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Managerial efficiency in Taiwan bank branches: A network DEA

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A B S T R A C T

Taiwan's banking industry remains highly fragmented and competitive after a series of financial liberalization and restructuring. With the enforcement of these fiscal policies, domestic banking institutions face a more dynamic, increasingly intense and highly competitive environment even as the banking industry's overall efficiency has gradually been enhanced. This structural change has further forced individual banking institutions, especially state-owned banks, to inspect the performance of their branches and identify improvement directions so as to gain further competitive advantages. To conduct a valid, fair and reliable evaluation on Taiwan's bank branches, we integrate a two-stage series performance model and fuzzy multiobjective model. A new scheme that considers the complementation of production and intermediation activities within a branch and overcomes the shortage of the traditional network DEA methodology about DMUs cannot be assessed on a common base. The results indicate that the overall performances of mixed ownership bank branches are superior to those of state-owned bank branches, representing that the advantages of banking privatization have some remedial effects for improving the managerial inefficiency of state-owned banks. In addition, the sensitivity analysis and decision-making matrix herein help bank management to identify branches' efficiency, weakness, and directions for improvement.

1. Introduction

Taiwan's banking industry remains highly fragmented and competitive after a series of financial liberalization and restructuring. Starting in the early 1990s Taiwan's government embarked on financial reforms to deregulate and restructure the domestic banking industry in order to construct a sound financial system, which is expected to support economic growth and respond to the challenges of powerful competition from international financial groups. Yu (1999) indicated that the financial sector has played a key role in the process of Taiwan's economic development. To strengthen the efficiency and performance of banking institutions, Taiwan's financial industry has experienced several important reforms. The first stage in 1991 relaxed entrance barriers to the financial market when Taiwan's government announced the Commercial Bank Establishment Promotion Decree to deregulate barriers and invite private domestic enterprises and foreign investors to participate in domestic banking. Soon afterwards, 27 new commercial banks and mixed ownership banks were set up, and more funds have been attracted into the loanable funds supply market, along with an improvement in banking operation efficiency.

Financial deregulation has also brought about some unsatisfied effects. An excessive amount of banks made up Taiwan's banking industry with fierce competition among them leading to several financial crises such as abnormal peaks in banks' non-performing loans (NPL) ratio, credit losses, and an inferior capital adequacy ratio. In order to overcome these financial obstacles to sustain competitive advantages in the industry, the government in the second stage decided to embark on various reforms and restructuring programs, referred to as the first financial restructuring (FFR), so as to reduce bad debt banking, encourage mergers and acquisitions among banks, and to push for the set-up of financial holding companies (FHC). Through these polices, Taiwan's government has successfully controlled banks' operation costs and risks, seen the sector's average NPL ratio fall under 5%, the capital adequacy ratio rise above 8%, and approved mergers among some financial institutions as financial holding companies to cope with the problem of over-competition in the overcrowded market.

The third stage involved the second financial restructuring (SFR) in 2004, which continues the reform of the FFR to improve upon the characteristic of "too many in number and too small in size" in Taiwan as compared to other Asian countries (Lo and Lu, 2009). The main goals of this stage are to achieve the emergence of one or two very large and strong regional financial institutions with a market share of at least 10% each in Taiwan, a reduction of government ownership in financial institutions, and a drop in the number of banking institutions. Although the number of banks in Taiwan fell from 50 in 2004 to 44 at the end of 2006, the goals of SFR have not been completely

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achieved and the banking industry still remains highly fragmented and competitive.

With the enforcement of financial liberalization and restructuring, the overall efficiency and competitiveness of Taiwan's banking industry have gradually improved and several main financial institutions have gained a greater market share, but they now face a more dynamic, increasingly intense and highly competitive environment. Such an environment forces financial institutions to develop their capabilities to gain more competitive advantages. Hill and Jones (2004) indicated a firm's competitive advantages come from both the resources it has and the capabilities to use these resources. Thus, banks have to identify the inefficient costs of acquiring funds and efficient functions of generating profits and then try to enhance competitive advantages in responding to external changes, which increases their survival.

Some earlier studies (Giokas, 2008; Pastor et al., 2006; Schaffnit et al., 1997) showed that the enhancement of a bank's performance mainly depends on if branch performance can be managed efficiently, and identifying the source of branches' inefficiency is an essential first step in improving a bank's competitive advantages (Pastor et al., 2006). Hence, to confront the dynamic financial domestic market and improve their own performances, financial institutions in Taiwan need to identify inefficient sources and profit niches in their branches by using the most effective method in order to ensure their survival. In addition, mixed ownership banks, encompassing state and private shareholdings within one enterprise, were set up in Taiwan's banking system during the process of financial liberalization and privatization. Differing from the pursuit of profit maximization for private banks and socio-political goals for state-ownered banks, mixed ownership banks can achieve both profitability and social goals (Li et al., 2004). Moreover, mixed ownership means a more efficient shareholding structure in Taiwan than state banks and private banks, accrued from taking the advantages of private banks' managerial utility and flexibility and state banks' bureaucratic power and robust internal control mechanism. Therefore, by conducting an efficiency analysis and comparison, this study explores the sources of cost inefficiency and profit niche and the effect of privatization for bank branches in Taiwan's banking system.

Efficiency has been an important topic in banking research for a long time, with data envelopment analysis (DEA) one of the methods used extensively to evaluate banking and branch efficiency. Major academic journals have published special issues on banking efficiency using the DEA method, including the European Journal of Operation Research in 1997 and Management Science in 1999. Most previous studies evaluate banking efficiency according to the bank's activities using the production approach (Athanassopoulos and Giokas, 2000; Ferrier and Lovell, 1990; Sherman and Gold, 1985), whereby banking activity is depicted as the production of services using input resources and expenses to produce desired outputs, i.e. deposits and non-interest incomes, or using the intermediation approach (Athanassopoulos and Giokas, 2000; Casu and Molyneux, 2003), and they describe banking activity as a process of transforming deposit costs into income from loans and investments. In light of efficiency evaluation, the former places emphasis on how to acquire outputs by using minimum resources, while the latter focuses on generating the maximum incomes by using the available resources. However, performance improvement and competitiveness enhancement cannot rely on either production or intermediation activities alone. These two types of banking activities occur simultaneously and both are crucial for improving the competitive capabilities of a bank and should not be evaluated separately. Thus, the more accurate way for identifying the competitive advantages of a bank branch is to consider the complementation of production and intermediation activities under a banking performance evaluation. Therefore, this study proposes a network relationship framework to include these two types of activities in the productivity stage and profitability stage, which could provide bank management not only insight into figuring out whether the overall inefficiency of a branch resides in its productivity stage or in its profitability stage, but also to further identify the sources of cost inefficiency and profit niches.

To provide sufficient and informative details to achieve our purpose for analyzing bank branch performance in Taiwan by considering both productivity and profitability efficiencies, this study proposes the modified DEA technique, called the fuzzy multiobjective network DEA model, which combines the network DEA model, fuzzy approach, and the multiple objective programming approach in the context of bank branch evaluation. By using this network DEA model, all branches can be fairly evaluated on the same scale with a set of common multipliers, and branch performance can be decomposed into several interrelated stages. Detailed evaluation information and insights related to the specific source of branch inefficiency can be further identified, thus enabling bank management to take some remedial actions.

In addition to the introductory section, there are five more sections in this study. Section 2 reviews the literature of bank branch efficiency and introduces the traditional DEA model and network DEA model. Section 3 sketches the mathematical models of the fuzzy multiobjective network model, which can calculate a set of common multiples and all decision making units can be evaluated on a common base. Section 4 introduces the performance model and data resources. Section 5 presents the empirical results and analyses. Finally, Section 6 offers some conclusions.

2. Literature review

2.1. Bank branch performance

The evaluation of bank branch performance is a very difficult task attributed to harder availability of operation data, having different operating size, offering multiple products, and providing complex service content to different customers. However, such a performance evaluation can be accomplished on the basis of a financial ratio or operation research technology using available financial or accounting data. In the literature, there are several methods used to measure branch performance, such as financial ratio analysis, regression analysis, and frontier efficiency analysis (Berger et al., 1993; Paradi et al., 2011b). Financial ratio analysis is employed for assessing branch performance primarily based on the use of accounting data. By conducting single input and output analysis, financial ratio analysis provides branch management not only with indicators to monitor operation conditions and financial performance, but also further information to make better managerial decision. Regression analysis is an alternative method to measure branch performance using the central trend method to identify the interaction between a bank branch's input and output variables. If the satisfactory regression model is found, it can assist branch management in identifying the determinants of the production or cost function. Branch management also can use it to estimate the performance gap between the actual and expected values and then translate the values into the ratio of an actual value to expected value for identifying relative efficiency among branches.

Although effective in many business areas, financial ratio analysis and regression analysis have many inherent limitations making them unsuitable for the evaluation of branch performance. For example, financial ratio analysis takes into account only single inputs and outputs in each evaluation, leaving out of the analysis situations with multiple inputs and outputs (MIMO). Moreover, it is difficult to provide a useful aggregated performance score for comparative purposes. Each financial ratio has its specific function in diagnosing different aspects of branch operation, and thus simply subjectively aggregating these ratios together may result in a misleading indicator of overall performance and provide little contribution for the identification of benchmarking policies. As to the limitations of regression analysis, this method is first suitable only for the evaluation model with a single dependent variable (input or output) and cannot be used to deal with analytical situations with MIMO systems. Second, regression analysis is a parametric method that requires specifying a particular functional form between the dependent variables and explanatory variables and the residual of the evaluation model should follow the assumption of normal distribution. Third, owing to the use of the central trend technique in regression analysis, the estimate of this method is a mean relationship providing less information to directly identify each branch's performance.

A recent alternative method for the performance of bank branches that surpasses the application of traditional methods is the frontier efficiency method, which estimates how well a branch performs relative to the frontier formed by best branches under the same operational conditions. The major advantage of this method is that it removes the effects of price differences in analytical variables as well as other external market factors and provides branch management a determined quantitative tool to identify best practices in a complex operational environment (Bauer et al., 1998). The methodology for frontier efficiency can be divided into parametric and non-parametric methods, including Data Envelopment Analysis (DEA), Stochastic Frontier Approach (SFA), Free Disposal Hull (FDH), Thick Frontier Approach (TFA), and Distribution Free Approach (DFA). The primary differences among these approaches are the restrictions imposed on the specification of the best practice frontier, the assumptions of random error and inefficiencies, and the existence of random errors (Bauer et al., 1998; Paradi et al., 2011a). Compared to other approaches, DEA is a non-parametric approach which is recognized as being a better and robust efficiency analysis tool since it uses actual data from evaluated units to construct the efficiency frontier without setting up a specific functional form, which reduces the possibility of a bias measure of efficiency due to specification error. In addition, it permits efficiency to change over time and allows for the existence of random errors. It also has the capability of dealing with the analysis of MIMO systems without requiring an explicit specification of the relationship between inputted and outputted variables (Berger and Humphrey, 1997).

Ever since the development of DEA technology, numerous studies have applied this approach and its extended models to analyze the efficiency of bank and branch systems. A survey of DEA applications in financial institutions and the banking industry can be found in Berger and Humphrey (1997) and Fethi and Pasiouras (2010). However, apart from using diverse DEA models for exploring the performance of banking industries around the world, another ongoing discussion in the banking literature is how to select appropriate inputs and outputs for conducting the evaluation of a bank or branch performance. By considering different dimensions of banking performance, Berger and Humphrey (1997) indicated that two main approaches are widely applied in the evaluation of branch performance: the production approach and the intermediation approach. The former assumes branches are a production unit that produces variables related to transaction services as outputs based on the use of capital and labour expenses as inputs, while the latter regards branches as the entity between savers and investors, transforming deposit costs into income from loans and investments. Fethi and Pasiouras (2010) in their recent survey identified that 30 studies use DEA-like techniques to estimate branch level efficiency, in which 16 adopt the production approach, 10 adopt the intermediation approach, and only 4 use both approaches at the same time. This review also releases that most previous studies focus on the single performance dimension and only few studies try to evaluate branch performance from different dimensions. However, in banking two types of activities, banks as financial transaction providers or financial intermediaries, occur simultaneously and should not be evaluated separately. Berger and Humphrey (1997) presented that neither the production approach nor intermediation approach can fully capture the overall financial activities in a branch. Although some studies try to assess branch performance from different perspectives using production, intermediation, or even other extended approaches in their evaluation framework, they still assume these activities are independent and just estimate the fragment of performance separately from each perspective, while not considering the complementation and relationship between these activities.

Production and intermediation activities are both carried out in banking practice and should be integrated on one side rather than as an individual activity in evaluating banking efficiency. Hence, based on the complementation between production and intermediation activities, this study refers to the transformation process of Denizer et al. (2007) to propose a two-stage network framework, as shown in Fig. 1, to estimate a bank branch's overall performance. Owing to provide a more sound methodology for assessing branch performance from the network dimension, this study exploits a modified DEA technique that combines the network DEA model, fuzzy approach, and multiple objective programming approach in the context of bank branch evaluation. By using the modified DEA technique and the network framework of branch performance, all branches can be fairly evaluated to identify the specific source of branch inefficiency and then enable the bank as well as branch management to take some remedial actions.

2.2. Conventional network DEA models

Data envelopment analysis, which was initially developed by Charnes et al. (1978), is a well-established methodology for measuring relative efficiency and can be a management tool in identifying inefficiencies and potential improvements for maintaining and enhancing competitive advantages. Expanded DEA models have been subsequently presented, such as the BBC model (Banker et al., 1984), the additive model (Charnes et al., 1985), the FDH model (Tulkens, 1993), the SBM model (Tone, 2001), and others. However, Färe and Grosskopf (2000) indicated that the common underlying assumption among these models treats their reference technologies as “black boxes”, in which the transformation processes of converting inputted resources into outputted products are not modeled explicitly. In other words, performance management simply specifies what enters the box and what exits, but ignores the structures of the transformation processes that perhaps consist of several interrelated subcomponents in some applications. To measure the efficiency of such an interrelated system, the network DEA models, proposed by Färe and Grosskopf (1996, 2000), provide fuller access to the underlying diagnostic information of the black box and measure the overall and corresponding subcomponent performance of the DMUs.

According to the structure of the black box's transformation process, the network DEA model has several forms. Färe and Grosskopf (2000) classified the network DEA into three models: First, the static model replicates the black box as the production process. In this production process, some outputs of one process are transformed as the inputs of the other process. Second, the dynamic model takes some outputs of the process at one period, which are then consumed by the process in the next period as the inputs. The third model is composed of several parallel processes in the black box, and thus the inputs have to be allocated into these processes and the outputs are an aggregation of these processes.

Drawing on the methodology of the conventional network DEA model, one has access to look into the underlying diagnostic information of efficiency measurement and evaluate overall performance and subcomponent performance. In order to achieve a better application of the model, the conventional network DEA model allows researchers to add or modify the structure of the model's efficiency measurement. Thus, the conventional network DEA has several model extensions. An extensive discussion on these models can be found in Färe and Grosskopf (2000) and Kao (2009). According to the structure of the transformation process, Färe and Grosskopf (2000) classified the network DEA into three models: static model,

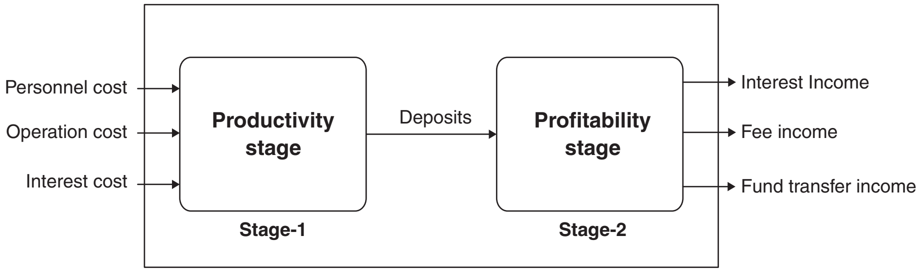

Fig. 1. Network efficiency model for a bank's branch network.

dynamic model, and parallel model. Kao (2009), on the other hand, viewed the transformation process as a system and classified the related models into another three structures: one is the series structure that is composed of several connected processes in a series. Second, opposed to the series structure is the parallel structure, which is a system that has several processes in parallel. The third structure is the relational model that consists of the series and parallel structure within a system simultaneously.

Following the network relationship between production and intermediation activities in Fig. 1, the two-stage series structure is chosen as the appropriate version of the network DEA model for the purpose of this study. For any DMU_j $(j=1\ldots n)$ of this model, it uses m inputs x_{ij} $(i=1\ldots m)$ to produce intermediate products z_{pj} $(p=1\ldots q)$ in stage-1, which are then consumed in stage-2 to finally generate outputs y_{rj} $(r=1\ldots s)$. The DEA model without considering the transformation process, the efficiencies of the whole system, and the two stages can be viewed as three unrelated parts, and they are calculated independently. Under the assumption of constant returns-to-scale, the efficiency of the whole system for DMU_k is measured by the CCR model (Charnes et al., 1978):

$$\begin{aligned}&\theta_k=\max\sum_{r=1}^{s}u_r y_{rk}\Big/\sum_{i=1}^{m}v_i x_{ik}\\&\text{s.t.}\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&u_r,v_i\ge\varepsilon>0 r=1,\ldots,s; i=1,\ldots,m\end{aligned}\tag{1}$$

where: θ_k of Model (1) is the overall efficiency of DMU_k, and each DMU applies m inputs to produce s outputs, which do not consider intermediate products z_{pj} and the transformation process.

Since the relationship of the transformation between inputs and outputs is not considered, the whole structure can be decomposed into two independent parts and can use the same model as Model (1) to measure the efficiencies of stage-1, θ_k^1 of Model (2a), and stage-2, θ_k^2 of Model (2b), respectively.

$$\begin{aligned}&\theta_k^1=\max\sum_{p=1}^{q}\eta_p z_{pk}\Big/\sum_{i=1}^{m}v_i x_{ik}\\&\text{s.t.}\ \sum_{p=1}^{q}\eta_p z_{pj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\eta_p,v_i\ge\varepsilon>0\quad p=1,\ldots,q; i=1,\ldots,m\end{aligned}\tag{2a}$$

$$\begin{aligned}&\theta_k^2=\max\sum_{r=1}^{s}u_r y_{rk}\Big/\sum_{p=1}^{q}\eta_p z_{pk}\\&\text{s.t.}\ \sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\&u_r,\eta_p\ge\varepsilon>0\quad r=1,\ldots,s; p=1,\ldots,q\end{aligned}\tag{2b}$$

On the contrary, the two-stage series model considers the transformation process, and the intermediate products z_{pj} are the outputs in stage-1 as well as the inputs in stage-2, such that the efficiencies should not be calculated independently. The evaluation model must consist of the series' relationship between the whole system and the two corresponding stages, and then the overall efficiency (θ_k) must be the product of two-stage efficiencies (θ_k^1, θ_k^2). Based on these concepts, the way to estimate the overall efficiency θ_k is to combine the ratio constraints of the two stages into Model (1) and then the relational overall efficiencies model as Model (3a):

$$\begin{aligned}&\theta_k=\max\sum_{r=1}^{s}u_r y_{rk}\Big/\sum_{i=1}^{m}v_i x_{ik}\\&=\max\left[\sum_{p=1}^{q}\eta_p z_{pk}\Big/\sum_{i=1}^{m}v_i x_{ik}\times\sum_{r=1}^{s}u_r y_{rk}\Big/\sum_{p=1}^{q}\eta_p z_{pk}\right]\\&\text{s.t.}\ \sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{p=1}^{q}\eta_p z_{pj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\&u_r,\eta_p,v_i\ge\varepsilon>0\quad r=1,\ldots,s; i=1,\ldots,m; p=1,\ldots,q\end{aligned}\tag{3a}$$

Because z_{pj} are the outputs of stage-1, which are also the inputs of stage-2, the multipliers associated with z_{pj} should be the same in both stages, and then the overall efficiency can be transformed into the product of the stages' efficiencies. The stage efficiency models are shown as Model (3b) and Model (3c):

$$\begin{aligned}&\theta_k^1=\max\sum_{p=1}^{q}\eta_p z_{pk}\Big/\sum_{i=1}^{m}v_i x_{ik}\\&\text{s.t.}\ \sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}=\theta_k\\&\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{p=1}^{q}\eta_p z_{pj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\&u_r,\eta_p,v_i\ge\varepsilon>0 r=1,\ldots,s; i=1,\ldots,m; p=1,\ldots,q\end{aligned}\tag{3b}$$

$$\begin{aligned}&\theta_k^2=\max\sum_{r=1}^{s}u_r y_{rk}\Big/\sum_{p=1}^{q}\eta_p z_{pk}\\&\text{s.t.}\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}=\theta_k\\&\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{p=1}^{q}\eta_p z_{pj}\Big/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\&\sum_{r=1}^{s}u_r y_{rj}\Big/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\&u_r,\eta_p,v_i\ge\varepsilon>0 r=1,\ldots,s; i=1,\ldots,m; p=1,\ldots,q\end{aligned}\tag{3c}$$

3. The fuzzy multiobjective network model

For most conventional network DEA models, each DMU selects a set of multipliers for inputs and outputs with maximal flexibility to reach a perfect performance, but this maximal flexibility also hinders a common base for comparison, which leads to the conventional network DEA models resulting in multiple efficient DMUs and provides less discriminative information about the ranking of the DMUs. However, in some decision making situations, the managers perhaps want to precisely compare information across DUMs rather than just use different sets of multipliers to classify DMUs into an efficient or inefficient group. Therefore, in order to compare all DMUs on the same base, a methodology for generating common multipliers in the network DEA framework is necessary.

Roll et al. (1991) first introduced the idea of common multipliers in standard DEA, and several methods have been proposed to generate the common multipliers. The first method is the average multipliers of Doyle (1995), who found the common multipliers by averaging the optimal multipliers of all DMUs. The second method is based on the multivariate statistical analysis having two types. One is canonical correlation analysis (CCA), which maximizes the correlation between the composited inputs and the composited outputs to find the common multipliers. The other is discrimination analysis (DA), which constructs a discriminant analysis of a ratio function between the linear combination of inputs and the linear combination of outputs in order to provide a common multiplier for all DMUs. Some examples include Friedman and Sinuany-Stern (1997), Retzlaff-Roberts (1996), Sinuany-Stern and Friedman (1998), Sueyoshi (1999, 2001, 2006), and Sueyoshi and Goto (2009). The third method is the compromise solution proposed by Kao and Hung (2005), who regarded the efficiency scores calculated from DEA as the ideal solution for each DMU so as to achieve and use the shortest distance function to discriminate the best common multipliers. Although many methods have been proposed in the standard DEA framework to generate common multipliers, none of the methods have been applied to the network DEA. Therefore, the main idea of this paper is to propose a model in network DEA to provide common multipliers for comparing the DMUs, in both the efficiency and inefficiency groups.

In order to fairly compare the performance of each DMU on the same scale and provide sufficient details for management to identify sources of inefficiency, the concept of common multipliers is adopted in the performance model. The idea of finding common multipliers to evaluate all DMUs on one scale is similar to the optimization problem, which figures out the multipliers to optimize the efficiencies of all DMUs simultaneously. Based on this similarity, this paper employs the multiple objectives programming approach to the two-stage series model. The advantage of this approach is in providing a more comprehensive measurement of efficiencies and multipliers while simultaneously considering the efficiency optimization of each DMU. Thus, the single objective network DEA model like Model (3a) for each DMU can be transformed into a multiple objectives network DEA model like Model (4).

$$\begin{array}{l}
\theta_1 = \max\sum_{r=1}^{s}u_r y_{r1}/\sum_{i=1}^{m}v_i x_{i1}\\
\theta_2 = \max\sum_{r=1}^{s}u_r y_{r2}/\sum_{i=1}^{m}v_i x_{i2}\\
\vdots\\
\theta_n = \max\sum_{r=1}^{s}u_r y_{rn}/\sum_{i=1}^{m}v_i x_{in}\\
\text{s.t.}\sum_{r=1}^{s}u_r y_{rj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\
\sum_{p=1}^{q}\eta_p z_{pj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\
u_r,\eta_p,v_i\ge\varepsilon>0\ r=1,\ldots,s; i=1,\ldots,m; p=1,\ldots,q
\end{array}\tag{4}$$

In order to determine the compromise solution of Model (4), there are four major approaches: the utility approach (DeWispelare and Sage, 1981), goal programming (Charnes and Cooper, 1977), interactive approach (Sakawa, 1982), and fuzzy approach (Sakawa, 1983; Zimmermann, 1978). Although each of these approaches has its own advantages and disadvantages relative to the other approaches, Zimmermann (1978) indicated that the fuzzy approach solves the multiple objective problems quite easily, provides an efficient solution, and acquires less additional prior or extraneous information than others. For each DMU, the single objective network DEA may have fuzzy goals. Thus, this paper adopts the fuzzy approach to determine the solution of Model (4). In the maximization problem for each single objective function, the fuzzy goal stated by the decision maker may be to achieve "the objective function θ_k to be substantially larger than or equal to some value of p'' and be quantified by the corresponding membership function.

The fuzzy approach utilizes the membership function to transfer the multiple objectives programming into one objective programming. By means of the membership function, each DMU expresses its degree of achievement with respect to its objective function value. Therefore, the related membership function is defined as:

$$f_j\left(\theta_j\right) = \begin{cases} 0 \quad \text{if } \theta_j \le \theta_j^l \\ \dfrac{\theta_j-\theta_j^l}{\theta_j^u-\theta_j^l} \quad \text{if} \theta_j^l \le \theta_j \le \theta_j^u \\ 1 \ \text{if } \theta_j \ge \theta_j^u \end{cases}\tag{5}$$

Here, θ_j is the efficiency value of Model (4); θ_j^u and θ_j^l denote the maximum and the minimum of the objective functions, respectively; and $f_j(\theta_j)$ is the membership function of θ_j, which refers to the level of achievement of the efficiency ratio for DMU_j. The efficiency ratio of the objective functions in Model (4) being between 0 and 1 represents that the degree of the membership function is also located within this interval.

Drawing on the transformation of the membership function, $f_j(\theta_j) = 1$ is defined as the highest achievement and $f_j(\theta_j) = 0$ is the lowest. It is well known that the approach to solving the conjunction of the fuzzy set is to maximize the minimum of the membership functions, which can be expressed as Model (6):

$$\max_{u,v,\eta}\ \min_{j}^{n} f_j\left(\theta_j\right)\tag{6}$$

Therefore, Model (4) is rewritten in max–min form as shown in Model (7).

$$\begin{array}{l}
\max_{u,v,\eta}\ \min_{j}^{n} f_j\left(\theta_j\right)\\
\text{s.t.}\sum_{r=1}^{s}u_r y_{rj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\
\sum_{p=1}^{q}\eta_p z_{pj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, j=1,\ldots,n\\
u_r,\eta_p,v_i\ge\varepsilon>0\ r=1,\ldots,s\ ; i=1,\ldots,m; p=1,\ldots,q
\end{array}\tag{7}$$

Since $\theta_j \in [0, 1]$ for any DMU, this simplifies the membership function of Model (7) into $f_j(\theta_j) = \theta_j$. By introducing an auxiliary variable λ, the equivalent Model (8) can now be obtained.

$$\begin{array}{l}
\max_{u,v,\eta}\ \lambda\\
\text{s.t.}\sum_{r=1}^{s}u_r y_{rj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, \quad j=1,\ldots,n\\
\sum_{p=1}^{q}\eta_p z_{pj}/\sum_{i=1}^{m}v_i x_{ij}\le 1, \quad j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}/\sum_{p=1}^{q}\eta_p z_{pj}\le 1, \quad j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}/\sum_{i=1}^{m}v_i x_{ij}\ge\lambda, \quad j=1,\ldots,n\\
u_r,\eta_p,v_i\ge\varepsilon>0 r=1,\ldots,s\ ; i=1,\ldots,m; p=1,\ldots,q
\end{array}\tag{8}$$

With an easy transformation, Model (8) can be rewritten as the following equivalent conventional mathematical programming problem:

$$\begin{array}{l}
\max_{u,v,\eta}\ \lambda\\
\text{s.t. }\sum_{r=1}^{s}u_r y_{rj}-\sum_{i=1}^{m}v_i x_{ij}\le 0, \quad j=1,\ldots,n\\
\sum_{p=1}^{q}\eta_p z_{pj}-\sum_{i=1}^{m}v_i x_{ij}\le 0, \quad j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}-\sum_{p=1}^{q}\eta_p z_{pj}\le 0, \quad j=1,\ldots,n\\
\sum_{r=1}^{s}u_r y_{rj}-\lambda\sum_{i=1}^{m}v_i x_{ij}\ge 0 \quad j=1,\ldots,n\\
u_r,\eta_p,v_i\ge\varepsilon>0 r=1,\ldots,s\ ; i=1,\ldots,m; p=1,\ldots,q
\end{array}\tag{9}$$

Although Model (9) is non-linear programming, the bisection method proposed by Sakawa and Yumine (1983) can be applied to solve it and find the common multipliers (u_r^*, η_p^*, v_i^*) in order to calculate the efficiency score of each DMU. The efficiency can be measured by Model (10).

$$\begin{aligned}\theta_j^F &= \sum_{r=1}^{s} u_r^* y_{rj} / \sum_{i=1}^{m} v_i^* x_{ij} \\ &= \left[\sum_{p=1}^{q} \eta_p^* z_{pj} / \sum_{i=1}^{m} v_i^* x_{ij}\right] \times \left[\sum_{r=1}^{s} u_r^* y_{rj} / \sum_{p=1}^{q} \eta_p^* z_{pj}\right] \\ &= \theta_j^{F1} \times \theta_j^{F2}\end{aligned} \tag{10}$$

Here, θ_j^F, θ_j^{F1} , and $\theta_j^{F2}$of Model (10) represent the overall efficiency and corresponding stage's efficiencies calculated from the fuzzy multiobjective network model.

This paper sequentially applies the fuzzy multiobjective network model to generate the common multipliers without additional information about objective functions or constraints for all bank branches. These multipliers provide the common base for a fair evaluation of overall performance, the decomposition of efficiency, and the identification of inefficient sources and profit niches for enhancing a bank branch's competitive advantage.

4. Performance model and data resources

4.1. Performance model

A bank's activities are a complex phenomenon and its performance cannot be fully captured either by the production approach or by the intermediation approach in the evaluation of bank branch efficiency. By taking the advantage of complementation between production and intermediation activities, this study refers to the transformation process of Denizer et al. (2007) to propose a two-stage network approach, as shown in Fig. 1, to estimate the overall performance of a bank branch. In this performance model, the first stage is the production approach that depicts banking activity as the traditional production process converting a bank's resources and expenses into collecting deposits. The second stage is the intermediation approach that describes banking activity as the intermediate process of transforming the costs of deposits into income from loans and investments. In light of management's consideration, the evaluation from a production approach can be viewed as productivity efficiency, as the branch can evaluate and decompose the cost of deposits collected from depositors or fund providers, while the evaluation of the intermediation approach can be regarded as profitability efficiency, whereby the branch can assess profits and income generated from transforming the collected deposits into financial products.

Fig. 1 indicates that the productivity stage (stage-1) measures a branch's productivity to generate deposits, consisting of four types of its major costs (personnel cost, operation cost, and interest cost) and one output (deposits). The profitability model (stage-2) measuring a branch's profitability in the financial market consists of the input that is the output of stage-1 and four outputs (interest income, fee income, and fund transfer income). The output and input variables used in this study are defined as follows.

- Personnel cost also includes overtime salary in a branch.
- Operation cost reflects a range of consumption by a branch, consisting of electricity, telephone, insurance, advertising expenses, stationary, and other supplies.
- Interest cost is related to the costs of all deposit portfolios, including demand deposits, demand savings deposits, time deposits, and foreign exchange deposits.
- Deposits are the branch's total at the year-end.
- Interest income is interest earned on cash held in loan portfolios and other investments in a branch except for fund transfer income.
- Fee income comprises all kinds of service charges, including nonsufficient funds, overdrafts, and account service.
- Fund transfer income refers to the interest income from a branch's funds that are transferred to the head office and other branches.

4.2. Data sources

The analysis concerning the exploration of the sources of cost efficiency and profit niches and the effect of privatization for bank branches in Taiwan's banking system is further examined empirically using branch data from two Taiwan banks. Because branch data in Taiwan's banking system are not public information, we called on the representative bank of state-owned banks and mixed ownership banks, respectively, to collect 55 branches' financial data (30 from a state-owned bank and 25 from a mixed ownership bank). The sample's state-owned bank (SOB) is Taiwan's largest public bank with 162 domestic branches, has made many contributions to Taiwan's economic development, and has played an important role in sociopolitical goals. Its deposits and loans account for 13.18% and 10.85%, respectively, of Taiwan's financial market. On the other hand, the sample's mixed ownership bank (MOB) is the first specialized bank set up by the government for the purpose of providing financing assistance to enterprises. To comply with the policy of privatizing state-owned banks, this bank was transformed into a mixed ownership bank in 1998, in which private capital has 60% ownership and the government still reserves about 40% ownership. At the end of 2008, MOB has 125 domestic branches with deposits and loans accounting for 4.39% and 4.83% of Taiwan's financial market, respectively. Although there is a difference in the ownership structure and operating scale between the two sample banks, their domestic branches face the same fierce challenges in Taiwan's highly competitive and saturated environment after the enforcement of financial liberalization and restructuring. This situation prompted bank management to evaluate self-performance and relative performance compared to others for further identifying the weaknesses and strengths in bank and branch operations.

This study chooses 55 domestic branches as the research sample. Although the sample does not include the entire branch network of two types of banks due to the scarcity of branch data in Taiwan's banking system, the sample may provide a sufficient proxy to explore the strengths and weaknesses of a bank branch's competitive capability and the effect of privatization in Taiwan's banking system. Each of these branches is treated as a decision making unit (DMU) in the DEA analysis. The data used cover the financial year 2008. Table 1 presents the related descriptive statistics.

The DEA method assumes existence of the relationship between input and output data in the empirical application, and Table 2 presents the correlation analyses for relevant variables. The results indicate that most input variables are highly correlated with output variables in both stages, implying each branch that employs more input resources will increase its intermediate deposits and final income. Golany and Roll (1989) showed that the number of DMUs should be at least twice the number of considered input and output variables when conducting the DEA model. In this study the number of branches is 55, which is over seven times the 7 variables for the productivity stage and profitability stage. Hence, the preceding depictions conclude that the DEA model developed in this paper based on a two-stage series network framework meets construct validity requirement.

5. Results and analysis

5.1. Overall branch performance analysis

The evaluation of a branch's productivity and profitability efficiencies is conducted for the year 2008. The inputs for each branch in the productivity stage are personnel cost, operational cost, and interest cost. The intermediate is deposits. The profitability stage outputs are interest income, fee income, and fund transfer income. The initial calculation involves the overall, productivity and profitability efficiencies for overall branches using the fuzzy multiobjective

Table 1
Descriptive statistics for 55 branches in 2008 (in million NT$).

Variables	Mean	Median	Q1	Q3	Minimum	Maximum	Std. dev.
Personnel cost	44.736	43.413	37.675	50.561	28.366	70.932	9.491
Operation cost	88.054	39.040	22.892	79.703	4.991	953.254	155.758
Interest cost	187.314	149.395	97.234	245.387	26.079	580.735	122.961
Deposits	11000.262	9109.755	6715.197	14335.447	3340.813	31254.079	5803.562
Interest income	222.445	179.894	138.563	255.538	74.146	745.146	142.298
Fee income	6.712	5.710	2.562	9.669	0.736	20.847	4.858
Other income	156.847	131.027	58.351	223.409	30.662	459.844	113.925
Fund transfer income	14534.641	10438.054	6901.189	15258.860	3371.930	81654.126	12884.471

model, which can generate the common bas in the network framework. Model (10) calculates the overall efficiencies θ_j^{F} and corresponding stage's efficiencies (θ_j^{F1}, θ_j^{F2}) of 55 branches. Table 3 shows all the results.

The average score of the whole system computed from the fuzzy multiobjective model is 0.375. None of the 55 branches perform efficiently in both stages and the top 4 branches with higher scores in these non-efficient overall scores occur at the mixed ownership bank. The average scores for the productivity stage and profitability based on the network relationship are 0.657 and 0.521, respectively. In the productivity stage, 3 MOB branches, MOB1, MOB6, and MOB7, perform efficiently, which can be regarded as the productivity benchmark of other inefficient branches in using the extant resources to collect deposits. Two branches, MOB20 from the mixed ownership bank and SOB18 from the state-owned bank, are at perfect efficiency, which are the profitability benchmark of other inefficient branches in using the collected deposits to create profits and revenues.

As for the decomposition of overall branch performance, the productivity stage has a higher average score and more efficient branches than the profitability stage, indicating that a lower overall performance of these branches may be attributed to their worse performance in the profitability stage and implying that the performance of profitability for each branch plays a critical role in the branch's performance although they present a better performance in the productivity stage. In order to provide bank management with a better understanding of the operation of each branch, Table 3 draws a further decomposition of the efficiency scores to provide further insight. The multipliers obtained from the DEA methodology represent the measure for the importance of the input and output variables and also represent the relative contribution of the corresponding variables to efficiency. Thus, in the productivity stage, the main purpose of decomposition is to realize the importance of input variables to deposits' productivity.

The equation of Model (10) shows that the productivity efficiency of branch j can be decomposed into the contribution from personnel cost, operation cost, and interest cost by the ratio of $v_i^* x_{ij} / \sum_{i=1}^{m} v_i^* x_{ij}$. These ratios also reflect the importance of input variables to productivity efficiency, which is the managerial focus of branch operations. Regarding the importance of these input variables to the productivity efficiency score, the interest cost has the largest contribution with a mean score of 0.521 and accounting for 80.2% of the average productivity score. Personnel cost is second, and its mean score of 0.118 is approximately 17.2% of the average productivity score. The last one is operation cost with a 0.017 mean score and 2.6% contribution.

Table 2
Correlation coefficients among inputs and outputs for productivity stage.

Variables	Personnel cost	Operational cost	Interest cost	Deposits
Personnel cost	1.000			
Operation cost	0.402	1.000		
Interest cost	0.666	0.492		
Deposits	0.752	0.602	0.951	1.000

Correlation coefficients among inputs and outputs for profitability stage

Variables	Deposits	Interest income	Fee income	Fund transfer income
Deposits	1.000			
Interest income	0.570	1.000		
Fee income	0.675	0.556	1.000	
Fund transfer income	0.856	0.268	0.465	1.000

In the profitability sage, identifying the profit niche is a major concern in the efficiency decomposition. According to the equation of Model (10), profitability efficiency can be decomposed into the contribution from interest income, fee income, and fund transfer income, respectively, by the ratio of $u_r^* y_{rj} / \sum_{r=1}^{s} u_r^* y_{rj}$. In other words, the profitability efficiency is also the aggregation of the individual performance of interest income, fee income, and fund transfer income. Regarding the contribution of these output variables to the profitability efficiency score, fund transfer income has the largest contribution with a mean score of 0.355, which accounts for 59.6% of the average profitability score. Interest income is second, and its mean score of 0.228 is approximately 40.4% the average profitability score. The last is fee income with no contribution to average profitability score. In sum, investigating the contribution of the input and output variables is very helpful for identifying the efficiency difference among the branches. Table 3 indicates that each branch management is able to detect the major variables contributing to the branches' efficiencies, identifies the area where the greatest gains can be acquired from improvements, and suggests to the branches some adjustments for resource reallocation and business strategy.

5.2. Efficiency comparison between MOB branches and SOB branches

In order to explore the effect of privatization and the source of cost inefficiency and profit niche for bank branches in Taiwan's banking system, the efficiency comparison of the two groups of branches is conducted and shown in Table 4. Table 4 indicates that MOB branches have better mean efficiency than the SOB branches. Moreover, the MOB branches' efficiency ranking is significant higher than the rankings of SOB branches (Mann–Whitney *U* Test, $U = 521$, $P = 0.013$), suggesting the overall performance of MOB branches is superior than the SOB branches, and the advantages of a mixed ownership enterprise have some remedial effects for improving the managerial performance of SOB branches.

As for identifying the sources of cost inefficiency and profit niches of the two groups of branches, Table 4 reports that SOB branches have superior ability in profit-making and inferior ability in cost management than MOB branches. More specifically, the state-owned bank in Taiwan has some traditional advantages accruing from its existing market share, financial stability and reputation, and customer trust, which enable its branches to create more interests and profits by using collected deposits and capital, while the productivity advantage of MOB branches arising from lower capital costs, operating flexibility, and less bureaucratic restrictions leads to cost and managerial efficiency. However, the profitability advantage of SOB branches seems to fade away gradually. Table 4 shows MOB branches not only have superior mean overall and productivity efficiencies, but also can reach higher

Table 3
Efficiency scores and decomposition of 55 bank branches.

Branches	Overall efficiency	Productivity efficiency	Efficiency decomposition			Profitability efficiency	Efficiency decomposition		
			Personnel cost	Operation cost	Interest cost		Interest income	Fee income	Fund transfer income
SOB-01	0.329(41)	0.553(44)	0.044	0.009	0.500	0.595(18)	0.198	0.000	0.397
SOB-02	0.295(50)	0.577(35)	0.037	0.059	0.481	0.511(40)	0.131	0.000	0.380
SOB-03	0.325(42)	0.553(45)	0.057	0.008	0.488	0.588(20)	0.196	0.000	0.393
SOB-04	0.373(19)	0.636(27)	0.096	0.013	0.526	0.586(22)	0.255	0.000	0.332
SOB-05	0.342(38)	0.668(23)	0.061	0.011	0.596	0.512(39)	0.102	0.000	0.410
SOB-06	0.449(8)	0.555(42)	0.044	0.010	0.501	0.809(4)	0.121	0.000	0.688
SOB-07	0.362(26)	0.553(43)	0.042	0.014	0.496	0.654(13)	0.142	0.000	0.512
SOB-08	0.349(34)	0.660(25)	0.061	0.005	0.594	0.529(37)	0.110	0.000	0.419
SOB-09	0.317(44)	0.599(31)	0.076	0.004	0.518	0.530(36)	0.197	0.000	0.333
SOB-10	0.354(29)	0.563(40)	0.039	0.008	0.516	0.630(15)	0.145	0.000	0.485
SOB-11	0.354(30)	0.561(41)	0.069	0.008	0.483	0.632(14)	0.228	0.000	0.404
SOB-12	0.347(36)	0.592(32)	0.056	0.019	0.517	0.585(23)	0.131	0.000	0.454
SOB-13	0.432(9)	0.649(26)	0.079	0.004	0.566	0.665(11)	0.205	0.000	0.460
SOB-14	0.321(43)	0.601(30)	0.075	0.023	0.503	0.535(34)	0.144	0.000	0.391
SOB-15	0.349(33)	0.534(51)	0.051	0.007	0.476	0.655(12)	0.136	0.000	0.519
SOB-16	0.370(21)	0.544(47)	0.074	0.007	0.463	0.681(10)	0.231	0.000	0.449
SOB-17	0.292(51)	0.541(49)	0.072	0.029	0.440	0.540(32)	0.222	0.000	0.318
SOB-18	0.520(5)	0.520(54)	0.065	0.005	0.449	1.000(1)	0.183	0.000	0.817
SOB-19	0.350(32)	0.592(33)	0.063	0.007	0.522	0.591(19)	0.142	0.000	0.449
SOB-20	0.336(39)	0.573(38)	0.065	0.009	0.499	0.587(21)	0.158	0.000	0.429
SOB-21	0.389(15)	0.634(28)	0.097	0.007	0.530	0.614(16)	0.199	0.000	0.415
SOB-22	0.289(52)	0.690(18)	0.112	0.006	0.573	0.419(52)	0.259	0.000	0.160
SOB-23	0.332(40)	0.576(37)	0.072	0.006	0.498	0.577(25)	0.182	0.000	0.395
SOB-24	0.313(46)	0.541(48)	0.101	0.017	0.423	0.580(24)	0.303	0.000	0.277
SOB-25	0.418(12)	0.576(36)	0.049	0.015	0.511	0.726(6)	0.151	0.000	0.575
SOB-26	0.306(47)	0.549(46)	0.107	0.007	0.436	0.558(29)	0.263	0.000	0.295
SOB-27	0.279(55)	0.673(22)	0.130	0.010	0.533	0.414(53)	0.240	0.000	0.174
SOB-28	0.422(11)	0.584(34)	0.127	0.001	0.456	0.723(7)	0.170	0.000	0.553
SOB-29	0.297(49)	0.531(52)	0.089	0.008	0.434	0.559(28)	0.290	0.000	0.269
SOB-30	0.372(20)	0.523(53)	0.063	0.011	0.449	0.711(8)	0.202	0.000	0.509
MOB-01	0.454(7)	1.000(1)	0.212	0.044	0.744	0.454(49)	0.326	0.000	0.127
MOB-02	0.402(14)	0.704(16)	0.060	0.068	0.576	0.571(27)	0.439	0.000	0.132
MOB-03	0.484(6)	0.844(5)	0.155	0.022	0.667	0.573(26)	0.166	0.000	0.407
MOB-04	0.286(54)	0.676(21)	0.091	0.008	0.576	0.423(50)	0.254	0.000	0.170
MOB-05	0.305(48)	0.567(39)	0.127	0.015	0.425	0.538(33)	0.348	0.000	0.190
MOB-06	0.527(4)	1.000(1)	0.521	0.017	0.462	0.527(38)	0.231	0.000	0.297
MOB-07	0.379(18)	1.000(1)	0.209	0.024	0.767	0.379(55)	0.221	0.000	0.158
MOB-08	0.687(1)	0.744(12)	0.110	0.120	0.514	0.923(3)	0.609	0.000	0.315
MOB-09	0.355(28)	0.862(4)	0.249	0.016	0.597	0.412(54)	0.282	0.000	0.129
MOB-10	0.365(25)	0.733(13)	0.156	0.009	0.568	0.498(43)	0.191	0.000	0.307
MOB-11	0.315(45)	0.747(10)	0.164	0.018	0.566	0.421(51)	0.266	0.000	0.155
MOB-12	0.383(17)	0.816(6)	0.136	0.011	0.669	0.469(46)	0.228	0.000	0.241
MOB-13	0.416(13)	0.684(19)	0.146	0.008	0.529	0.608(17)	0.186	0.000	0.422
MOB-14	0.387(16)	0.715(15)	0.131	0.008	0.576	0.541(31)	0.196	0.000	0.345
MOB-15	0.344(37)	0.683(20)	0.190	0.011	0.482	0.504(41)	0.266	0.000	0.238
MOB-16	0.348(35)	0.694(17)	0.164	0.007	0.523	0.502(42)	0.245	0.000	0.257
MOB-17	0.353(31)	0.660(24)	0.189	0.013	0.459	0.535(35)	0.247	0.000	0.288
MOB-18	0.369(23)	0.744(11)	0.182	0.013	0.549	0.495(44)	0.202	0.000	0.293
MOB-19	0.367(24)	0.780(9)	0.160	0.009	0.611	0.471(45)	0.194	0.000	0.276
MOB-20	0.534(3)	0.534(50)	0.137	0.015	0.382	1.000(1)	0.426	0.000	0.574
MOB-21	0.431(10)	0.792(8)	0.196	0.012	0.584	0.544(30)	0.198	0.000	0.346
MOB-22	0.286(53)	0.622(29)	0.134	0.009	0.479	0.460(48)	0.257	0.000	0.203
MOB-23	0.541(2)	0.718(14)	0.108	0.096	0.515	0.753(5)	0.477	0.000	0.276
MOB-24	0.370(22)	0.793(7)	0.239	0.010	0.543	0.467(47)	0.186	0.000	0.280
MOB-25	0.357(27)	0.516(55)	0.168	0.011	0.337	0.691(9)	0.235	0.000	0.456
Average	0.375	0.657	0.118	0.017	0.521	0.583	0.228	0.000	0.355

Table 4
Efficiency comparison between SOB branches and MOB branches.

	Overall efficiency	Productivity efficiency	Efficiency decomposition			Profitability efficiency	Efficiency decomposition		
			Personnel cost	Operation cost	Interest cost		Interest income	Fee income	Fund transfer income
Mann–Whitney *U* test	$U = 521$ ($p = 0.02^{**}$)	$U = 664$ ($p < 0.001^{**}$)				$U = 545$ ($p = 0.03^{**}$)			
Average efficiency									
SOB branches	0.353	0.583	0.072 (12.4%)	0.012 (2.0%)	0.499 (85.6%)	0.610	0.188 (32.1%)	0 (0%)	0.422 (67.9%)
MOB branches	0.402	0.745	0.173 (23.0%)	0.173 (3.2%)	0.548 (73.8%)	0.550	0.275 (50.4%)	0 (0%)	0.275 (49.6%)

[**] $p < 0.05$.

Table 5
Sensitivity analysis of eliminating fund transfer income for the fuzzy multiobjective model.

Branch	Original efficiency			Fund transfer income eliminated		
	Overall	Productivity	Profitability	Overall	Productivity	Profitability
SOB-01	0.329	0.553	0.595	0.255[−0.074]	0.553[0]	0.461[−0.134]
SOB-02	0.295	0.577	0.511	0.211[−0.084]	0.577[0]	0.365[−0.146]
SOB-03	0.325	0.553	0.588	0.214[−0.111]	0.553[0]	0.387[−0.201]
SOB-04	0.373	0.636	0.586	0.372[−0.001]	0.636[0]	0.585[−0.001]
SOB-05	0.342	0.668	0.512	0.185[−0.157]	0.668[0]	0.276[−0.236]
SOB-06	0.449	0.555	0.809	0.174[−0.275]	0.555[0]	0.314[−0.495]
SOB-07	0.362	0.553	0.654	0.164[−0.198]	0.553[0]	0.296[−0.358]
SOB-08	0.349	0.660	0.529	0.159[−0.190]	0.660[0]	0.241[−0.288]
SOB-09	0.317	0.599	0.530	0.311[−0.006]	0.599[0]	0.520[−0.010]
SOB-10	0.354	0.563	0.630	0.171[−0.183]	0.563[0]	0.305[−0.325]
SOB-11	0.354	0.561	0.632	0.279[−0.075]	0.561[0]	0.498[−0.134]
SOB-12	0.347	0.592	0.585	0.178[−0.169]	0.592[0]	0.301[−0.284]
SOB-13	0.432	0.649	0.665	0.311[−0.121]	0.649[0]	0.479[−0.186]
SOB-14	0.321	0.601	0.535	0.281[−0.040]	0.601[0]	0.468[−0.067]
SOB-15	0.349	0.534	0.655	0.153[−0.196]	0.534[0]	0.287[−0.368]
SOB-16	0.370	0.544	0.681	0.227[−0.143]	0.544[0]	0.418[−0.263]
SOB-17	0.292	0.541	0.540	0.296[0.004]	0.541[0]	0.548[0.008]
SOB-18	0.520	0.520	1.000	0.225[−0.295]	0.520[0]	0.433[−0.567]
SOB-19	0.350	0.592	0.591	0.326[−0.024]	0.592[0]	0.551[−0.040]
SOB-20	0.336	0.573	0.587	0.224[−0.112]	0.573[0]	0.391[−0.196]
SOB-21	0.389	0.634	0.614	0.385[−0.004]	0.634[0]	0.607[−0.007]
SOB-22	0.289	0.690	0.419	0.493[0.204]	0.690[0]	0.714[0.295]
SOB-23	0.332	0.576	0.577	0.222[−0.110]	0.576[0]	0.386[−0.191]
SOB-24	0.313	0.541	0.580	0.481[0.168]	0.541[0]	0.889[0.309]
SOB-25	0.418	0.576	0.726	0.180[−0.238]	0.576[0]	0.312[−0.414]
SOB-26	0.306	0.549	0.558	0.309[0.003]	0.549[0]	0.562[0.004]
SOB-27	0.279	0.673	0.414	0.300[0.021]	0.673[0]	0.446[0.032]
SOB-28	0.422	0.584	0.723	0.190[−0.232]	0.584[0]	0.325[−0.398]
SOB-29	0.297	0.531	0.559	0.436[0.139]	0.531[0]	0.820[0.261]
SOB-30	0.372	0.523	0.711	0.215[−0.157]	0.523[0]	0.410[−0.301]
MOB-01	0.454	1.000	0.454	0.648[0.194]	1.000[0]	0.648[0.194]
MOB-02	0.402	0.704	0.571	0.598[0.196]	0.704[0]	0.848[0.277]
MOB-03	0.484	0.844	0.573	0.282[−0.202]	0.844[0]	0.334[−0.239]
MOB-04	0.286	0.676	0.423	0.416[0.130]	0.676[0]	0.615[0.192]
MOB-05	0.305	0.567	0.538	0.535[0.230]	0.567[0]	0.942[0.404]
MOB-06	0.527	1.000	0.527	0.416[−0.111]	1.000[0]	0.416[−0.111]
MOB-07	0.379	1.000	0.379	0.509[0.130]	1.000[0]	0.509[0.130]
MOB-08	0.687	0.744	0.923	0.744[0.057]	0.744[0]	1.000[0.077]
MOB-09	0.355	0.862	0.412	0.491[0.136]	0.862[0]	0.569[0.157]
MOB-10	0.365	0.733	0.498	0.277[−0.088]	0.733[0]	0.378[−0.120]
MOB-11	0.315	0.747	0.421	0.430[0.115]	0.747[0]	0.575[0.154]
MOB-12	0.383	0.816	0.469	0.326[−0.057]	0.816[0]	0.399[−0.070]
MOB-13	0.416	0.684	0.608	0.215[−0.201]	0.684[0]	0.314[−0.294]
MOB-14	0.387	0.715	0.541	0.242[−0.145]	0.715[0]	0.339[−0.202]
MOB-15	0.344	0.683	0.504	0.308[−0.036]	0.683[0]	0.451[−0.053]
MOB-16	0.348	0.694	0.502	0.304[−0.044]	0.694[0]	0.439[−0.063]
MOB-17	0.353	0.660	0.535	0.283[−0.070]	0.660[0]	0.429[−0.106]
MOB-18	0.369	0.744	0.495	0.439[0.070]	0.744[0]	0.590[0.095]
MOB-19	0.367	0.780	0.471	0.292[−0.075]	0.780[0]	0.375[−0.096]
MOB-20	0.534	0.534	1.000	0.405[−0.129]	0.534[0]	0.757[−0.243]
MOB-21	0.431	0.792	0.544	0.292[−0.139]	0.792[0]	0.368[−0.176]
MOB-22	0.286	0.622	0.460	0.270[−0.016]	0.622[0]	0.434[−0.026]
MOB-23	0.541	0.718	0.753	0.718[0.177]	0.718[0]	1.000[0.247]
MOB-24	0.370	0.793	0.467	0.288[−0.082]	0.793[0]	0.363[−0.104]
MOB-25	0.357	0.516	0.691	0.208[−0.149]	0.516[0]	0.402[−0.289]
Average	0.375	0.657	0.583	0.324	0.657	0.493

overall efficiency scores and performance rankings by improving their profit-making capabilities. Therefore, for the management of SOB branches, their critical competitive strategy is to maintain their existing profitability advantage and then take some remedial actions to improve their productivity inefficiency, while the managements of MOB branches should target their relative efficiency in the productivity stage to enlarge their profit niches.

Regarding the comparison of managerial focus for cost efficiency and profit niches between the two groups of branches, there is no difference about the direction of improving cost inefficiency for extant inputted resources in the productivity stage — that is, for all branches, interest cost is the prior managerial focus, but the management of MOB branches could pay more attention to personnel cost due to its relative importance for cost efficiency in the mixed ownership bank. On the other hand, the results of the profitability stage indicate that the major profit niche of SOB branches is fund transfer income (67.9%), MOB branches' niches are interest income (50.4%) and fund transfer income (49.6%), and fee income has no significant contribution to branches' profitability, indicating the branches of Taiwan's banking system highly depend on fund transfer income as their major profit niche. This phenomenon puts the branch management, especially in SOB branches, in an operating predicament due to the nature of fund transfer income. Fund transfer income refers to the interest incomes from a branch's idle funds that are transferred to the head office of the bank and other branches, meaning branches are capable of collecting a lot of funds, but are unable to use them efficiently to create more profits and interest income by themselves. Therefore, for the management of SOB branches, the remedial strategies should integrate their existing advantages and the virtue of mixed ownership banks to enlarge the profitability from interest income by reconsidering loans and customer mix as well as the incentive mechanism, which can increase a branch's competitive capability and reduce overdependence on fund transfer income and inefficiency of interest costs.

5.3. Sensitivity analysis about fund transfer income

The profitability efficiency decomposition of the branches reveals that fund transfer income plays a critical role in branch profitability, as the income is transfer pricing that measures the value of products furnished by one profit center to another responsibility center within a company (Kocakülâh and Egler, 2006). In Taiwan, the gross savings to GNP ratio hit 29.7% in 2009, marking a society with a high savings rate (Mckenzie, 2006) and abundant capital funds, leading the financial system to have more deposits than loans for most bank branches. Thus, in Taiwan's banking system, fund transfer income encompasses the deposits collected by branches and used by the head office of the bank to fund other loans or investments. Although the funds transferred between branches and the head office can increase interest income, earnings, and profitability of the whole bank, the interest income from these transferred funds also hinders the evaluation of real profitability and any further identification for the competitive capabilities of the branches. In this context, the real profitability of each branch can be defined as all types of incomes except fund transfer income, which contributes 51.5% of the average profitability performance.

In order to explore the profitability change of branches, sensitivity analysis is applied to investigate the effect from fund transfer income. The topic of sensitivity analysis has been used in some studies (Chen, 2002; Lo et al., 2001), and this paper utilizes it to look at the difference of the relative efficiencies of branches by withdrawing fund transfer income from the original fuzzy multiobjective model consideration. Table 5 summarizes the results of the sensitivity analysis. As shown in Table 5, the performance scores of overall and profitability efficiencies present a significant difference ($p<0.01$ for both performance scores) after eliminating fund transfer income. The values with parentheses in Table 5 represent the differences between the original efficiency scores and eliminated ones. These values reveal that only 16 out of 55 branches have a better performance without fund transfer income while the other branches have lower efficiency scores. Based on sensitivity analysis, bank management can identify the main weakness in branch operations and competitive capabilities — that is, most branches have the ability to collect excess deposits than they can loan out, but branches lack the capability to utilize these deposits to create more profits than do the transferring funds. Therefore, a branch manager should adjust the operation strategy and reallocate resources to develop other value-add transactions to increase competitive advantages.

5.4. Managerial decision-making matrix

By combining the original efficiencies and revised efficiencies without considering fund transfer income, this paper designs the managerial decision-making matrix to help bank management position branches in the banking network and to provide direction for improving branch performance. First of all, the results in regard to the original efficiencies of branches as the horizontal axis of the matrix represent the nominal profitability performance, including the achievement by each branch itself and the contribution from fund transfer income. A larger score implies an effective utilization of resources and less urgency for managerial improvement, while a small score means poor operation efficiency, which needs an urgent managerial strategy to improve performance. Second, the result of

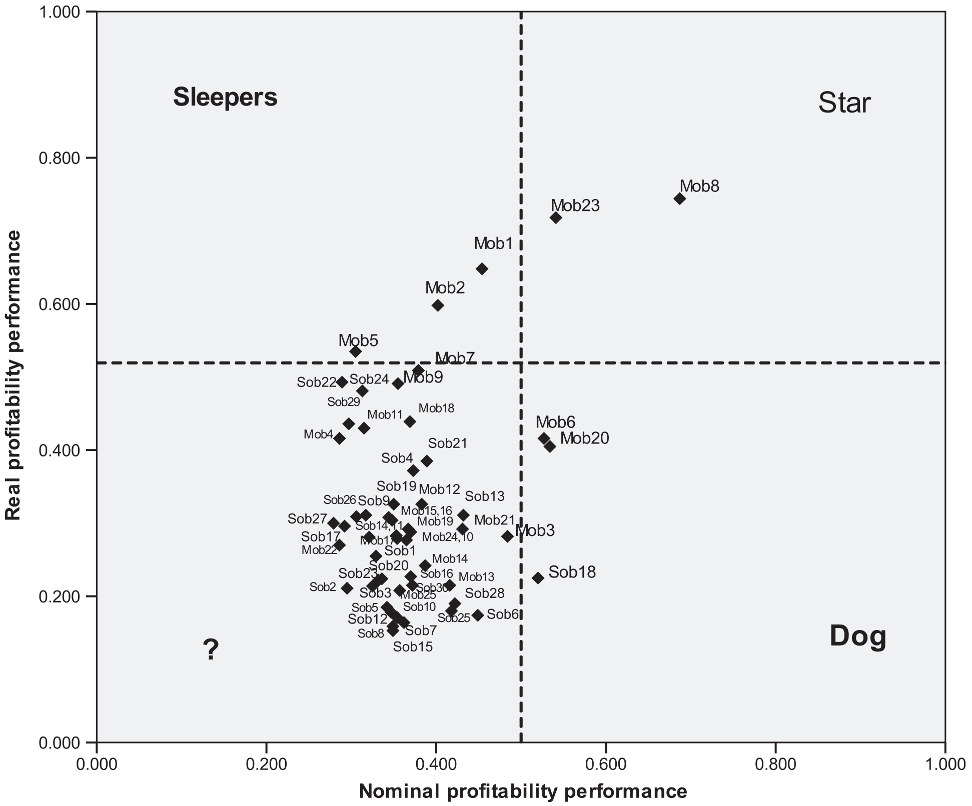

Fig. 2. Nominal profitability vs. real profitability.

sensitivity analysis with fund transfer income eliminated represents that the real profitability performance of branches is taken as the vertical axis. Here, the branch with a larger value means having high capabilities to generate short-term and long-term profits without external support. By contrast, the branch with a smaller value means it is inefficient to generate the profits and scope to improve performance. The threshold of this matrix is 90% for good nominal and real profitability performances, respectively, which are derived from the fuzzy multiobjective model. According to these two criteria, the branches can be divided into four quadrants in the decision-making matrix as shown in Fig. 2.

On the whole, the matrix echoes the results of the preceding sections that the MOB branches perform superior to the SOB branches. In other words, 8 branches have better performance either in nominal profitability or in real profitability, but only 1 branch (Sob18) belongs to the state-owned bank, indicating that the managerial mechanism of a private enterprise may have a significant effect for improving the performance of SOB branches. In addition, this matrix can serve as a managerial tool for bank and branch management to provide further improvement directions and efforts. The detailed discriminative groups of the branches are described as follows.

Star quadrant: These branches enjoy better performance both in nominal profitability and real profitability and are classified as “Star”. Two branches are included here: Mob23 and Mob23. These branches are the benchmarks for the others and achieve outstanding resource utilization as well as profit generation. Bank managers in the state-owned bank and the mixed ownership bank should identify operational strategies and administrate the skills of these branches and promote them to other inefficient branches in order to enlargeverall performance.

Sleepers quadrant: These branches experience better real profitability performance, but a decreasing variation in the nominal profitability performance, and are classified as “Sleepers”. Three branches are included: Mob1, Mob2, and Mob5. The branches located in this quadrant generate better performance without considering funds' transfer pricing, which implies that these branches are capable of using their capital to create profit by themselves, but still have room for improvement in utilizing their resources efficiently to generate more outputs in the productivity stage. It is worth noting that these branches should be prime candidates for efficiency improvement efforts and can be a potential “star group” if they place more emphasis on activities that are aimed at improving operational management.

Dog quadrant: These branches have better nominal profitability performance, but low real profitability performance. Three branches, Mob6, Mob20, and Sob18, are in this quadrant. It is interesting to note that these branches would have good efficiency if fund transfer income is considered, but these branches have lower profitability in contrast to having outstanding resource utilization. Strategies should be adopted to improve the profitability of these branches and to actively expand their product and customer mix to increase the economic value of products.

Question mark quadrant: These branches in the bottom-left quadrant perform worse in terms of real profitability performance and nominal profitability performance. This group includes 47 out of 55 branches. In the viewpoint of bank management, they are the problematic branches and have scope for improvement both in profit generation and resource utilization. Diagnostic actions should be taken to remedy their problems. It is suggested that these branches need to immediately adjust their operational management to be more efficient and then expand profit generation thereafter.

6. Conclusions

This paper considers that the complementation of production and intermediation activities within a branch should be evaluated simultaneously and proposes a two-stage series model in the network framework to measure branch performance in Taiwan's banking system. In order to overcome the shortage of a traditional network DEA methodology about branches that cannot be assessed on the same base, we combine the multiple objectives programming approach and the fuzzy approach to propose the fuzzy multiobjective model to evaluate this network problem. The application of the fuzzy multiobjective model is expected to provide a fair evaluation for branch performance and produce a valid investigation and persuasive results for bank and branch management to identify a branch's efficiency, weakness, and improvement directions.

Our main results are summarized as follows: (1) The evaluation under the common base indicates that most Taiwan bank branches perform better in the productivity stage, but branches with a good score in the profitability stage have better efficiency in overall performance, implying that the profitability of branches still plays a critical role for a branch's performance although they present better performance in the productivity stage. (2) Efficiency decomposition indicates that interest cost is the largest factor in the productivity stage, while fund transfer income and interest income offer key contributions for branches' profitability. This result identifies the area where the greatest gains can be acquired from improvements, and bank management can assist their branches in making some adjustments for resource reallocation and business strategy. (3) A comparison between SOB branches and MOB branches reveals that the latter perform better than the former, indicating the managerial mechanism of a private enterprise may have some remedial effect for improving the branch performance of a state-owned bank. In addition, although SOB branches have been identified as having superior ability in profit-making, this profitability advantage seems to gradually fade away. Therefore, the prior strategy of SOB branches is to integrate their existing advantages and the virtue of MOB branches to improve their cost inefficiency first and then to enlarge the profit niche. (4) By means of sensitivity analysis, the sources of cost inefficiency and profit niche in branches' operations and competitive capability have been identified in that most Taiwan bank branches have the ability to collect more excess deposits than they can loan, yet lack the capability to utilize these deposits to create more profits versus transferring funds. (5) By combining nominal profitability performance and real profitability performance, the decision-making matrix is presented to help bank management to position branches in their banking network. The matrix indicates that MOB branches not only have superior performance either in real profitability or in nominal profitability, but also have some branches as the benchmark for providing direction of for improving the performance of inefficient branches.

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