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Measuring the relative efficiency and reorganization−The example of CDFAs of the NAN−TOU County in Taiwan

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Abstract

Data envelopment analysis (DEA) has become a practicable approach to evaluate the relative efficiencies of decision−making units (DMUs) in various contexts. This paper conducted a DEA study to measure the relative efficiencies of 13 Credit Department of Farmers¡¦ Associations (CDFAs) of the NAN−TOU County in Taiwan. In addition, this paper also investigated the alternatives for reorganizing the CDFAs via efficiency measurement. The results showed that the proposed reorganization alternatives have better efficiency scores.

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I. INTRODUCTION

Data envelopment analysis (DEA) (Charnes et al., 1978; Banker et al., 1984) has been established as one of the most advanced methodologies for measuring efficiency of many homogenous entities [i.e., decision-making units (DMUs), in various contexts]. This paper presents a DEA study to evaluate the relative efficiencies of Credit Department of Farmers' Associations (CDFAs) of the NAN-TOU County in Taiwan. As the CDFAs facing the challenges from its globalization and the liberalization of bank industry, it is critical to maintain the competitive advantage by increasing the operational efficiency and reducing the operational costs. In particular, CDFAs has recognized the importance of using its manpower efficiently to stimulate the organizational potentiality while maintaining its service quality. Therefore, some changes of internal operation environment were considered necessarily in CDFAs. The author has used DEA models to assess the relative efficiencies of CDFAs in Taiwan (Liu, 2004). Furthermore, this study focused on the most inefficient district, NAN-TOU, to evaluate the relative efficiencies of all CDFAs in NAN-TOU County and investigate the alternatives for reorganizing them to increase overall efficiency of this district.

The DEA is a linear programming method that can consider many inputs and outputs simultaneously to measure the relative efficiencies of evaluated entities. In particular, the DEA model does not require the assignment of predetermined weights to input and output factors. In contradistinction to the parametric approach, DEA also does not require any assumptions about the production form. DEA models have been effectively applied for measuring the relative efficiency of the DMUs in many fields. The original DEA model, Charnes et al. (1978) and subsequent extensions of it can be found in Cooper et al. (2000) and Thanassoulis (2001).

The organization of the paper is as follows. Section Ⅱ presents the foundations of the DEA models and reviews the related literatures. Section Ⅲ details the empirical study and illustrates the results of efficiency evaluation. Section Ⅳ discusses the reorganization of CDFAs. Section Ⅴ concludes with the findings of this study.

II. DATA ENVELOPMENT ANALYSIS MODELS

The DEA approach was first introduced by Charnes et al. (1978), called Charnes–Cooper–Rhodes (CCR) model, to produce an efficiency frontier based on the concept of Pareto optimum. The DMUs that lie on the efficiency frontier are nondominated and are thus called Pareto-optimal units or efficient DMUs. Alternatively, DMUs that do not lie on the efficiency frontier are regarded as relatively inefficient. In particular, the efficiency of a CDFA is calculated by the ratio of a weighted sum of outputs to a weighted sum of inputs. The determination of such weights can be difficult and controversial. DEA is a nonparametric approach that does not require the assignment of predetermined weights to the input and output factors. Suppose there are N DMUs, with m input factors and n output factors, let k ($1 \leqq k \leqq N$) denote one of N DMUs. The efficiency h_k of the kth DMU, with outputs Y_{rk} (with r=1, … , n) and inputs X_{ik} (with i=1, …, m), is calculated by the following CCR model:

$$\text{MAX} \quad h_k = \frac{\sum_{r=1}^{s} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik}}$$

$$\text{s.t} \quad \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \leq 1$$

$$U_r, V_i \geq \varepsilon > 0 \qquad (1)$$
$$i = 1,\ldots, m$$
$$r = 1,\ldots, s$$
$$j = 1,\ldots, n$$

where ε is a non-Archimedean quantity. The above constraints restrict the efficiencies of all of the DMUs (j= 1, …, n) to have an upper bound of 1. The kth DMU is efficient when h_k equal 1 and inefficient if h_k less than 1. The variables Ur(r=1,…,s) and Vi(I=1,…,m) are the weights to be derived for the corresponding output and input factors while maximizing the efficiency of the kth DMU. That is, DEA allows that individual DMUs may have their own preference structures and value systems, and thus, can determine their own weights.

In addition, Banker et al. (1984) developed the Banker, Charnes, and Cooper (BCC) model that produce variable returns to scale (VRS) efficiency frontier to measure the technical efficiency. In particular, the BCC model for measuring the input technical efficiency of the kth DMU is as follows:

$$\text{MAX} \quad h_k == \frac{\sum_{r=1}^{s} U_r Y_{rk}}{\sum_{i=1}^{m} V_i X_{ik} + v_k}$$

$$\text{s.t} \quad \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij} + v_k} \leq 1 \qquad (2)$$
$$U_r, V_i \geq \varepsilon > 0$$
$$r = 1,\ldots, s$$
$$i = 1,\ldots, m$$
$$j = 1,\ldots, n$$

Note that v_k indicates the returns to scale at specific points on the efficient frontier. The value of v_k can be positive, zero, or negative denoting that the corresponding DMU presents decreasing, constant, or increasing returns to scale, respectively. A DMU that is not overall efficient could be either technical inefficient or scale inefficient or technical and scale inefficient. It is shown that the overall efficiency, calculated from the CCR model, can be decomposed into the technical efficiency measured by BCC model and the scale efficiency (1984). Indeed, the scale efficiency score of a DMU is the ratio of the overall efficiency to the technical efficiency. Therefore, a DMU is overall efficient if and only if it is technical efficient and scale efficient. The overall efficiency of a DMU is less than or equal to its technical efficiency. The overall efficiency of a DMU equals to its technical efficiency if and only if this DMU is operating at the most productive scale size, and thus, its scale efficiency is 1. Alternatively, if the scale efficiency is less than 1, the DMU will be operating either at decreasing returns to scale if a proportional increase of all input levels produces a less-than-proportional increase in output levels or increasing return to scale at the converse case. This implies that resources may be transferred from DMUs operating at decreasing returns to scale to those operating at increasing returns to scale to increase average productivity at both sets of DMUs (Boussofiane et al., 1992). That is, using the BCC model can specify the major sources causing overall inefficiency.

Relevant studies on mergers among financial institutions involve cost efficiency analysis based on data after the merger has taken place (Berger & Humphery, 1992; Mester, 1994; Berger & Mester, 1997). Only a few such studies are concerned with cost efficiency models based on the institutions before the merger takes place (Savage, 1991; Shaffer, 1993). As for the method adopted to evaluate the results of the merger, the financial ratios are compared before and after the merger, especially those related to profitability, such as the return on assets (ROA) and the return on equity (ROE) ratios, to judge the results of the mergers. However, because Taiwan lacks real examples of mergers (Liu, 2002; 2004), such empirical methods are inappropriate. Many different views currently exist in Taiwan regarding mergers involving farmers' associations. In the past, mergers among farmers' associations took place because their operating structures were relatively weak, their membership was decreasing, agricultural conditions were inadequate, and because administrative district boundaries were redrawn, leaving no alternative but to merge. However, the mergers did not strengthen operating structures, or have other positive effects. Furthermore, the past contributions of the literature can largely be classified as fitting into either one of two kinds, namely, the non-frontier approach and the frontier approach. The former focuses on the statistical method used, which is based on the average concept of efficiency value, without considering the economic meaning of efficiency, while the latter focuses on the efficiency aspect, being based on the concept of Pareto-efficient outcomes. This latter approach incorporates the frontier concept, and consequently conforms more closely to the economic meaning of efficiency. The non-frontier method is frequently applied in financial management, and involves applying factor analysis or principal component analysis to select certain financial ratios to serve as variables for constructing a statistical model to perform the analysis. The statistical models adopted include analytical models based on regions, PROBIT models and LOGIT models, which are mostly used in the selection process and which have statistical meaning. Furthermore, in terms of the approach adopted for performing the statistical analysis, numerous hypotheses must be developed before proceeding, which does not conform to the meaning of efficiency as originally defined by Farrell. Therefore, this study adopts the frontier approach, which has economic connotations, to conduct the analysis.

In terms of the empirical analysis, the evaluation of the efficiency of the frontier approach may also be divided into two further approaches, namely, the parametric and nonparametric approaches. In contrast with the parametric approach, the nonparametric approach does not determine a priori the functional form of the production frontier. For this reason, it is not limited by the functional form, and also does not require the many assumptions that arising from the use of statistical methods for function estimation and efficiency measurement. Moreover, the nonparametric approach is more straightforward than the parametric approach in terms of dealing with the evaluation problems associated with many outputs and inputs. For this reason, this study adopts the nonparametric approach for the subsequent empirical analysis.

III. EMPIRICAL STUDY

This section details an empirical study of applying DEA of the CCR and BCC models to evaluate operating efficiencies of CDFAS of the NAN-TOU County. In the previous study (Cooper et al., 2000), we found that the NAN-TOU County has the lowest efficiency score among the CDFAs. Thus, in this study, we evaluated the relative efficiencies of the 13 CDFAS of NAN-TOU County and also investigated the alternatives of reorganizing its CDFAS to increase its efficiency. Following Golany and Roll (1989), this empirical study involves the following tasks: 1) determination of input and output factors for measuring the relative efficiency of the selected DMUs, and 2) the discussion of the DEA results from both the CCR model and the BCC model.

3.1 The Input Factors and Output Factors

According to Keeney and Raiffa (1993), a desirable set of measurement factors should be complete, decomposable, operational, nonredundant, and minimal. There exists considerable disagreement in finance literature on the definition of outputs and inputs of a financial institution. In general, two alternative approaches - i.e. ‘intermediation or asset’ and ‘value-added or production’ - have evolved (1992). In terms of measuring efficiency, the production approach lays emphasis on the operating costs of the bank, and is suitable for measuring overall efficiency. Meanwhile, the intermediation approach, besides considering overall bank operating costs, also focuses on measuring bank competitiveness. This focus arises because the intermediation approach serves as the principle for determining the bounds of the input and output variables used in this study. Thus, two output items are obtained, namely, loans and non-interest income, along with two input items, namely, salaries, and non-interest expenditure. The present data are obtained from the annual reports for each level of farmers’ associations in Taiwan for 2001.

For the validation of the developed DEA model, we examined the assumptions of the “isotonicity” relationships between the input and output factors, i.e., an increase in any input should not result in a decrease in any output (1985). Following Golany and Roll (1989), regression analysis on the selected input and output factors is a useful procedure to examine the isotonicity relationships between the input and output factors. If the correlation of the selected input and output factors is positive, these factors are isotonically related and can be included in the model. The factor that has a weak isotonicity relation to the other factors should be reexamined. Alternatively, a strong correlation may indicate that the information contained in one factor is already represented redundantly by other factors. In addition, according to Golany and Roll (1989), the number of DMUs should be at least twice of the total number of input and output factors considered when applying the DEA model. In this study the number of DMUs was 13, at least twice of the selected four factors. Therefore, in this study, the proposed DEA model has high construct validity.

3.2 Efficiency Analysis for Inefficient DMUs

We applied the CCR model, with constant returns to scale, to evaluate the overall efficiency of each CDFA of the NAN-TOU County. In particular, a computer program called DEAP (1996) is executed on a PC running with a Pentium II processor with 350-MHz clock speed and 256-MB random-access memory (RAM). The output is a text file and the elapsed time is less than 1.

The overall efficiencies of 13 CDFAs are presented in Table 1. The average efficiency score is 0.898 and only five CDFAs (i.e., DMUs 1,3,4,6, and 12) are overall efficient among the others.

Table 1

Operating Efficiency of Credit Departments of Farmers' Associations

DMUs	Overall Efficiency	Technical Efficiency	Scale Efficiency	Returns To Scale
1	1.000	1.000	1.000	CRTS
2	0.770	0.890	0.865	IRTS
3	1.000	1.000	1.000	CRTS
4	1.000	1.000	1.000	CRTS
5	0.912	0.990	0.922	DRTS
6	1.000	1.000	1.000	CRTS
7	0.893	1.000	0.893	IRTS
8	0.884	0.893	0.989	IRTS
9	0.827	0.978	0.846	IRTS
10	0.722	0.938	0.770	IRTS
11	0.836	0.957	0.874	IRTS
12	1.000	1.000	1.000	CRTS
13	0.827	0.956	0.865	IRTS
Ave	0.898	0.969	0.926	

Furthermore, we also found that most of the medium and small sized CDFAS (i.e., DMUs 2,9,10,11,and 13) are relatively inefficient. In particular, the DMUs 10 has the lowest efficiency score (i.e., 0.722). This result appears to hide the fact that these DMUs, because of their relatively small regional spheres of operation, do not possess economies of scale, or possibly, because they have experienced problems with their internal controls, they have been unable to compete with other institutions and have also been hampered by poor quality staff. Therefore, We used BCC model to decompose the total efficiency and to evaluate the technical efficiency and the scale efficiency in the next section.

3.3 Technical and Scale Efficiency Analysis

We applied the BCC model, with variable returns to scale, to evaluate the technical efficiency of each CDFA of the NAN-TOU County. Also, the scale efficiency can be derived by the ratio of overall efficiency to technical efficiency. Table 1 summarizes the results. The six overall efficient CDFAs have the technical efficiency and five overall efficient CDFAs have the scale efficiency. In particular, DMUs 7 has the technical efficiency scores equal to 1 while their scale efficiency scores are less than 1. It should adjust their scales of operation to improve their scale efficiencies as well as overall efficiencies. A DMU may be scale inefficient if it exceeds the most productive scale size (thus experiencing decreasing returns to scale), or if it is smaller than the most productive scale size (thus having not taken the full advantage of increasing returns to scale). Indeed, most of the inefficient CDFAS present increasing returns to scale that can increase the scales to effectively improve their efficiencies. In particular, seven of the scale inefficient CDFAs (i.e., DMU 2, 5, 7, 9, 10, 11, and 13) had their technical efficiency scores higher than the scale efficiency scores, respectively. This implies that the overall inefficiency is primarily due to the scale inefficiency. Only DMU 5 present the decreasing returns to scale that can decrease their scales to possibly improve their efficiencies. On the other hand, one overall inefficient CDFA (i.e., DMUs 8) is mainly due to the technical inefficiency because their technical inefficiency scores are lower than scale efficiency scores. The technical inefficient CDFA should improve their productivity and make better use of their resources.

Furthermore, the decision makers should examine the scale sizes of the scale inefficient CDFAs. On one hand, five urban CDFAs (i.e., DMUs 1, 3, 4, 8, and 13) have similar levels of the inputs and outputs. However, DMUs 1, 3, and 4 present the constant returns to scale. The other one urban CDFA (i.e., DMUs 5) present the decreasing returns to scale. On the other hand, the CDFAs that are located in rural areas are small or medium sized and they all present increasing returns to scale. One way for increasing their efficiency is to adjust their scales by transferring resources from CDFAs operating at decreasing returns to scale to those operating at increasing returns to scale returns to scales.

IV. REORGANIZATION OF THE CDFAs

Thus, we continued this study with the discussions on the alternatives of reorganizing the CDFAs of the NAN-TOU County. In Taiwan, the competitive environment for operating bank industry has undergone drastic changes owing to the liberalization of financial market. Reorganizations and operation mergers are feasible methods to increase organizational competitiveness and efficiency.

Based on the results of DEA, we also investigated the reorganization alternatives of CDFAs by comparing the efficiency evaluation results before and after the reorganizations. Furthermore, a traceable decision analysis method such as DEA was essential to avoid the potential political and social pressures and would also facilitate effective communication between the decision makers and the employees. For example (Kao & Yang, 1992), applied the DEA models to measure the relative efficiency of 13 forest districts and investigate their reorganization. The authors also applied the DEA models to measure the relative efficiencies of 277 CDFAs in Taiwan and compare the various reorganization alternatives (Cooper et al., 2000).

In particular, this study compared two different reorganization alternatives by the efficiency evaluations. Due to geographical limitations, only the adjacent CDFAs can be possibly combined into a new large one. Table 2 summaries the new DMUs generated in the two different reorganization alternatives. In particular, the first alternative refers to the initial idea of the NANTOU County in which only the two adjacent CDFAs can be possibly combined into a new large one. The second reorganization alternative based on the results of efficiency analysis in Section Ⅲ was proposed to increase their scales since most of the inefficient DMUs presented increasing returns to scale.

Table 2

Created DMUs of merged CDFAs of two reorganization alternatives

Reorganization alternatives	No. of DMUs*	CDFAs
Ⅰ	14	DMU 2, DMU 3
	15	DMU 4, DMU 5
	16	DMU 7, DMU 8
	17	DMU 9, DMU 10
	18	DMU 11, DMU 13
Ⅱ	19	DMU 2, DMU 3, DMU 5
	20	DMU 7, DMU 9
	21	DMU 8, DMU 10
	22	DMU 11, DMU 13

* it denotes the number of new CDFAs in this study

To examine the different reorganization alternatives, we applied the CCR model to compare the efficiency of the CDFAs among all of the two alternatives. Since DEA measures the relative efficiencies among the DMUs, we evaluated all of the CDFAs among the different reorganization alternatives together. Thus, for validation, the efficiency scores of the DMUs among the different reorganization alternatives can be compared at the same basis. Also, for validation, we found that the total number of the DMUs is more than twice the total number of input and output factors. The results of efficiency evaluation were summarized in Table 3. For each reorganization alternative, only the considered CDFAs were evaluated, respectively. We also calculated the average values of the efficiency scores among the different reorganization alternatives. As shown in Table 3, the first alternative of combining the CDFAs belonging to the adjacent town has the higher average efficiency score (i.e., 0.916) than the existing status (i.e., 0.898). The second alternative has also higher average efficiency score (i.e., 0.923) than the average efficiency score (i.e., 0.898) of the existing status. Thus, the proposed two alternatives based on the efficiency analysis results in Section Ⅲ are better than the existing status. They can increase the overall operating efficiency of the whole set of CDFAs. DEA provides a feasible direction for generating a reorganization alternative and an effective mechanism for evaluating the various alternatives for better decisions.

Table 3

Results of overall efficiency of two reorganization alternatives

DMUs	Overall Efficiency	Reorganization Alternatives	
		I	II
1	1	1	1
2	0.77	…...	…...
3	1	…...	…...
4	1	…...	0.988
5	0.912	…...	…...
6	1	0.986	0.984
7	0.893	…...	…...
8	0.884	…...	…...
9	0.827	…...	…...
10	0.722	…...	…...
11	0.836	…...	…...
12	1	0.966	1
13	0.827	…...	…...
14	NA	0.908	NA
15	NA	0.841	NA
16	NA	0.903	NA
17	NA	0.851	NA
18	NA	0.874	NA
19	NA	NA	0.861
20	NA	NA	0.876
21	NA	NA	0.824
22	NA	NA	0.854
Total No. of CDFAs	13	8	8
Ave	0.898	0.916	0.923

The "…..." mark denotes the DMU is merged into the new DMU and its efficiency is not calculated.

V. CONCLUSION

In this paper DEA models were applied to evaluate the efficiency of the CDFAs of the NAN-TOU County in Taiwan since the NAN-TOU County was the least efficient among the others. Two DEA models (CCR model and BCC model) were used to evaluate the overall efficiency, technical efficiency, and scale efficiency of each of the 13 CDFAs. Based on the results, we found that most of the inefficient CDFAs present increasing returns to scale.

Moreover, we also investigated the mergers of CDFAs to increase their operation scales, and thus, increase the overall efficiency of the whole set of CDFAs. The proposed reorganization alternatives based on DEA had higher averages of the efficiency scores than the current CDFAs. Therefore, this empirical study may provide useful information to the policy makers of CDFAs.

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