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Ownership and Production Efficiency: Evidence from Taiwanese Banks

YANG LI, JIN-LI HU and YUNG-HO CHIU

In the early 1990s, Taiwan began her deregulation trend in order to enhance competition and economic efficiency across all industries. We derive a theoretical framework to predict possible rankings in technical efficiencies of public, mixed, and private banks. A panel data set with 43 Taiwanese banks during 1997–1999 is used for empirical analysis. We then apply a translog distance function to estimate technical efficiencies. The relationship between technical efficiency and government shareholding is also examined. Empirical results show that a public bank in Taiwan can improve its technical efficiency by mixed ownership at a diminishing rate. Moreover, banks in Taiwan on average performed worse after the 1997 Asian financial crisis.

INTRODUCTION

After the Conservative Party led by Margaret Thatcher won the 1979 election, the UK started to privatise public enterprises with full effort. The UK privatisation experience has since become an example followed by many developed and developing countries. One of the main objectives of privatisation is to improve the efficiency of a public enterprise [Bishop et al., 1994]. Most countries fulfil privatisation through the transfer of ownership; however, during the process of privatisation, the government may not transfer all of its shareholdings. As a result, private and public sectors will jointly own an enterprise. Boardman et al. [1986] define a mixed enterprise as ‘encompassing various combinations of government and private joint equity

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participation'. In the early 1990s Taiwan began to pursue privatisation of its public enterprises in order to enhance competition and economic efficiency across all industries.

Deregulation in Taiwan's banking industry consists of two major aspects: Privatisation of public enterprises and entrance opportunity. During the past 11 years, nine state-owned banks have been privatised, including Chang Hwa Commercial Bank, First Commercial Bank, Hua Nan Commercial Bank, Taiwan Business Bank, Taiwan Development & Trust Corporation, Farmers' Bank of China, Chiao Tung Bank, Bank of Kaohsiung, and Taipei Bank.

In 1991 Taiwan's government released the Commercial Bank Establishment Promotion Decree in order to relieve the legal entrance barriers to banking markets. Twenty-five new commercial banks were established afterwards, bringing the total number of domestic commercial banks in Taiwan in 1999 to 43. Taiwan's government is still trying to make banking markets more competitive for public, mixed, and private banks.

Bank efficiency has received much attention in the existing literature. In earlier studies most efficiency literature focused on estimating the functional characteristics and economies of scale and scope, e.g. Bell and Murphy [1968], Hunter and Timme [1986], Berger et al. [1987], Ferrier and Lovell [1990], Berger and Humphrey [1991], McAllister and McManus [1993], Rhoades [1993], and Huang [1998, 2000], etc. Recently, the emphasis on bank efficiencies has shifted to the decomposition into allocative and technical efficiencies. There are two methods to estimate efficiencies of the sample banks: parametric and non-parametric approaches. Most researchers use DEA (data envelopment analysis) as a non-parametric approach to estimate the total productivity and efficiency of banks: e.g., Berger et al. [1987], Berger and Humphrey [1991], Oral and Yolalan [1990], Favero and Papi [1995], Sherman and Ladino [1995], and Miller and Noulas [1996]. Recently, Resti [1997], Bhattacharyya et al. [1997], Chen and Yeh [2000], and Huang and Wang [2002] apply both parametric and non-parametric approaches to estimate bank efficiencies.

The major goal of a private enterprise is profit maximisation. However, for public enterprises, profit maximisation is never the primary goal. Public enterprises are required to achieve particular social ends, such as reducing unemployment rate, promoting economic development, etc. Most governments set up mixed enterprises, intending to combine economic efficiency of private enterprises with a socio-political goal of public enterprises.

Eckel and Vining [1985] provide the first step to analyse mixed enterprises' performance. They suggest three reasons for converting public enterprises to mixed enterprises: First, mixed enterprises easily achieve higher profitability and social goals at a lower cost than public

enterprises. Second, mixed enterprises have less bureaucratic restrictions than public enterprises. Third, mixed enterprises need less capital investment from the government than public enterprises. Boardman et al. [1986] also point out that mixed enterprises have three major advantages in comparison with public enterprises. The first advantage is that mixed enterprises demand less capital cost than public enterprises. The second advantage is that mixed enterprises are more efficient than public enterprises, while the third advantage is flexibility such that mixed enterprises achieve both profitability and social goals and are more efficient than public enterprises.

Boardman et al. [1986] indicate that the conflict of interest between shareholders and managers reduces mixed enterprises' performance. Boardman and Vining [1991] discuss the effect of government vis-à-vis private ownership on the internal management of an enterprise. They argue that public ownership is inherently less efficient than private ownership since public banks lack a sufficient incentive and generate higher cost inefficiencies. They argue that 'different ownership conditions affect the extent to which mixed enterprises engage in profit maximisation, socio-political goal maximisation, and managerial utility maximisation; it also affects the degree of conflict between one owner and another'. They further predict that mixed enterprises have high owner conflict and poor performance – the worst of both worlds. However, more empirical evidence is required to judge whether or not mixed enterprises have the highest inefficiencies.

Chiu et al. [2002] establish a theoretical model with an incentive problem to show that an increase in the government stock share decreases the manager's effort to reduce cost inefficiency. The theoretical model predicts that when the inefficiency caused by owner conflict is sufficiently small, the public, mixed, and private enterprises have the highest, medium, and lowest cost inefficiency, respectively. However, when the inefficiency caused by owner conflict is sufficiently large, the ranking of cost inefficiencies, from the highest to the lowest, becomes mixed, public, and private enterprises. They apply the model of Battese and Coelli [1995] to simultaneously estimate the parameters of stochastic frontier and the inefficiency model. The panel data of 74 manufacturing firms in Taiwan during 1996–1997 are used to estimate the translog cost function and the cost inefficiency function. According to their empirical findings, the rankings of cost inefficiencies in Taiwan, from the highest to the lowest, are mixed, public and private enterprises.

There are two approaches used in the empirical analysis of mixed enterprises, which are performance and efficiency. Before 1994, most empirical analyses focused on evaluating a mixed enterprise's performance by employing

profit and productivity. For example, Boardman and Vining [1989] consider the 500 largest non-US industrial firms as compiled by *Fortune* magazine in 1983, including 419 private enterprises, 23 mixed enterprises, and 58 public enterprises. They apply the approach of OLS (ordinary least squares) to estimate the performance of private, mixed, and public enterprises, and find that the performance of mixed and public enterprises is worse than that of private enterprises. Moreover, the profitability, and productivity of mixed enterprises are no better than, and sometimes even worse than, those of public enterprises.

Vining and Boardman [1992] confirm that ownership plays an important role in determining corporations' technical efficiency and profitability. They randomly chose a sample set of 249 private enterprises, 93 mixed enterprises and 12 public enterprises from 1986 data on 500 non-financial corporations in Canada. The OLS approach is applied for estimation. Their result is that the technical efficiency and profitability of public and mixed enterprises on average are worse than those of private enterprises. Furthermore, the technical efficiency and profitability of public enterprises on average are worse than those of mixed enterprises.

After 1994, researchers changed their interest from performance analysis to efficiency analysis when studying a mixed enterprise. For example, Ehrlich et al. [1994] use a translog cost function model to estimate and make a comparison of cost inefficiency among public, private, and mixed enterprises. They use the panel data of airline companies in 23 countries during the period 1973–1983. Both the long-run and short-run cost inefficiencies of private enterprises are lower than those of public and mixed enterprises. In the short run, there is no significant difference in the cost inefficiency of public and mixed enterprises. However, the long-run cost inefficiencies of public enterprises are higher than those of mixed enterprises.

The efficiency of mixed enterprises, especially in mixed banks, has received limited attention. Most existing research on mixed enterprises' efficiency focuses on cost efficiency, but not on technical and allocative efficiencies. It is well known that public and mixed enterprises achieve socio-political objectives at the price of a higher cost inefficiency [Chiu et al., 2002]. The goal of mixed and public enterprises is neither profit maximisation nor cost minimisation. Therefore, it is not adequate to judge the performance of public and mixed enterprises by cost efficiency. While public and mixed enterprises have a higher allocative inefficiency, because of government regulations on employment and procurement, if cost inefficiency is decomposed into technical and allocative efficiencies, then public and mixed enterprises are still likely to perform better than private enterprises in some aspects.

This article employs parametric approach methodologies to establish a benchmark measure for a bank's technical efficiency. We will also explain how government shareholding affects a manager's incentive to offset inefficiencies. The panel data set of 43 banking firms in Taiwan during the period 1997–1999 is used to estimate the translog distance function. This article is organised as follows: The next section provides the theoretical model. The third section explains the construction of the model and the data source. The fourth section consists of the empirical results, followed by a concluding section.

THEORETICAL FOUNDATION

Three essential factors should be taken into account to determine the technical efficiency rankings in public, mixed, and private banks: Agency cost, owner conflict, and bureaucratic power. Chiu et al. [2002] establish a principal-agent model to show that an increase in the government stock share decreases the manager's effort to reduce cost inefficiency. A similar story can be applied to technical efficiency. Denote the government stock share by S with $0 \leq S \leq 1$. The manager's payoff becomes less correlated with the enterprise's profit as the government stock share increases and hence the manager will input less effort to offset stochastic technical inefficiencies. Therefore, agency cost inefficiency (*ACI*) is strictly increasing with the government stock share and can be expressed by the following function:

$$ACI(S) = a_1 S^\alpha, \quad (1)$$

with $a_1 > 0$, $\alpha > 0$, and $\partial ACI(S)/\partial S > 0$.

Owner conflict occurs due to different goals of the public and private owners. We use a Cobb-Douglas function to measure the owner conflict inefficiency (*OCI*) as a function of the government stock share:

$$OCI(S) = a_2 S^\beta (1 - S)^{1-\beta}, \quad (2)$$

with $a_2 > 0$ and $0 < \beta < 1$. Owner conflict inefficiency first increases and then decreases with the government stock share. This is because a more diversified ownership structure increases ownership conflict.

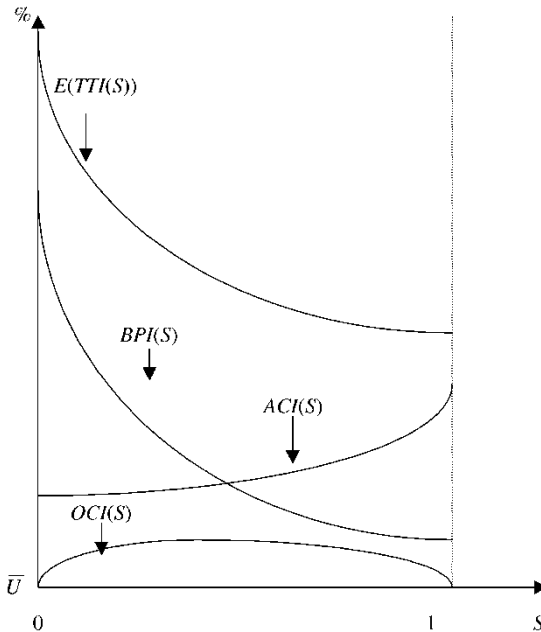
Bureaucratic power becomes more important to productivity in a more centralised, constrained, or imperfect economic environment. Tian [1997, 2000] explicitly models the bureaucratic power and degree of market perfection into a Cobb-Douglas production function. Following Tian's model,

we may rewrite the bureaucratic power inefficiency (*BPI*) as a function of government stock share:

$$BPI(S) = a_3(1 - \rho)(1 - S)^\gamma, \tag{3}$$

with $a_3 > 0, 0 \leq \rho \leq 1, \gamma > 0$. A higher value of parameter ρ reflects a higher degree of economic freedom, decentralisation and market perfection. Note that $\partial BPI(S)/\partial S < 0$ with $\rho \neq 1$. In many developing countries, bureaucratic power helps much with procurement, asset acquisition, subsidies, franchises, etc. For instance, Taiwan's government has a yearly quota to subsidise housing loans to people who work in government or public schools. Private banks are excluded from such loans projects promoted by the government. The eligible people have to go to some public banks to receive these subsidised loans, which usually cannot fully satisfy their monetary borrowing requirements. The remaining amount of money required to be borrowed will come from the same public bank at a regular interest rate. These loans are a little less risky since people who work in the public sector are highly

FIGURE 1
THE CASE WITH A HIGH MARKET IMPERFECTION



credible, mainly because of their steady income. The bureaucratic power has no effect on the technical efficiency at all if the market is perfect ($\rho = 1$).

Summing up, the total technical inefficiency (TTI) function can be written as:

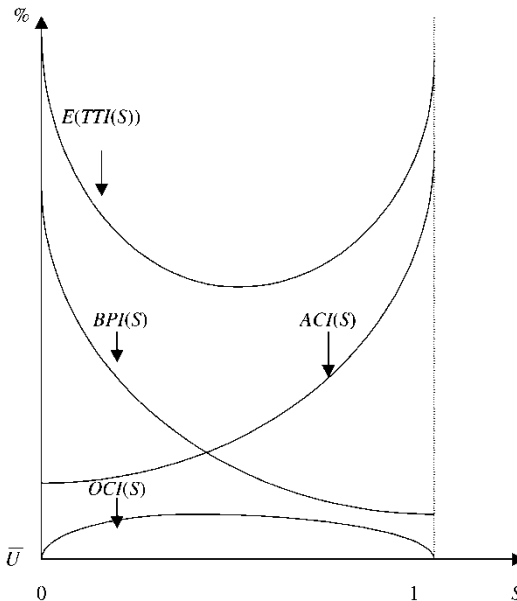
$$\begin{aligned} TTI(S) &= ACI(S) + OCI(S) + BPI(S) + U \\ &= a_1 S^\alpha + a_2 S^\beta (1 - S)^{1-\beta} + a_3 (1 - \rho)(1 - S)^\gamma + U. \end{aligned} \quad (4)$$

The variable U is a non-negative random variable with mean $\bar{U} > 0$, representing the stochastic technical inefficiency. Therefore, the expected total technical inefficiency is:

$$\begin{aligned} E(TTI(S)) &= ACI(S) + OCI(S) + BPI(S) + E(U) \\ &= a_1 S^\alpha + a_2 S^\beta (1 - S)^{1-\beta} + a_3 (1 - \rho)(1 - S)^\gamma + \bar{U}. \end{aligned} \quad (5)$$

From Equation 5, we find that all kinds of orderings in technical efficiencies among public, mixed, and private enterprises can take place. For example, public enterprises have lower technical inefficiencies versus mixed and private

FIGURE 2
THE CASE WITH A HIGH MARKET IMPERFECTION AND A SERIOUS INCENTIVE PROBLEM



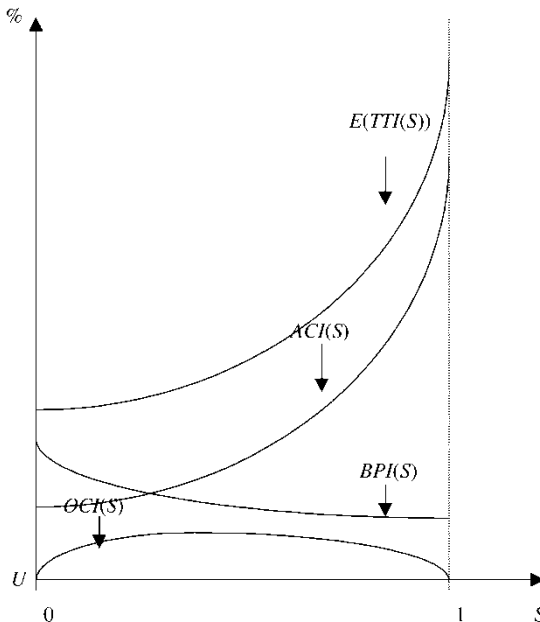
enterprises when the market is imperfect such that bureaucratic power is important to productivity (see Figure 1). Mixed enterprises will have lower technical inefficiencies than others when agency cost is high and bureaucratic power is important to productivity (see Figure 2). Private enterprises will have lower technical inefficiencies than others when agency cost is high and the market is relatively perfect (see Figure 3).

EMPIRICAL MODEL

Construction of the Empirical Model

Research on bank efficiency has two major streams: The first stream is the parametric approach, and the other stream is the non-parametric approach. Efficiency can be evaluated from the perspective of three types of inefficiencies, namely cost, allocative, and technical inefficiencies. Cost inefficiency is also labelled overall inefficiency, representing the gap in the ratio of minimum cost to actual cost. Allocative inefficiency occurs when banks do not employ the least costly combination of inputs to produce output, whilst technical inefficiency refers to the situation arising from a bank's failure to operate at its efficient production frontier.

FIGURE 3
THE CASE WITH A RELATIVELY PERFECT MARKET



The parametric approach, which is generally concerned with the production or cost function base, focuses on an estimation of the function's characteristics, whilst also undertaking a measurement of the scale of economics, under the assumption that all banks are operating efficiently. Following Farrell's [1957] introduction of the frontier production function to measure efficiency, many researchers further developed the concept of the stochastic frontier production function [Aigner et al., 1977; Meeusen and Broeck, 1977]. Pitt and Lee [1981] and Schmidt and Sickles [1984] extend the stochastic frontier model to panel data, but they assume that the technical efficiency was invariant for individual firms. The advanced model, proposed by Cornwell et al. [1990] and Battese and Coelli [1992, 1995], allows us to estimate time-varying efficiency levels.

If efficiency varies, then it is natural to seek determinants of efficiency variation. Early researchers applied a two-stage approach to analyse efficiency effects in terms of appropriate explanatory variables [Pitt and Lee, 1981]. The first of these stages includes the specification and estimation of the stochastic frontier function and the prediction of the technical (or cost) efficiency. The second stage involves the specification of the regression model for the predicted technical (cost) efficiency. However, this two-stage procedure consists of inconsistent assumptions regarding the identical distribution of efficiency effects in the two estimation stages. Kumbhakar et al. [1991], Huang and Liu [1994], and Battese and Coelli [1995], etc., follow this by adopting a single-stage approach in which explanatory variables are incorporated directly into the efficiency error component.

As discussed above, the public enterprises are required to achieve particular social ends. The behaviour assumptions of profit maximisation and/or cost minimisation are unlikely to be valid in public and mixed banks. Hence, this study focuses only on technical efficiency. Furthermore, banks are multi-output industries. Traditional methods model multi-output technology by a dual-cost function, and this is apparently inappropriate. Distance functions allow us to characterise the structure of production technology when multiple inputs are used to produce multiple outputs without the need to specify a behaviour objective such as cost minimisation or profit maximisation. An output distance function takes an output-expanding approach to the measurement of the distance, which is the maximal proportional expansion of the output vector, given an input vector.¹

According to Shephard [1970], the output distance function can be defined as follows:

$$D_o(X, Y) = \min \left\{ \theta : \left(\frac{Y}{\theta} \right) \in P(X) \right\}, \quad (6)$$

where $P(X)$ is the output sets of production technology, describing the sets of output vectors that are feasible for each input vector X . That is,

$$P(X) = \{Y: X \text{ can produce } Y\}. \quad (7)$$

This gives the minimum amount by which an output vector can be deflated and still remain producible with a given input vector. The output distance function $D_o(X, Y)$ is non-decreasing, positively linearly homogeneous and convex in Y , and non-increasing in X [Kumbhakar and Lovell, 2000]. Note that $D_o(X, Y) \leq 1$ if Y belongs to the production possibility set of $(Y \in P(X))$ and that $D_o(X, Y) = 1$ if Y belongs to the frontier of the production possibility set of X .

The statistical formulation of the output distance function defined in Equations 6 and 7 can be specified as:

$$D_o(X, Y) = f(X, Y, \delta)e^v \quad (8)$$

Here δ is a vector of unknown coefficients to be estimated and v is the random disturbance term intended to capture the measurement error and statistical noise and is assumed to be *iid* $N(0, \sigma_v^2)$.

An appropriate functional form $f(\cdot)$ in Equation 8 would ideally be flexible, easy to calculate and permit the imposition of homogeneity. The translog form does satisfy the above criteria and has been used by a number of authors [Lovell et al., 1994; Grosskopf et al., 1996; Coelli and Perelman, 2000].² The translog distance function with M outputs and J inputs is specified as:

$$\begin{aligned} \ln D_{on} = & \alpha_0 \sum_{m=1}^M \alpha_m \ln y_{mn} + \frac{1}{2} \sum_{m=1}^M \sum_{k=1}^M \alpha_{mk} \ln y_{mn} \ln y_{kn} + \sum_{j=1}^J \beta_j \ln x_{jn} \\ & + \frac{1}{2} \sum_{j=1}^J \sum_{h=1}^J \beta_{jh} \ln x_{jn} \ln x_{hn} + \sum_{m=1}^M \sum_{j=1}^J \lambda_{mj} \ln y_{mn} \ln x_{jn} + v_n, \\ & n = 1, \dots, N, \end{aligned} \quad (9)$$

where n denotes the n th firm in the sample. The restriction of linear homogeneity in outputs requires:

$$\sum_{m=1}^M \alpha_m = 1, \sum_{k=1}^M \alpha_{mk} = 0, \quad m = 1, \dots, M; \text{ and } \sum_{m=1}^M \lambda_{mj} = 0, \quad j = 1, \dots, J.$$

Furthermore, the restriction of symmetry requires:

$$\alpha_{mk} = \alpha_{km}, \quad m, k = 1, \dots, M, \text{ and } \beta_{jh} = \beta_{hj}, \quad j, h = 1, \dots, J.$$

One basic problem in estimating Equation 9 is that the dependent variable $\ln D_{on}$ is unobservable. Fortunately, we can solve this problem by imposing the linear homogeneity in outputs [Färe and Primont, 1995]. That is,

$$\begin{aligned} \ln\left(\frac{D_{on}}{y_{Mn}}\right) &= \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln y_{mn}^* + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{k=1}^{M-1} \alpha_{mk} \ln y_{mn}^* \ln y_{kn}^* \\ &\quad + \sum_{j=1}^J \beta_j \ln x_{jn} + \frac{1}{2} \sum_{j=1}^J \sum_{h=1}^J \beta_{jh} \ln x_{jn} \ln x_{hn} \\ &\quad + \sum_{m=1}^{M-1} \sum_{j=1}^J \lambda_{mj} \ln y_{mn}^* \ln x_{jn} + v_n, \quad n = 1, \dots, N, \end{aligned} \quad (10)$$

where $y_i^* = y_i/y_M$. Equation 5 can be rewritten as

$$\begin{aligned} -\ln y_{Mn} &= \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln y_{mn}^* + \frac{1}{2} \sum_{m=1}^{M-1} \sum_{k=1}^{M-1} \alpha_{mk} \ln y_{mn}^* \ln y_{kn}^* \\ &\quad + \sum_{j=1}^J \beta_j \ln x_{jn} + \frac{1}{2} \sum_{j=1}^J \sum_{h=1}^J \beta_{jh} \ln x_{jn} \ln x_{hn} \\ &\quad + \sum_{m=1}^{M-1} \sum_{j=1}^J \lambda_{mj} \ln y_{mn}^* \ln x_{jn} + v_n - \ln D_{on} \quad n = 1, \dots, N. \end{aligned} \quad (11)$$

We then replace the unobservable component $-\ln D_{on}$ by a non-negative random variable u_n . The latter is assumed to be independently distributed, truncated at zero of $N(\mu, \sigma_u^2)$, and independently distributed of v_n .

The predicted value of the output distance for the n th firm, $\hat{D}_{on} = \exp(-u_n)$, is not directly observable since u_n only appears as part of the composed error term, $\varepsilon_n = v_n + u_n$. The conditional expectation of u_n , given $\varepsilon_n = v_n + u_n$, can be used to obtain the predicted value of the output distance function. The output distances would hence be predicted as:

$$\hat{D}_{on} = E[\exp(-u_n) | \varepsilon_n]. \quad (12)$$

Technical efficiency can be estimated by using the property that the output distance function coincides with the Farrell output-oriented measure of technical efficiency [Kumbhakar and Lovell, 2000]. Equations 11 and 12 can be estimated by the maximum likelihood method [Coelli and Perelman, 2000].

Data Collection and Choice of Outputs and Inputs

This study uses data from four public enterprises (where government shareholding in an enterprise is 100 per cent), 15 mixed enterprises (where government shareholding in an enterprise ranges from 0.1 to 99.9 per cent), and 24 private listed companies for the period 1997–1999, giving a total of 43 bank enterprises in our sample set. The data sources are financial releases and public statements and Taiwan Economic Journal database.

There are three types of banking output: the provision of loan services (including business and individual loans), portfolio investment (mainly government securities and shares, along with public and private enterprise securities), and other real revenues. There are three types of input, namely bank staff, fixed assets, and total deposits. We refer to total bank deposits (NT\$ thousand) as being accounted for by current deposits, time deposits and savings deposits. Since the data cover three years, we have deflated some variables, including three outputs, fixed assets and total deposits, by CPI (1996 = 1.00). Table 1 describes the definition and explanation of variables.

This study applies the model proposed by Battese and Coelli [1995] to estimate the parameters of the distance function and the efficiency model

TABLE 1
DEFINITION AND EXPLANATION OF VARIABLES

Variable	Definition
Y_1	Real loan services (including business and individual loans) (NT\$ billion)
Y_2	Real portfolio investment (mainly government securities and shares, along with public and private enterprise securities)
Y_3	Other real revenues
L	Total number of employees
K	Real fixed assets (NT\$ thousand)
M	Real total deposits (NT\$ thousand)
t	Time periods subtracting 1996
S	Percentage of government shareholding
SSQ	$S \times S/100$

Notes: We divide firms' Y_1 , Y_2 , Y_3 , K , and M by CPI (1996 = 1.00).

Sources: Financial releases and public statements from each company; Taiwan Economic News Service.

simultaneously. This method helps avoid inconsistent assumptions regarding the identical distribution of efficiency effects in the two-stage approach. The technical efficiency effects are defined by

$$-u_{nt} = \phi_0 + \phi_1 t + \phi_2 S_{nt} + \phi_3 SSQ_{nt} + \omega_{nt}, \quad (13)$$

where $-u_{nt} = \ln D_{ont}$ and the random disturbances ω_{nt} are assumed to be independently distributed as truncated at $-(\phi_0 + \phi_1 t + \phi_2 S_{nt} + \phi_3 SSQ_{nt})$ of $N(0, \sigma_u^2)$. In other words, the non-negative random variable u_{nt} is assumed to be independently distributed as truncations at zero of $N(-(\phi_0 + \phi_1 t + \phi_2 S_{nt} + \phi_3 SSQ_{nt}), \sigma_u^2)$. The computer software package Frontier 4.1 is used to estimate the parameters of the distance function and the efficiency model.

EMPIRICAL RESULTS

The empirical results from estimating the output distance function are presented in Table 2, while the underlined parameters are calculated under the homogeneity condition. We apply the likelihood ratio test for separability between inputs and outputs: $H_0: \lambda_{mj} = 0, m = 1, \dots, 3, j = 1, \dots, 3$. The value of the likelihood ratio test is 35.65, which is far away from the critical value 18.5476 ($=\chi_{(6), 0.005}^2$). Therefore, the input–output separability model is rejected. This is reasonable since efficiency measures take both outputs and inputs into account. We are unable to judge whether the input usage is efficient without the output vector; and vice versa. The estimated $\gamma = 0.999$ is significantly greater than zero, suggesting that the term u_{nt} should be treated as a random variable.

The estimated coefficients for the technical efficiency function are of particular interest in this study and are presented in Table 3. All estimated coefficients are statistically, significantly different from zero at the one per cent level. The negative coefficient of the time variable suggests that commercial banks in Taiwan, on average, performed worse after the 1997 Asian financial crisis. This result compares to Huang and Wang [2002], in which they find cost efficiencies of Taiwanese banks turned worse during 1982–1997.

The quadratic effects of the coefficients of government shareholding on the technical efficiency imply that the technical efficiency increases as the government shareholding in a bank goes higher up to 42.3 per cent, while thereafter it decreases. When the government share is greater than 42.3 per cent, the technical efficiency of a commercial bank then increases with privatisation. However, when the government share achieves 42.3 per cent, its technical efficiency then decreases with privatisation.

TABLE 2
ESTIMATED RESULTS OF THE OUTPUT DISTANCE FUNCTION

Variable	Estimated parameter	Standard error	t-Value
Constant	1.85709**	0.81310	2.28396
ln y_1	0.63129	0.45302	1.39353
ln y_2	0.23401	0.34487	0.67940
ln y_3	<i>0.13470</i>	—	—
ln y_1 ln y_1	0.24123***	0.08131	2.96643
ln y_1 ln y_2	-0.23522***	0.05783	-4.06726
ln y_1 ln y_3	<i>-0.00601</i>	—	—
ln y_2 ln y_2	0.24913***	0.08581	2.90311
ln y_2 ln y_3	<i>-0.01391</i>	—	—
ln y_3 ln y_3	<i>0.01992</i>	—	—
ln L	-1.27553***	0.26915	-4.73910
ln K	1.09694**	0.49133	2.23258
ln M	-0.87372	0.69310	-1.26060
ln L ln L	0.13864*	0.08272	1.67593
ln L ln K	1.04354***	0.20361	5.12518
ln L ln M	-0.56680**	0.24370	-2.32584
ln K ln K	0.40776	0.25376	1.60687
ln K ln M	-1.37187***	0.40602	-3.37883
ln M ln M	1.32040**	0.58638	2.25180
ln y_1 ln L	-0.20805***	0.06194	-3.35898
ln y_1 ln K	-0.81638***	0.18208	-4.48377
ln y_1 ln M	0.70932***	0.22550	3.14553
ln y_2 ln L	-0.10255**	0.04567	-2.24553
ln y_2 ln K	0.53094**	0.23644	2.24558
ln y_2 ln M	-0.20531	0.22937	-0.89509
ln y_3 ln L	<i>0.31060</i>	—	—
ln y_3 ln K	<i>0.28544</i>	—	—
ln y_3 ln M	<i>0.50401</i>	—	—
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	0.08229	0.01570	5.24033
$\gamma = \sigma_u^2 / \sigma^2$	0.99993	0.00005	0.21844×10^5

*Significant at 10% level.

**Significant at 5% level.

***Significant at 1% level.

Note: Parameters in italics are calculated under the homogeneity condition. $N = 129$. Log-Likelihood = 214.27866.

The estimated efficiencies of each bank are listed in Table 4. The ranking of overall mean efficiency, from the highest to the lowest, is mixed banks (0.958), public banks (0.953), and private banks (0.926). This ranking is the same as that in 1997 and in 1999, but the situation was different in 1998. The mean efficiency then, from the highest to the lowest, is mixed banks (0.94086), private banks (0.93241), and public banks (0.93058). In summary, mixed banks have the highest level of technical efficiency among Taiwanese commercial banks. Furthermore, technical efficiencies of the

TABLE 3
THE ESTIMATED RESULTS OF THE EFFICIENCY MODEL

Variable	Estimated parameter	Standard error	<i>t</i> -value
<i>Constant</i>	2.15052***	0.48837	4.40351
<i>T</i>	-0.49712***	0.11861	-4.19119
<i>S</i>	0.03333***	0.00864	3.85992
<i>SSQ</i>	-0.03940***	0.01027	-3.83604

***Significant at 1% level.

(completely or partially) government-owned banks are higher than those of purely private-owned banks.

Most existing research on the efficiencies of mixed enterprises focuses on cost efficiency, but not on technical efficiencies. For example, Vining and Boardman [1992] and Ehrlich et al. [1994] show that private enterprises demonstrate higher cost efficiencies than public and mixed enterprises. However, the behaviour assumption of cost minimisation is unlikely to be valid in public and mixed banks. Indeed, cost efficiency may not be appropriate for evaluating public, mixed, and private banks. By focusing only on technical efficiencies, we find that mixed banks have higher technical efficiencies than private and public banks. Public banks also have higher technical efficiencies than private banks. Therefore, mixed ownership helps with improving the technical efficiency of public enterprise.

Our empirical findings show that mixed banks have the highest technical efficiency and private banks the lowest technical efficiency. This may be because Taiwan's banking markets are not perfect, in which bureaucratic power still plays an important role in improving efficiency. Mixed banks also provide a better incentive scheme than public banks. If the owner conflict is not too severe, then mixed banks benefit from balancing bureaucratic power and the internal incentive scheme.

Before privatisation, public banks already possessed a long-run social reputation and connection. In Taiwan, internal control in private banks is sometimes less robust. For example, a few new commercial banks were involved in scandals of embezzlement and risky loans to the bank owners' family businesses. The government shareholdings provide more internal control measures for these commercial banks. Under the compulsory deposit insurance system in Taiwan, the government is the de facto final insurer in banking markets, helping people feel more confident if the government also owns the bank.

Public and mixed banks on average are larger than private banks. This is because Taiwan's banking markets were mainly occupied by a few public banks for half a century after World War II. The public and mixed banks now thus enjoy benefits of economies of scale which help improve

TABLE 4
EFFICIENCY ASSESSMENT

Bank	1997		1998		1999	
	TE	ST (%)	TE	ST (%)	TE	ST (%)
1	0.928768	42.25	0.916926	30.93	0.937141	29.41
2	0.93539	61.94	0.938285	36.98	0.994451	36.64
3	0.996354	43.38	0.936543	41.42	0.960024	41.17
4	0.995598	45.07	0.911618	44.16	0.984038	44.16
5	0.959909	1.17	0.960063	1.17	0.955278	0
6	0.999098	0.65	0.980026	1	0.976615	0
7	0.995294	0.02	0.942812	0	0.939225	0
8	0.949654	0.06	0.889374	0.13	0.878086	0
9	0.990624	0.02	0.982668	0	0.99399	0
10	0.99651	0.94	0.985848	0.53	0.977127	0
11	0.99367	2.17	0.97235	2.06	0.99438	0
12	0.997084	59.65	0.989215	59.65	0.995202	45.12
13	0.995544	60.48	0.936399	60.44	0.997162	36.03
14	0.930938	21.72	0.904327	22.73	0.904783	20.25
15	0.78499	0	0.772911	0	0.844461	0
16	0.975687	0	0.94958	0	0.977951	0
17	0.974075	85.71	0.967952	85.71	0.974468	85.71
18	0.992446	0	0.967773	0	0.987002	0
19	0.995694	48.08	0.995412	46.7	0.995119	28.46
20	0.895705	0	0.834995	0	0.90226	0
21	0.940985	0	0.913105	0	0.858113	0
22	0.956894	0	0.918885	0	0.893239	0
23	0.899398	0	0.885602	0	0.925868	0
24	0.837692	0	0.750683	0	0.894997	0
25	0.997411	0	0.99098	0	0.850542	0
26	0.956415	0	0.976833	0	0.974625	0
27	0.976443	0	0.966543	0	0.975642	0
28	0.850051	0	0.828421	0	0.935708	0
29	0.932304	0	0.875092	0	0.868435	0
30	0.992572	0	0.992214	0	0.814178	0
31	0.996191	0	0.952888	0	0.882783	0
32	0.963714	100	0.917523	61.22	0.930933	48.86
33	0.928083	0	0.995649	0	0.92665	0
34	0.9363	0	0.889554	0	0.950693	0
35	0.940881	100	0.838705	100	0.980732	100
36	0.972335	100	0.963233	100	0.472279	100
37	0.959936	100	0.995591	100	0.507995	100
38	0.961033	0	0.943208	0	0.995432	0
39	0.996991	0	0.943636	0	0.981266	0
40	0.978671	0	0.982159	0	0.941432	0
41	0.868218	0	0.992013	0	0.99635	0
42	0.996064	0	0.988512	0	0.972688	0
43	0.917233	0	0.978716	0	0.880588	0
Public Banks	0.96403	–	0.93058	–	0.96387	–
Mixed Banks	0.96418	–	0.94086	–	0.96911	–
Private Banks	0.94539	–	0.93241	–	0.89991	–

Overall efficiency of public banks, 0.95828; of mixed banks, 0.958051; of private banks, 0.926073.

Notes: TE = technical efficiency; ST = government stock.

their technical efficiencies. Consequently, in Taiwan the government stockholdings have positive effects on technical efficiency improvement.

CONCLUDING REMARKS

In the early 1990s, Taiwan began her deregulation trend in order to enhance competition across all industries and to promote economic efficiency. We apply the concept of a stochastic frontier function to evaluate the efficiency of banks and to investigate the relationship between government shareholding and technical efficiency. Banks are in a multi-output industry and traditional methods model the multi-output technology as a dual-cost function. This is, however, an inappropriate setup since the behavioural assumption of cost minimisation is unlikely to be valid in public and mixed banks. Distance functions allow us to characterise the structure of production technology when multiple inputs are used to produce multiple outputs without the need to specify a behaviour objective such as cost minimisation or profit maximisation.

Most existing research on mixed enterprises' efficiency focuses on cost efficiency. Nevertheless, the goal of mixed and public enterprises is neither profit maximisation nor cost minimisation. It is well known that public and mixed enterprises achieve socio-political objectives at the price of higher cost inefficiency. Therefore, it is not adequate to judge the performance of public and mixed enterprises by cost efficiency. While public and mixed enterprises may have a higher allocative inefficiency due to government regulations on employment and procurement, if cost inefficiency is decomposed into technical and allocative efficiencies, public and mixed enterprises are likely to perform better than private enterprises in some aspects.

We apply a translog distance function to estimate technical efficiency and to examine the relationship between technical efficiency and government shareholdings. The main findings are as follows: First, public banks in Taiwan can improve technical efficiencies by mixed ownership at a diminishing rate. Second, mixed banks have a higher technical efficiency than private and public banks. Third, banks in Taiwan on average performed worse after the 1997 Asian financial crisis. Finally, the model hypothesis on input-output separability is rejected.

The loan as an output of the bank is risky. In this article we do not take loan quality into account. However, default loans do reduce a bank's output and/or increase its cost and hence reduce the estimated efficiency indexes. Introducing loan quality may alter the rankings in estimated efficiency. In the future loan quality can be incorporated into the model, making the estimation more accurate. Furthermore, a comparison between different estimation

approaches, such as stochastic cost frontiers and DEA, has been a worthy direction for research in this field.

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NOTES

1. A distance function can be specified with either an input orientation or output orientation. The output distance function is selected over the input distance function, because it would be easier for a public or mixed bank to expand output rather than to reduce the usage of inputs.
2. The Cobb-Douglas functional form, which is one of the most popular functional forms in production analysis, only satisfies the latter two points, because of its restrictive elasticity of substitution and scale property. Moreover, it is not an appropriate model of a firm in a competitive industry since it is not concave in output dimensions [Klein, 1953].

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