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Productivity change in Taiwan's farmers' credit unions: a nonparametric risk-adjusted Malmquist approach

Po-Chi Chen[a], Ming-Miin Yu[b], Ching-Cheng Chang[c], Shih-Hsun Hsu[d,*]

[a]Department of International Trade, Chung Hua University, Hsinchu, and Ph.D. Candidate, Department of Agricultural Economics, National Taiwan University, Taipei, Taiwan

[b]Department of Transportation and Navigation Science, National Taiwan Ocean University, Keelung, Taiwan

[c]Institute of Economics, Academia Sinica, and Professor, Department of Agricultural Economics, National Taiwan University, Taipei, Taiwan

[d]Department of Agricultural Economics, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, 10617 Taiwan

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Abstract

This article proposes an extended three-stage DEA methodology similar to Fried et al. (2002) to improve the measurement of productivity growth when the assumption of free disposability of undesirable output does not apply. A directional distance function is used to construct adjusted Malmquist–Luenberger productivity indexes which simultaneously account for the impacts of undesirable outputs, environmental variables, and statistical noise. Panel data for 263 farmers' credit unions (FCUs) in Taiwan covering the 1998–2000 periods are employed to illustrate the advantages of this method. On average, the productivity of Taiwan's FCUs is found to have deteriorated over the 1998–2000 period. Although an improvement in efficiency has been observed, the major reason for the deterioration is found to be due to the regression of technology.

JEL classification: C61, D24, Q13

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1. Introduction

Farmers' credit unions (FCUs) have played an important role in financing Taiwan's rural development. The major activities of FCUs are receiving deposits from and extending loans to their members. This means that their profits largely come from their issuing loans. Over the period from 1961 to 1994, total FCU loans grew dramatically, registering an average annual growth rate of 23%. The increase in FCU savings was also substantial, with an average growth rate of 23.4% being recorded during the 1961–1990 period. In 1993, total FCU loans for agricultural usage exceeded NT$350 billion, accounting for more than 50% of Taiwan's total agricultural loans (Chang, 1999). However, the shares of the total deposits and loans of the FCUs in the entire financial market fell dramatically from 17.93% in 1993 to 9.29% in 2003. This reduction indicates that the FCUs encountered severe problems in making profits.

Following the promulgation of the Criteria for the Establishment of Commercial Banks in 1990, the number of banks in Taiwan increased from 24 in 1990 to 40 in 1992 (Huang and Huang, 2002). Inevitably, Taiwan's FCUs were confronted with a situation in which other commercial banks were vigorously expanding their banking services into the rural communities where most of Taiwan's FCUs' were located. On the other hand, the FCUs had their own internal problems that they needed to resolve, such as those related to credit screening and loan monitoring (Chen et al., 2002). As a result, many FCUs experienced financial difficulties. During 2001–2002, 34 of the 287 FCUs went bankrupt and were taken over by commercial banks. The average ratio of nonperforming loans to loans outstanding for FCUs climbed substantially from 5.07% in 1995 to 17.57% in 2003, a ratio about four times that for Taiwan's domestic commercial banks. Therefore, in monitoring their efficiency performance, asset quality and risk factors need to be taken into account, otherwise, FCUs that scrimp on credit evaluations or generate excessively risky loans might be mistakenly regarded as being efficient or more productive, while FCUs that expend more resources to ensure that their loans are of higher quality might be considered to be inefficient or less productive.

In recent years, a number of studies have attempted to obtain risk-adjusted or quality-based measures when evaluating the

* Corresponding author. Tel.: +886-2-3366-2677; fax: +886-2-2362-8496.
E-mail address: m577@ntu.edu.tw (Shih-Hsun Hsu).

managerial efficiency or productivity growth of financial institutions. For example, Chang (1999) treated nonperforming loans as a joint but undesirable output and derived a risk-adjusted nonparametric efficiency measure that takes into account the costs associated with risk reduction. Pastor (2002) regarded total bad loans as an indictor of risk. Since bad loans may either arise due to bad management on the part of the bank, or else arise because of adverse economic circumstances beyond the bank's control, Pastor proposed a three-stage sequential technique in which total bad loans were decomposed into two components: bad loans due to bad managerial performance and bad loans due to the economic environment. Efficiency measures adjusted for both risk and the environment were hence derived. Park and Weber (2006) also treated nonperforming loans as a joint but undesirable output. They applied the directional distance function and sequential technology to estimate efficiency and productivity growth of the Korean banking industry during the period 1992–2002. However, their measurement did not exclude the impacts of the environment. Isik and Hassan (2003a, 2003b) included risk-adjusted off-balance sheet items in the output vector to examine the productivity change, efficiency and technical progress of Turkish banks using Malmquist productivity indexes. Off-balance sheet items were risk-adjusted using Basel Accord risk weights in order to provide conformity with directly-issued loans in terms of risk.

The major purpose of this study is to investigate factors (either exogenous or endogenous) that might explain the profusion of banking crises among the FCUs in Taiwan. In particular, we will focus on the productivity growth of FCUs using the Malmquist total factor productivity (MTFP) index method. The MTFP method has become very popular in the banking literature in which the impact of financial reform (or liberalization) on management efficiency and productivity growth has been explored (e.g., Chen and Yeh, 2000; Devaney and Weber, 2000; Gilbert and Wilson, 1998; Grifell-Tatje and Lovell, 1996; Grifell-Tatje and Lovell, 1997; Isik and Hassan, 2003a, 2003b; Leightner and Lovell, 1998; Mukherjee et al., 2001; Park and Weber, 2006; Sathye, 2002), because it rests exclusively on quantity information, requiring neither price information nor a behavioral assumption in its construction.[1] Moreover, through the use of a distance function, the MTFP index may easily accommodate multi-output cases when panel data are available. Finally, changes in the MTFP index can be further decomposed into the components of efficiency change and technical change and offer more insights into the sources of productivity growth (Färe et al., 1994).

According to Fried et al. (2002), the performance of producers is influenced by three very different phenomena, namely, the efficiency with which a manager organizes production activities, the characteristics of the environment in which production activities are carried out, and the impact of good or bad luck (i.e., statistical noise). Therefore, in order to improve measures of managerial efficiency performance, Fried et al. proposed a three-stage approach to purge the impacts of exogenous environmental features and statistical noise. In this study, we adopt the spirit of the three-stage methodology of Fried et al. and extend the conventional Malmquist TFP index to an adjusted Malmquist–Luenberger TFP index that includes credit risk as an undesirable output. In the first stage, we choose nonperforming loans as an indictor of risk, and treat nonperforming loans as an undesirable output produced together with desirable outputs. Instead of using the hyperbolic output measures proposed in Chang (1999) and Färe et al. (1989), we use the directional distance function developed in Chung et al. (1997) to calculate the output slack (or surplus) for each output where the firm's activities to reduce its bad outputs and increase its good outputs are credited asymmetrically. In the second stage, we use stochastic frontier analysis (SFA) to regress the estimated output slacks against the observed environmental variables and use the regression results to adjust the observed output values while purging the influences of the operating environment and statistical noise. In the third stage, we re-run the DEA model based on the directional distance function using the adjusted output and input data. The Malmquist–Luenberger TFP index and its decomposition are then obtained. Panel data for 263 of Taiwan's FCUs covering the years 1998–2000 are used as an example.

The remainder of this study is organized as follows. The next section describes the three-stage methodology of TFP measurement followed by a brief description of the data and empirical model. Section four presents the empirical results and the final section concludes.

2. Methodology

2.1. Directional distance function

We arrive at an adjusted Malmquist–Luenberger productivity measure by means of a three-stage process in which an undesirable output (namely, credit risk), environmental effects and statistical noise are taken into account. The conventional Malmquist productivity index introduced by Caves et al. (1982) and popularized by Färe et al. (1994) only considers input variables and desirable outputs in evaluating a producer's productivity performance. Chung et al. (1997) however, incorporate undesirable output variables and develop a new index that is referred to as a Malmquist–Luenberger productivity index. To allow for the possibility of crediting firms for the reduction in undesirable outputs, Chung et al. use a directional output distance function to replace the Shephard output distance function when the conventional Malmquist productivity index is constructed.

The directional distance function approach is designed to avoid the computational problems involving the calculation

[1] Profits from FCUs are transferred to other departments of the Farmers' Associations in order to improve their cooperative marketing, supply, sales and extension activities (Wang et al., 2001). Therefore, they are not profit-maximizers. For this reason, if we wish to explore the performance of Taiwan's FCUs, it would be inappropriate to model their behavior using an intertemporal profit function, or a Tornqvist productivity index that assumes cost-minimizing and revenue-maximizing behavior (Grifell-Tatje and Lovell, 1996).

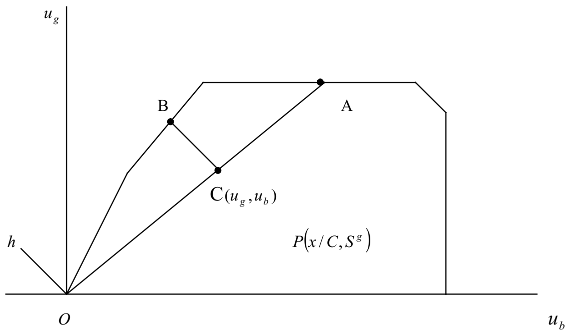

Fig. 1. Directional output distance function

of output efficiency as a solution to nonlinear programming problems. Moreover, it avoids the occurrence of an ill-defined Malmquist productivity index when we try to compute the mixed-period distance function. In contrast to the Shephard output distance functions which seek to increase the goods and the bads simultaneously, the directional output distance function seeks to increase the goods and decrease the bads directionally as depicted by the following formulation:

$$\vec{D}_O\left(\left(u_g^k, u_b^k\right), x^k\right) = \sup\left\{\lambda : \left(u_g^k, u_b^k\right) + \lambda \cdot h \in P(x/C, S^g)\right\}, \quad (1)$$

where $h = (u_g^k, -u_b^k)$ is the vector of "directions" in which both desirable outputs (u_g^k) and undesirable outputs (u_b^k) are scaled, and the output reference set $P(x/C, S^g)$ satisfies the assumptions of constant returns to scale, a strong disposability of desirable outputs, and a weak disposability of undesirable outputs.

Fig. 1 illustrates the idea of a directional output distance function. The output set, $P(x/C, S^g)$, is the area bounded from above by the isoquant, Isoq-$P(x/C, S^g)$. The value of the output directional distance function for point C, which defines the production point where firm C uses input x to produce the desirable output u_g and undesirable output u_b, is equal to the ratio $\lambda = BC/Oh$. However, Shephard's output distance function applied to the output vector (u_g^k, u_b^k) at C would place it on the boundary of $P(x/C, S^g)$ at A as a reference point, and would yield a value of OA/OC. The relationship between the output distance function and output directional distance function is characterized as

$$\vec{D}_o((u_g, u_b), x; h) = (1/D_o((u_g, u_b), x)) - 1, \quad (2)$$

where $D_o((u_g, u_b), x) = \inf\left\{\lambda : ((u_g, u_b)/\lambda \in P(x/C, S^g)\right\}$ (see Chung et al.).

2.2. Three-stage DEA

Stage 1: The Initial DEA Evaluation Accounting for Undesirable Output

Stage 1 in our approach is similar to the first stage conducted in Fried et al. That is, we use the original unadjusted input and output data to identify a DEA frontier. However, our procedure allows for the possibility of undesirable output, and hence the conventional DEA model adopted by Fried et al., which implicitly assumes that all outputs are "goods," has to be modified.

In many production activities, undesirable outputs (bads), such as pollution, noise and nonperforming loans or bad loans, are produced together with desirable outputs. When evaluating the performance of producers it makes sense to credit them for their provision of desirable outputs and penalize them for their provision of undesirable outputs (Färe et al., 1989). In the case of the financial industry, this means that if we intend to dispose of these bad outputs (e.g., nonperforming loans or risky assets), it is necessary for the banks to either give up some of their loans or else maintain a certain amount of risk-reducing funds in order to tighten their lending service (Chang, 1999).

To incorporate the idea that a reduction in bads is costly, following Chung et al. (1997) we assume that undesirable outputs are weakly disposable and that desirable outputs are strongly disposable (or freely disposable), and employ the directional output distance function instead of the traditional Shephard output distance function to represent technology. For each firm k', at time period t, the directional output distance function can be obtained by solving the following linear programming problem with a constant-returns-to-scale (CRS) technology:

$$\vec{D}_o^t\left(x^{k'}, u_g^{k'}, u_b^{k'}; u_g^{k'}, -u_b^{k'}\right) = \max\theta \quad (3)$$

$$\text{s.t.} \sum_{k=1}^{K} z_k^t u_g^{k.t,m} \geq (1+\theta) u_g^{k',t,m}, \quad \forall m = 1, \cdots, M,$$

$$\sum_{k=1}^{K} z_k^t u_b^{k.t,i} = (1-\theta) u_b^{k',t,i}, \quad \forall i = 1, \cdots, I,$$

$$\sum_{k=1}^{K} z_k^t x^{k.t,n} \leq x^{k',t,n}, \quad \forall n = 1, \cdots, N,$$

$$z_k^t \geq 0, \quad k = 1, \cdots, K.$$

Here $\vec{D}_o^t$ denotes the directional output distance function which seeks to increase the good outputs while simultaneously decreasing the bad outputs. We assume that, at each time period, there are K producers who use N inputs (x) to produce M desirable outputs (u_g) and I bad (or undesirable) outputs (u_b). The vector, z_k^t, denotes the intensity level of producer k at time period t. The vector z_k^t enables us to shrink or expand the individual observed activities of producer k for the purpose of constructing convex combinations of the observed inputs and outputs. θ represents the coefficient of "direction" in which outputs are scaled.

The inequalities for the inputs in (3) make them freely disposable, and the same holds for the good outputs. The bad outputs are modeled with equalities due to their weak disposability, namely, their not being freely disposable. Finally, the nonnegativity constraints on the intensity variables z_k^t allow the model to exhibit constant returns to scale (Chung et al., 1997).

Stage 2: Using SFA to Decompose Stage 1 Output Slacks

In Stage 2 we extend the procedure employed by Fried et al. to decompose Stage 1 output slacks into four effects, namely, environmental influences, managerial inefficiency, time effect, and statistical noise. The original output variables are then adjusted by the stochastic noise and the exogenous environmental variables.

Using the SFA approach, we choose the M + I Stage 1 output slacks as dependent variables and regress them against observable environmental variables and a composite error term which captures the effects of managerial inefficiency and statistical noise. Because the data is panel in nature, time dummy variables are added into the SFA as follows:

$$S_{mkt} = \alpha_0^m + \delta^m YD + \beta^m EN + \left(v_{kt}^m + u_{kt}^m\right), m = 1, \cdots, M,\quad k = 1, \cdots, K, \quad t = 1, \cdots T, \tag{4}$$

where S_{mit} is the output slack m of the kth producer in the tth time period; YD represents a vector of year dummy variables; EN is a vector of environmental variables; and α_0^m, δ^m, and β^m are, respectively, unknown parameters for the intercept, year dummies, and environmental variables. The year dummies in (4) represent the time-specific mean effect of each period and α_0^m denotes the time effect of the base year.

Moreover, the v_{kt}^m are random variables which are assumed to be $iid \sim N(0, \sigma_v^{m^2})$, and independent of the u_{kt}^m where the u_k^m are nonnegative random variables accounting for managerial inefficiency and which are assumed to be *iid* and truncated at zero from $N(\mu^m, \sigma_u^{m^2})$. Under such assumptions, equation (4) may be estimated using maximum likelihood estimation techniques. Following the parameterization of Battese and Corra (1977), we replace $\sigma_v^{m^2}$ and $\sigma_u^{m^2}$ with $\sigma^{m^2} = \sigma_v^{m^2} + \sigma_u^{m^2}$ and $\gamma^m = \sigma_u^{m^2} / (\sigma_v^{m^2} + \sigma_u^{m^2})$.[2]

The impacts of the environment variables on Stage 1 slacks are captured by the deterministic feasible slack frontier, which is estimated from the regression results in (4) as follows:

$$\hat{S}_{mkt} = \hat{\alpha}_0^m + \hat{\delta}^m YD + \hat{\beta}^m EN, \tag{5}$$

where $\hat{\beta}^m EN$ represents the external environment effect, and $\hat{\alpha}_0^m + \hat{\delta}^m YD$ the time effect. The estimated output slacks are used to adjust the observed outputs by eliminating the influences of environmental variables, time effect and statistical noise. The objective of this adjustment is "to level the playing field before repeating the DEA analysis" (see Fried et al., 2002, p. 163).

In addition to purging the effects of the operating environment, the observed outputs should be further adjusted for the influence of statistical noise. Before doing this, however, it is necessary to separate statistical noise from managerial inefficiency in the residuals of the model as depicted by equation (4) to obtain estimates of v_{kt}^m for each producer. Following Fried et al., the estimators for statistical noise are derived residually by means of

$$\hat{E}\left(v_{kt}^m \mid v_{kt}^m + u_{kt}^m\right) = S_{mkt} - \hat{S}_{mkt} - \hat{E}(u_{kt}^m \mid v_{kt}^m + u_{kt}^m) \tag{6}$$

where the $\hat{E}\left(u_{kt}^m \mid v_{kt}^m + u_{kt}^m\right)$, are the conditional estimators for managerial inefficiency. Thus, the effects of environmental variables and statistical noise are used to adjust the original desirable outputs u_{mkt}^g and undesirable outputs u_{mkt}^b by means of

$$u_{mkt}^{g,A} = u_{mkt}^g + \left[\left(\alpha_0^m + \delta^m YD + \hat{\beta}^m EN\right) - \min_{kt}\left(\alpha_0^m + \delta^m YD + \hat{\beta}^m EN\right)\right] + \left[\hat{v}_{kt}^m - \min_{kt}\left(\hat{v}_{kt}^m\right)\right] \tag{7}$$

and

$$u_{mkt}^{b,A} = u_{mkt}^b - \left[\left(\alpha_0^m + \delta^m YD + \hat{\beta}^m EN\right) - \min_{kt}\left(\alpha_0^m + \delta^m YD + \hat{\beta}^m EN\right)\right] - \left[\hat{v}_{kt}^m - \min_{kt}\left(\hat{v}_{kt}^m\right)\right], \tag{8}$$

where $u_{mkt}^{g,A}$ and $u_{mkt}^{b,A}$ denote the adjusted desirable and undesirable output quantities, respectively. The second terms in equations (7) and (8) are used to adjust for the environmental and time effects, while the third terms take care of the statistical noise. The purpose behind upwardly adjusting the output with minimum estimated output slacks is to establish a baseline equal to the most favorable set of external conditions. For example, a producer with external environmental variables that generate a higher level of estimated output slack would have its output vector adjusted upward to put it on the same basis as those producers with the most favorable external environment. Therefore, the output adjustments on the right-hand sides of equations (7) and (8) place all producers in a common environment with the most favorable environment and the luckiest situation observed in the sample.

Stage 3: Adjusted Malmquist–Luenberger productivity index

After eliminating the influences of environmental variables and statistical noise in Stage 2, we use the adjusted panel data to calculate the output-oriented Malmquist–Luenberger productivity index. The formula used to obtain this adjusted Malmquist–Luenberger productivity index is developed in Chung et al. (1997) and states that

$$ML_t^{t+1} = \left\{ \frac{\left(1+\vec{D}_0^t\left(x^t, u_g^t, u_b^t; u_g^t, -u_b^t\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, u_g^{t+1}, u_b^{t+1}; u_g^{t+1}, -u_b^{t+1}\right)\right)} \times \frac{\left(1+\vec{D}_0^{t+1}\left(x^t, u_g^t, b^t; u_g^t, -u_b^t\right)\right)}{\left(1+\vec{D}_0^{t+1}\left(x^{t+1}, u_g^{t+1}, u_b^{t+1}; u_g^{t+1}, -u_b^{t+1}\right)\right)} \right\}^{1/2}. \tag{9}$$

[2] Note that the parameter, γ^m, lies between 0 and 1. A value of γ^m close to zero indicates that the deviations from the stochastic feasible slack frontier are mostly due to noise. On the other hand, if the value of γ^m is close to 1, this means that the deviations are mostly due to managerial inefficiency.

Moreover, this index can be decomposed into two component measures, one accounting for efficiency change (*EFCH*), and the other one measuring technical change (*TECH*). These are:

$$EFCH_t^{t+1} = \frac{1 + \vec{D}_0^{t}\left(x^t, u_g^t, u_b^t; u_g^t, -u_b^t\right)}{1 + \vec{D}_0^{t+1}\left(x^{t+1}, u_g^{t+1}, u_b^{t+1}; u_g^{t+1}, -u_b^{t+1}\right)}, \text{ and} \quad (10)$$

$$TECH_t^{t+1} = \left\{ \frac{\left[1 + \vec{D}_0^{t+1}\left(x^t, u_g^t, u_b^t; u_g^t, -u_b^t\right)\right] \cdot \left[1 + \vec{D}_0^{t+1}\left(x^{t+1}, u_g^{t+1}, u_b^{t+1}; u_g^{t+1}, -u_b^{t+1}\right)\right]}{\left[1 + \vec{D}_0^{t}\left(x^t, u_g^t, u_b^t; u_g^t, -u_b^t\right)\right] \cdot \left[1 + \vec{D}_0^{t}\left(x^{t+1}, u_g^{t+1}, u_b^{t+1}; u_g^{t+1}, -u_b^{t+1}\right)\right]} \right\}^{1/2}. \quad (11)$$

To calculate this productivity index and its components, we need to compute four directional distance functions using DEA. These four directional distance functions are:

$\vec{D}_0^{t}\left(x^{t,k'}, u_g^{t,k'}, u_b^{t,k'}; u_g^{t,k'}, -u_b^{t,k'}\right)$,

$\vec{D}_0^{t+1}\left(x^{t+1,k'}, u_g^{t+1,k'}, u_b^{t+1,k'}; u_g^{t+1,k'}, -u_b^{t+1,k'}\right)$,

$\vec{D}_0^{t}\left(x^{t+1,k'}, u_g^{t+1,k'}, u_b^{t+1,k'}; u_g^{t+1,k'}, -u_b^{t+1,k'}\right)$,

and

$\vec{D}_0^{t+1}\left(x^{t,k'}, u_g^{t,k'}, u_b^{t,k'}; u_g^{t,k'}, -u_b^{t,k'}\right)$.

Each of them can be calculated as solutions to the following linear programming problems:

$$\vec{D}_0^{t+s}\left(x^{t+v,k'}, u_g^{t+v,k'}, u_b^{t+v,k'}; u_g^{t+v,k'}, -u_b^{t+v,k'}\right) = \max\theta \quad (12)$$

$$\text{s.t.} \sum_{k=1}^{K} z_k^{t+s} u_g^{t+s,k.m} \geq (1+\theta) u_g^{t+v,k',m}, m = 1, \cdots, M,, \text{s}, v = 0, 1$$

$$\sum_{k=1}^{K} z_k^{t+s} u_b^{t+s,k.i} = (1-\theta) u_b^{t+v,k',i}, i = 1, \cdots, I,, \text{s, v} = 0, 1$$

$$\sum_{k=1}^{K} z_k^{t+s} x^{t+s,k.n} \leq x^{t+v,k',n}, n = 1, \cdots, N,, \text{s, v} = 0, 1$$

$$z_k^{t+s} \geq 0, \quad k = 1, \cdots, K, \quad \text{s} = 0, 1$$

where

$\vec{D}_0^{t}\left(x^{t,k'}, u_g^{t,k'}, u_b^{t,k'}; u_g^{t,k'}, -u_b^{t,k'}\right)$ is calculated with $(s, v) = (0, 0)$,

$\vec{D}_0^{t+1}(x^{t+1,k'}, u_g^{t+1,k'}, u_b^{t+1,k'}; u_g^{t+1,k'}, -u_b^{t+1,k'})$ is calculated with $(s, v) = (1, 1)$,

$\vec{D}_0^{t}(x^{t+1,k'}, u_g^{t+1,k'}, u_b^{t+1,k'}; u_g^{t+1,k'}, -u_b^{t+1,k'})$ is calculated with $(s, v) = (0, 1)$, and

$\vec{D}_0^{t+1}(x^{t,k'}, u_g^{t,k'}, u_b^{t,k'}; u_g^{t,k'}, -u_b^{t,k'})$ is calculated with $(s, v) = (1, 0)$.

3. Data and variable specification

The sample used for this analysis consists of 263 FCUs out of a total of 287 FCUs in Taiwan for three consecutive years, 1998–2000, the other 24 FCUs being omitted due to a lack of consistency in their input or output data or because of missing data. Regarding the specification of the FCUs' input and output variables, we follow Chang (1999) in adopting the "intermediation approach" to define these variables. Accordingly, there are four inputs: loanable funds ($X1$), labor ($X2$), capital expense ($X3$), and fixed assets ($X4$), and three outputs which include two desirable outputs: total loans ($Y1$), and nonloan output ($Y2$), and one undesirable output: nonperforming loans (B). These data are obtained from the *Farmers' Association Yearbook* published by the Taiwan Provincial Farmers' Association (1999, 2000, and 2001). Data descriptions are listed in the Appendix.

Six environmental variables, which cannot be controlled by the general managers of farmers' associations, and two time dummy variables are specified as follows:

1. **Education:** The proportion of employees with a college degree and above is employed to characterize the employees' quality.[3] According to the laws governing farmers' associations in Taiwan, the general manager of a farmers' association has the right to make the decisions regarding personnel matters. Nevertheless, farmers' associations are grassroots organizations, and most of their employees are locally-based and have close relationships with the local faction leaders. Therefore, the general manager of a farmers' association will hardly ever fire his employees unless they make serious mistakes. For this reason, we treat this variable as part of the operating environment. Generally speaking, a higher educational level implies a better quality of employees, and thus it is expected that FCUs with higher education ratios will be more productive.
2. **Membership:** The members of FCUs consist of regular members (or voting members), and associate members (or nonvoting members). Only full-time farmers are initially eligible to become regular members. The associated members are mostly part-time farmers and rural residents (Wang and Chang, 2003). FCUs with high ratios of regular members to

[3] It is noted that this variable is computed on the basis of an entire farmers' association, since the Farmers' Association Yearbook for Taiwan only provides data on the employment of the entire farmers' association, and there is no data on each department. Therefore, it is assumed that the employment characteristics of a farmers' association are fair representations of the related characteristics of its credit department (Wang et al., 2001).

total members are more likely to be located in communities with a concentration of agricultural activities and hence this variable can be used to reflect an FCU's economic and community environment.

3. **Number of branches:** In general, the more branches an FCU has, the larger of scale of this FCU, because it is not easy for FCUs to increase or reduce the number of their branches within a short period (Fu and Lu, 2003). Hence, this variable is used as a proxy for an FCU's scale of operations. However, the relationship between an FCU's scale of operations and its performance has not been determined. It is possible that FCUs that have larger scales of operations will benefit from economies of scale due to cost saving. It is also possible, however, that a larger scale of operations will result in managerial inefficiency.
4. **Loan ratio:** The loan ratio refers to loans extended to associate members as a proportion of total loans. According to statistics released by the Ministry of Finance, loans of less than NT$1 million accounted for 52.9% of total loans extended by FCUs in 2002, and the nonperforming loan ratio for this portion of the loans was only 5.7%. Loans of between NT$1 million and NT$5 million accounted for a further 41.6%, and their nonperforming loan ratio was 8.8%. Loans exceeding NT$20 million accounted for only 0.5% of the total, but their nonperforming loan ratio reached a very high level of 41.9%. These figures suggest that loans of under NT$1 million were mostly extended to farmers (i.e., regular members of FCUs) for agricultural purposes, because the amount needed by farmers to finance their agricultural activities is generally very small. On the other hand, loans of over NT$20 million were often extended to nonfarmers (namely, associate members) for nonagricultural purposes. It is particularly important to note that the decisions as to whether or not to extend large loans to associate members are often beyond the FCUs' general managers' control, because many local politicians regard the FCUs as an important channel for funding their campaign activities. Therefore, we use this variable as a proxy to represent the political pressure faced by the FCUs.
5. **Number of local banks:** This variable is used as a proxy to represent the degree of market competition faced by FCUs.[4] In general, it can be expected that FCUs in areas with a higher number of banks face stronger competition and would be more likely to perform more poorly. The reason for this is that the business activities and areas in which FCUs are allowed to operate are more restricted[5] than those that apply to the regular commercial banks.
6. **Land price:** In general, the land prices in urban areas are higher than those in rural areas, and hence this variable can be used to reflect the location effect. In addition, the change in the land price of an area often coincides with movements in the business cycle (namely, economic fluctuations). In other words, when land prices go up, FCUs will tend to lend more.
7. **Year 1999 and Year 2000:** These two year dummies are used to reflect the fact that the population may have different distributions in different time period. The inclusion of these two dummy variables allows the intercept of regressions to differ across periods.

Table 1 lists the sample means and standard deviations of the input and output variables. We divide the FCUs into four regions based on their geographic location. The FCUs located in the north appear to be larger than those in the other three regions, while those located in eastern Taiwan are below average. It is also important to note that the nonperforming loans of the FCUs located in the southern region are above average. The statistics also indicate that the means for all four inputs increase slightly over the sample period, whereas the mean for total loans ($Y1$) is seen to have fallen from NT$2.5 billion in 1998 to NT$2.2 billion in 2000, a decline on average of 6.3% per year. Moreover, the mean for undesirable output (B) is seen to have increased dramatically from NT$0.25 billion to NT$0.44 billion over the same period, reflecting an average rate of increase of 31.9% per year. Therefore, even though the mean for nonloan output ($Y2$) increased from NT$2.0 billion in 1998 to NT$2.3 billion in 2000, total factor productivity overall is very likely to have diminished over the period.

4. Empirical results

Using the panel data, we proceed with the three-stage DEA methodology as delineated in Section 2. In the first stage, we use unadjusted data to compute the output slacks for each FCU in each year. In Stage 2, we pool the output slacks obtained from Stage 1 and use the SFA approach to attribute the variation in each output slack to the time effect, environmental effect, statistical noise, and managerial inefficiency. The results of the Stage 2 SFA regressions are based on a half-normal specification of the one-sided inefficiency error component and are summarized in Table 2. The desirable output slacks and undesirable output slacks are calculated from the expressions $\sum_{k=1}^{K} z_k^t u_g^{k,t,m} - u_g^{k\prime,t,m} \geq 0$ and $u_b^{k\prime,t,i} - \sum_{k=1}^{K} z_k^t u_b^{k,t,i} \geq 0$, respectively. Hence, regardless of which output slack is analyzed, we obtain a positive relationship between the slack and the inefficiency of the FCUs.

As shown in Table 2, all environmental variables are shown to have had significant impacts on all the slacks of $Y1$, $Y2$, and B. For example, the education ratio had a negative and significant impact on the slacks. This suggests that a FCU with a higher ratio of educated employees is capable of producing more output ($Y1$ and $Y2$) with less nonperforming loans (B). This result is consistent with our expectations. As for the membership and loan ratio, which represented, respectively, the location and the

[4] Owing to the lack of detailed data on market shares, the Herfindahl index cannot be constructed.

[5] For example, an FCU is not allowed to operate beyond the boundary of the township or village in which it is located. By contrast, regular commercial banks are not so restricted.

Table 1
Summary statistics of inputs by region, 1998–2000

	1998		1999		2000	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
$X1$ (Loanable funds, NT$ millions)						
North	6,456.7	6,550.7	6,843.6	6,858.2	6,809.1	6,764.8
Central	4,174.6	3,216.6	4,426.4	3,314.1	4,338.8	3,147.1
South	4,113.2	3,837.3	4,202.7	3,783.0	4,093.6	3,601.1
East	2,654.9	1,736.8	2,791.1	1,762.6	2,807.3	1,748.5
Total	4,430.5	4,279.3	4,638.1	4,400.4	4,563.6	4,275.8
$X2$ (Labor, No. of persons)						
North	51.4	38.3	50.8	38.0	51.2	38.2
Central	36.3	19.4	37.0	23.1	37.1	22.9
South	41.4	42.4	42.3	42.8	41.9	41.3
East	27.4	14.0	27.9	14.5	27.9	14.8
Total	40.1	33.3	40.6	34.2	40.6	33.5
$X3$ (Capital expense, NT$ millions)						
North	35.5	31.9	36.2	31.9	36.9	31.3
Central	24.5	14.8	23.3	12.1	24.3	13.0
South	22.6	16.3	21.7	15.2	21.8	15.3
East	18.7	9.0	19.5	9.2	20.1	10.4
Total	25.3	19.9	24.8	19.1	25.4	19.2
$X4$ (Fixed assets, NT$ millions)						
North	282.6	345.0	295.6	380.1	302.6	373.1
Central	174.8	166.2	181.8	173.4	188.8	170.3
South	161.5	179.0	169.8	178.4	171.8	182.2
East	133.5	88.9	142.4	88.5	151.5	99.0
Total	186.3	215.2	195.1	228.1	200.5	226.8
$Y1$ (Total loans, NT$ millions)						
North	3,359.7	3,691.4	3,129.9	3,315.8	3,013.4	3,203.1
Central	2,335.4	1,837.9	2,203.4	1,870.1	2,109.3	1,784.1
South	2,328.6	2,104.8	2,100.8	1,930.4	1,918.7	1,810.0
East	1,769.0	1,129.7	1,719.1	1,016.6	1,682.1	980.6
Total	2,469.6	2,374.0	2,293.1	2,209.0	2,169.2	2,113.5
$Y2$ (Nonloan output, NT$ millions)						
North	3,712.9	3,481.1	4,159.0	3,904.0	4,325.8	4,054.5
Central	1,734.1	1,382.6	2,149.7	1,666.3	2,040.4	1,478.4
South	1,477.8	1,421.7	1,668.8	1,526.9	1,676.3	1,474.9
East	1,105.5	724.1	1,212.4	797.3	1,240.0	817.0
Total	1,954.1	2,112.5	2,263.6	2,374.1	2,262.6	2,394.3
B (Nonperforming loans, NT$ millions)						
North	170.5	191.8	297.5	387.5	317.6	418.6
Central	260.2	254.0	383.9	369.4	429.8	388.1
South	336.2	361.0	562.2	686.2	604.9	698.2
East	86.1	102.3	97.7	124.3	121.3	120.8
Total	252.5	288.5	401.8	514.9	439.4	531.7

political factor in this study, we found that both had a positive impact on the slack of $Y1$, $Y2$, and B. This indicates that those FCUs located in agricultural communities and facing stronger political pressure are more likely to be associated with larger nonperforming loans. The land price was negatively related to the slacks of the good outputs, but positively related to the slack of the bad output. This indicates that FCUs located in areas with higher land values are more vulnerable to nonperforming loans.

Table 2
Estimation results of the stochastic frontier functions

Explanatory variables	Dependent variables		
	$Y1$ slack	$Y2$ slack	B slack
Constant	−146.29*	−332.33*	−232.80
	(−144.74)	(−134.14)	(−182.53)
Education ratio	−1.11*	−1.39*	−0.89*
	(−20.84)	(−3.38)	(−27.98)
Membership ratio	1.44*	2.56*	1.77*
	(103.20)	(71.76)	(100.85)
No. of branches	14.43*	17.14*	5.95*
	(30.73)	(12.21)	(25.34)
Loan ratio	1.27*	2.52*	1.12*
	(54.72)	(23.38)	(55.50)
No. of banks	0.47*	0.43*	0.55*
	(21.96)	(5.46)	(13.83)
Land price	−0.73*	−0.85*	0.12*
	(−35.08)	(−7.50)	(3.00)
Year 1999	−4.16*	71.99*	61.51
	(−4.16)	(10.98)	(77.97)
Year 2000	−54.66*	22.17*	54.82*
	(−25.64)	(3.88)	(46.89)
σ^2	360,670.75*	514,348.32*	214,268.89*
	(360,669.84)	(514,400.72)	(214,263.91)
γ^m	0.99*	0.99*	0.99*
	(60556944)	(415,196.43)	(39244534)
Log-likelihood function	−5,773.46	−5,841.54	−5,239.02
LR test of the one-sided error	215.98	295.05	738.56

*Significant at the 5% level or above.

The coefficients of the number of branches exhibit positive signs and they are all significant. This result implies that there are diseconomies of scale in Taiwan's FCUs. As for the number of banks, which represents the degree of market competition faced by FCUs, the coefficients estimated are also all positive and significant. This suggests that the FCUs' performance has not been maintained in the face of increasing competition from commercial banks. The estimated coefficients of the two year dummies are found to be both positive and significant in the equations for the slack of $Y1$, but negative and significant for the slack of $Y2$ and B. This suggests that holding all the environmental variables fixed, the slack of $Y1$ was on average larger in 1999 and 2000 than in 1998. On the other hand, the slack of $Y2$ and B were on average less in 1999 and 2000 than in 1998. Therefore, we cannot identify whether the production frontier shift outward or inward over time.

Finally, the values for the parameter γ^m are all found to be close to 1. This means that the deviations in these three output slacks are due mostly to managerial inefficiency and environmental variables. In other words, FCUs differ from each other in terms of their ability to adapt to the external environment.

Before implementing the Stage 3 procedure, the observed outputs are adjusted for the influences of the time effect, environmental variables and statistical noise by inserting the parameter estimates in Table 2 into equations (7) and (8). This

Table 3
Comparison of adjusted and unadjusted productivity indexes

	1998–1999			1999–2000		
	Unadjusted	Adjusted	*P*-value	Unadjusted	Adjusted	*P*-value
North	0.9702	0.9922	0.3828673	0.9823	0.9854	0.9016190
Central	0.9403	0.9629	0.7295151	0.9320	0.9889	0.0458508*
South	0.9052	0.9702	0.0000002*	0.9211	0.9908	0.0000016*
East	0.9376	0.9573	0.0340551*	0.9684	0.9962	0.0034875*
Total	0.9329	0.9704	0.3126392	0.9411	0.9897	0.0000034*

Note: Paired difference experiments are used to test for the same mean between two groups.
*Significant at the 5% level or above.

procedure is to adjust upward the desirable outputs of the producers with relatively unfavorable external environment and bad luck. However, the undesirable outputs of the producers with relatively unfavorable external environment and bad luck have to adjust downward, and it is possible that some extremely advantaged producers might have some undesirable outputs adjusted so far downward as to become negative. Therefore, we need to employ the method proposed by Portela et al. (2004) to handle the possible negative data problem before proceeding to Stage 3.

In Stage 3, we used DEA with the adjusted output data and compute the four directional distance functions as described in (12) where the Malmquist–Luenberger productivity index (*ML*) is constructed and further decomposed into two components (namely, *EFCH* and *TECH*) as specified in (9), (10) and (11). The geometric means are summarized in Table 3 according to regions and for two periods. The resulting values are all less than 1, implying that the productivity in Taiwan's FCUs has deteriorated on average over the sample period.

For comparison purposes, we also compute the *ML* based on the original panel data which did not account for the impacts of environmental variables and statistical noise. It is found that the adjusted *MLs* are greater than the unadjusted versions. This suggests that after removing the environmental effects and statistical noise, the productivity performance of the FCUs turns out to be better than if these factors had not been taken into consideration. The differences between the adjusted and unadjusted *ML* indexes are tested for statistical significance using an experimental test. The *p*-values in Table 3 indicate that most of their differences are significant except in the northern and central regions during the 1998–1999 period and the northern region during the 1999–2000 period. Since the adjustment implemented is to let all the FCUs operate on the same basis, it is reasonable to expect that the adjustment of the FCUs with the most favorable environment would be small, and the differences between the adjusted and unadjusted *ML* indexes for them would be insignificant. Therefore, the insignificant differences for the FCUs in the northern and central regions suggest that the FCUs in these two regions are operating with more favorable external environment. Another interesting observation is that before the data were adjusted, the FCUs located in the southern region had below average performance in terms of productivity growth in both periods. However, after adjusting for the environmental factors and statistical noise, their performance improves the most and turns out to be superior to some other regions. Therefore, regional rankings can be reversed by adjusting the data.

Table 4 summarizes the results for the adjusted *ML* and its two components, efficiency change (*EFCH*) and technical change (*TECH*). All regions display negative productivity growth in both periods, although there is a slight recovery over the 1999–2000 period. Although there are improvements in managerial efficiency over time, they are not sufficient to compensate for the losses in technical change. Therefore, the declining productivity growth of Taiwan's FCUs over the 1998–2000 period was mainly attributable to a continuous regression in technical change.

Table 5 compares the percentage of FCUs that experienced productivity gains with that of FCUs experiencing productivity

Table 4
The decomposition of the adjusted *ML* productivity indexes by region

	ML		*TECH*		*EFCH*	
	1998–1999	1999–2000	1998–1999	1999–2000	1998–1999	1999–2000
Northern	0.992	0.985	0.964	0.934	1.029	1.055
Central	0.963	0.989	0.943	0.953	1.021	1.038
Southern	0.970	0.991	0.943	0.957	1.028	1.035
Eastern	0.957	0.996	0.925	0.978	1.035	1.018
Total	0.970	0.990	0.945	0.953	1.027	1.038

Table 5
Shares of FCUs with productivity gain or loss-comparison between adjusted and unadjusted *ML* (%)

Region	Total number of FCUs	Unadjusted *ML*			Adjusted*ML*		
		Increase ($ML > 1$)	No change ($ML = 1$)	Decrease ($ML < 1$)	Increase ($ML > 1$)	No change ($ML = 1$)	Decrease ($ML < 1$)
I. 1998–1999							
Northern	50	30.0	2.0	68.0	40.0	0.0	60.0
Central	92	21.7	0.0	78.3	21.7	0.0	78.3
Southern	94	13.8	0.0	86.2	24.5	0.0	75.5
Eastern	27	11.1	0.0	88.9	18.5	0.0	81.5
Total	263	19.4	0.4	80.2	25.9	0.0	74.1
II. 1999–2000							
Northern	50	40.0	0.0	60.0	26.0	0.0	74.0
Central	92	34.8	0.0	65.2	31.5	1.1	67.4
Southern	94	16.0	2.1	81.9	26.6	0.0	73.4
Eastern	27	22.2	0.0	77.8	48.1	0.0	51.9
Total	263	27.8	0.8	71.5	30.4	0.4	69.2

losses by region. It is found that the number of FCUs with a value for *ML* of greater than 1 increased a lot in the southern and eastern regions for both two periods. Furthermore, Table 5 demonstrates that, before adjusting the data, a smaller percentage of the FCUs in the northern region were characterized by negative productivity growth than in the southern and eastern regions. However, after the data are adjusted, this superiority of the FCUs in the northern region disappears. This finding suggests that the FCUs in the northern region have higher productivity growth due to their favorable environment (such as more highly-educated employees, better infrastructure, and higher land prices) or because they are simply lucky instead of experiencing improvements in managerial efficiency or technical change.

Table 6 reports the percentage distributions of FCUs by classifying the values of *TECH* and *EFCH* into three categories, namely, >1, =1, and <1. The results show that only 16.7% of the FCUs experienced technological progress over 1998–1999, and this percentage dropped to 5.3 in 1999–2000. By contrast, more than 67.3% of FCUs experienced efficiency improvements during 1998–1999, but this percentage declined to 62.4 in 1999–2000. Among the four regions, the northern region was the only example of an increasing percentage of FCUs experiencing efficiency improvement.

Table 6
Percentage distribution of FCUs with and without technical and efficiency change based on the adjusted *ML* (%)

Region	Total no. of FCUs	Technology change (*TECH*)			Efficiency change (*EFCH*)		
		Increase ($TECH > 1$)	No change ($TECH = 1$)	Decrease ($TECH < 1$)	Increase ($EFCH > 1$)	No change ($EFCH = 1$)	Decrease ($EFCH < 1$)
I. 1998–1999							
Northern	50	28.0	0.0	72.0	72.0	6.0	22.0
Central	92	15.2	1.1	83.7	66.3	10.9	22.8
Southern	94	17.0	0.0	83.0	62.8	9.6	27.7
Eastern	27	0.0	0.0	100.0	77.8	0.0	22.2
Total	263	16.7	0.4	82.9	67.3	8.4	24.3
II. 1999–2000							
Northern	50	2.0	0.0	98.0	78.0	10.0	12.0
Central	92	3.3	0.0	96.7	63.0	12.0	25.0
Southern	94	3.2	0.0	96.8	54.3	14.9	30.9
Eastern	27	25.9	0.0	74.1	59.3	14.8	25.9
Total	263	5.3	0.0	94.7	62.4	12.9	24.7

5. Conclusion

In this article we have proposed a three-stage DEA approach similar to Fried et al. (2002) in order to improve the measurement of productivity growth when the assumption of free disposability of output no longer applies. Moreover, the directional distance function has been used to construct an adjusted Malmquist–Luenberger productivity index to simultaneously account for the impacts of an undesirable output, environmental variables, and statistical noise. A panel data set including 263 FCUs in Taiwan and covering the period 1998–2000 has been used to illustrate the advantage of this method.

Our results have clearly demonstrated that productivity measurement is sensitive to whether or not environmental variables and statistical noise are included. In addition, our adjusted Malmquist–Luenberger productivity indexes have shown that on average the productivity of Taiwan's FCUs has deteriorated over the 1998–2000 period. Although improvements in efficiency have been observed, the major reason for the slowdown in productivity has been found to be the regression of technology. This implies that Taiwan's FCUs should endeavor to invest in new technologies, e.g., electronic communications and information-based service systems, to maintain and upgrade their infrastructure, in order to provide better services or achieve cost savings. Generally speaking, an electronic banking system provides financial intermediaries with access to up-to-date asset information, efficient processing of transactions, reporting functions and research and financial information. Technology can also play a key role in modernizing the supervisory and monitoring process. Therefore, investment in such technologies should be helpful for FCUs to modernize their operations as they face competitive challenges and at the same time improve their risk management.

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Appendix: Data descriptions of variables

Symbol	Variable	Definition	Unit
Inputs			
$X1$	Loanable funds	Total deposits + borrowed money	NT$ millions
$X2$	Labor	Number of credit department employees	Persons
$X3$	Capital expense	Lease fees + business expenses + meeting expenses + management expenses + other expenses	NT$ millions
$X4$	Fixed assets	Net value of total fixed assets	NT$ millions
Desirable outputs			
$Y1$	Total loans	Unsecured loans + secured loans + government subsided loans	NT$ millions
$Y2$	Nonloan outputs	Deposits in other banks + noninterest income	NT$ millions
Undesirable output			
B		Nonperforming loans	NT$ millions
Environmental variables			
	Education	No. of employees with college degree / Total number of employees	%
	Membership	No. of regular members / Total number of members	%
	No. of branches	No. of branches of farmers' credit unions	
	Loan ratio	Loans to associated members / Total loans	%
	No. of local banks	No. of branches of domestic banks + No. of branches of foreign banks + No. of branches of credit cooperatives	
	Land price	Average land price for residential areas	NT$ thousands
	Year 1999	Year1999 = 0 for 1998, 1 for 1999, and 0 for 2000	
	Year 2000	Year2000 = 0 for 1998, 0for 1999, and 1 for 2000	

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