z was taken over by the government in the early 2007.

We firstly calculate the efficiency score for each DMU in Figure 1 and describe their locations. The result appears in Table 4.

Table 4. Take Figure 1 as an example to describe the DMUs' locations

DMU	BCC model	WPF-BCC model	Location	Notation
A	0.857	1.429	In an intermediate area	IA
B	0.632	1	On WPF	WPF
C	1	1	On an intersection of BPF and WPF	Intersection
D	1	1.667	On BPF	BPF
E	1	1.2	On BPF	BPF
F	0.6	1	On WPF	WPF
G	0.667	1.111	In an intermediate area	IA
H	0.75	1.2	In an intermediate area	IA

We distinguish the location for each DMU in Table 4 as follows:

(i) DMUs *D* and *E* with the efficiency score = 1 in BCC model and the efficiency score > 1 in WPF-BCC model are located on the best-practice frontier (BPF);

(ii) DMUs *B* and *F* with the efficiency score < 1 in BCC model and the efficiency score = 1 in WPF-BCC model are located on the worst-practice frontier (WPF);

(iii) DMUs *A*, *G*, and *H* with the efficiency score < 1 in BCC model and the efficiency score > 1 in WPF-BCC model are located in the intermediate area (IA);

(iv) DMU *C* with the efficiency score = 1 in BCC model and the efficiency score = 1 in WPF-BCC model are located on the intersection of BPF and WPF.

We secondly use both BCC model and WPF-BCC model to investigate the reason as to why bank *z* has a good efficiency score in BCC model, but was taken over by the government. Bank *z* is bank 10 in the sample. Since bank *z* has an efficiency score = 1 in BCC model and an efficiency score = 1 in WPF-BCC model, its location is on the intersection of BPF and WFP. Among 28 samples of commercial bank, bank *z* was later taken over by the government in early 2007. Finally, there are two main conclusions in this study: (i) a real more efficient DMU should have an efficiency score in BCC model as 1, and an efficiency score in WPF-BCC model to be larger than 1 such as banks 1, 8, 11, 20, 24, 27, and 28; (ii) a DMU is a potentially failed firm if its efficiency scores in BCC model and in WPF-BCC model are equal to 1 such as the bank 10, i.e., bank *z*. This study provides another way to predict the likelihood of bank failures. Our way is different with those provided by Siems (1992) and Luo (2003).

Table 5. The locations for 28 commercial banks in Taiwan

Bank	BCC model	WPF-BCC model	Location	Bank	BCC model	WPF-BCC model	Location
1	1	1.090	BPF	15	0.861	1.008	IA
2	0.923	1	WPF	16	0.956	1.117	IA
3	0.91	1	WPF	17	1	1	Intersection
4	1	1	Intersection	18	0.958	1	WPF
5	1	1	Intersection	19	0.983	1	WPF
6	0.982	1	WPF	20	1	1.206	BPF
7	0.833	1	WPF	21	0.915	1	WPF
8	1	1.135	BPF	22	0.939	1	WPF
9	1	1	Intersection	23	0.984	1	WPF
10 (*z*)	1	1	Intersection	24	1	1.132	BPF
11	1	1.132	BPF	25	1	1	Intersection
12	0.977	1.094	IA	26	1	1	Intersection
13	1	1	Intersection	27	1	1.157	BPF
14	1	1	Intersection	28	1	1.006	BPF

4. Conclusion

Researchers use a traditional DEA model to calculate the efficiency score of DMU and to estimate its efficiency level. The study here uses a BCC model to calculate the efficiency score of bank z in Taiwan and get its efficiency score as 1 in 2006. The result of the efficiency score in the BCC model shows that bank z has a good performance, but the bank z was taken over by government in early 2007. To explain this paradox phenomenon, we use the concept of the worst-practice frontier proposed by Liu and Chen (2009) to establish the WPF-BCC model to find the DMUs with the worst performance.

In the WPF-BCC model, the worst efficiency is not less than 1. The unit with a higher efficiency score is a more efficient DMU; on the contrary, the unit with an efficiency score being 1 is a worst efficient. The calculation result of the efficiency scores using both BCC model and WPF-BCC model shows that the efficiency scores of the bank z in BCC model and WPF-BCC model are 1. This result illustrates that bank z is located not only on the best-practice frontier but also on the worst-practice frontier; in other words, bank z lies on the intersection of the best-practice frontier and the worst-practice frontier. Hence, we suggest that a bank has a likelihood of bank failure when the location of a bank is the same as bank z. The main contribution of this study is to provide a new way for predicting the likelihood of bank failures. Our way is different with those provided by Siems (1992) and Luo (2003).

This study creates a combination of BCC model and WPF-BCC model for investigating a potentially failed firm such as bank z in Taiwan. The combination of BCC model and WPF-BCC model provides a new viewpoint to reconsider and re-examine an efficient DMU in the traditional DEA model. The concept of this study can also apply to examine the risk-taking industries for reducing investment risks. The concept of worst-practice frontier is also extended to other the traditional DEA model.

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