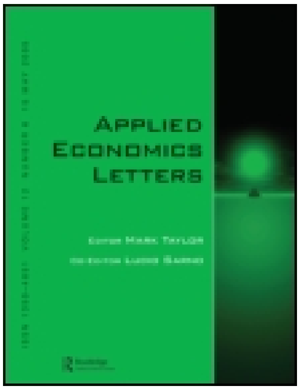

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On the study of confidence intervals of Taiwan's banking sector efficiency

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On the study of confidence intervals of Taiwan's banking sector efficiency

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This article applies a distribution-free approach to estimate the economic efficiencies of Taiwan's multioutput banking industry, under the framework of the cost frontier. The joint confidence interval estimates for economic efficiencies are constructed using multiple comparisons with the best (MCB) procedure. A salient characteristic of MCB procedure is that it is able to identify multiple efficient firms lying on the minimum cost frontier. The MCB intervals reveal at the 95 and 75% confidence levels that four out of 22 banks in the sample may be statistically efficient.

I. Introduction

Despite an extensive amount of literature concerning the estimation of firm-level economic efficiency (EE) in financial service industries, only a few researchers have devoted themselves to the construction and interpretation of confidence intervals for the point estimates of technical efficiency (TE) from stochastic production frontier. A point estimate is obtained through a particular way of using the data. Without further information, it is difficult to compare different estimation rules in terms of their sampling performance.

The construction of confidence intervals for the estimates gains an insight into the problems of inferential statistics, such as how close the estimate is likely to be to its population counterpart and is one firm's TE estimate significantly higher (or lower) than the others. Recently, there has been a surge of research activity that has attempted to characterize the nature and the empirical degree of the uncertainty associated with TE estimates. Among the stochastic frontier studies, Horrace and Schmidt (1996, 2000) and Fraser and Horrace (2003) systematically exploit the methodology of multiple comparisons with the best (MCB) procedure to construct joint confidence intervals of TE estimates for a sample of firms in the context of a production frontier.

If a fixed-effect frontier specification is adopted, then MCB allows the construction of simultaneous confidence intervals for all differences between the unknown maximal fixed-effect and the other effects. This corresponds to the vector of differences between the intercept of the best practice firm and those of the rest in a sample. For a pre-specified level of confidence, MCB is able to identify which firms may be fully efficient, and by offering upper and lower bounds on the deviations of all estimates from the maximal value, it is capable of distinguishing whether these deviations are statistically significant.

The rest of the current article is organized as follows. Section II develops a cost frontier incorporating input measures of TE. Section III discusses the

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estimation methods of MCB confidence intervals. In Section IV the data are first briefly described and then the empirical results are presented. The last section concludes the article.

II. Efficiency-Adjusted Cost Function

It is assumed that there is a set of multiproduct banks, denoted by $i=1,\ldots,I$, each producing two outputs, denoted by q_1 and q_2. Each bank hires three inputs, denoted by $X=(X_1\,X_2\,X_3)'$, which are defined from the intermediation approach. All of the two output markets as well as the three factor markets are assumed to be perfectly competitive.

According to Atkinson and Cornwell (1994) and Kumbhakar (1997), a firm's efficiency-adjusted cost function can be expressed as

$$\begin{aligned} C^*\left(q', \frac{W}{b}; \theta\right) &= \min_{bX}\left[\frac{W}{b}(bX)|F(q', bX')=0\right] \\ &= \frac{1}{b}C(q', W; \theta) \end{aligned} \tag{1}$$

when input-oriented TE is modelled. In Equation 1, $q=(q_1\,q_2)'$ denotes a 2×1 output vector of a firm, while b, $0<b\leq1$, is an unknown parameter scaling input usage and reflects the degree of input TE. The larger the value of b is, the more technically efficient is the firm. A firm is said to be fully technically efficient as $b=1$ and fully technically inefficient as $b=0$. Notation $W=(w_1\,w_2\,w_3)$ is a 1×3 vector of input prices; $C(q', W;\theta)$ represents the optimal cost frontier, in which vector θ represents all the unknown technology parameters.

By Shephard's lemma and the properties of factor demand functions, we can relate the actual expenditure (E) to C*, after taking natural logarithms, as

$$\ln E = \ln C - \ln b \tag{2}$$

When estimation, $\ln C$ will be specified as a standard translog cost function. The corresponding share equations can be expressed as

$$\frac{w_j X_j}{E} = S_j \equiv \frac{\partial \ln C}{\partial \ln w_j},\ j=1,2,3 \tag{3}$$

Based on microeconomic theory, some restrictions must be incorporated in the cost function. Specifically, it must be linearly homogeneous in input prices and symmetrical in input prices and output quantities. Other regularity conditions, such as a cost function being nondecreasing and concave in factor prices, will be examined after the unknown parameters are estimated.

III. Point and Interval Estimation

Point estimation

Rewrite Equation 2 in a panel data format as

$$\begin{aligned} \ln E_{it} &= \alpha_0 + X_{it}\beta + u_i + v_{it} \\ &= \alpha_i + X_{it}\beta + v_{it} \end{aligned} \tag{4}$$

Here i indexes banks, t indexes time periods, X_{it} is a $1\times K$ vector of all explanatory variables, such as (log) input prices, (log) output quantities and their cross-effect terms and α_0 and β are unknown parameters to be estimated. Notation v_{it} is white noise distributed as $N(0,\sigma_v^2)$ while $u_i=-\ln b$ represents increased cost due to X-inefficiency, assumed to be constant over time, but variant across firms. In the application of the MCB technique, u_i (and α_i) has to be treated as a fixed-effect.

By treating $\alpha_i=\alpha_0+u_i$ $(i=1,\ldots,I)$ as dummy variables for firms, we obtain estimates of $\alpha_1,\ldots,\alpha_1$ and β. Let $\alpha_{[1]}\leq\alpha_{[2]}\leq\cdots\leq\alpha_{[i]}$ be the population rankings of α_i. Thus, $\alpha_{[1]}=\min_{i=1}^{I}\alpha$, where column vector $\alpha=(\alpha_1,\ldots,\alpha_i)'$ and $\alpha_{[1]}\geq\alpha_0$ as $u_i\geq0$ by assumption. Firm [1] corresponds to the most efficient firm, while firm $[I]$ corresponds to the least efficient one. An alternative inefficiency measure is defined by comparing α_i to the within-sample standard $\alpha_{[1]}$, i.e., $u_i^*=\alpha_i-\alpha_{[1]}=u_i-u_{[1]}$, so that $0\leq u_i^*\leq u_i$. Equation 4 can thus be written as

$$\ln E_{it} = \alpha_{[1]} + X_{it}\beta + v_{3it} + u_i^* \tag{5}$$

The relative economic inefficiency measures u_i^* can be monotonically transformed into the EE measure by $\mathrm{EE}_i=\exp(-u_i^*)$.

Interval estimation by MCB techniques

After obtaining fixed-effect estimates of α_i, $\hat{\alpha}_i$ and therefore of u_i^*, $\hat{u}_i^*$, in the sequel, the joint confidence intervals of $\hat{u}_i^*$ are constructed by MCB technique. There are a few salient characteristics of the MCB technique worth mentioning. First, MCB is a powerful technique to construct simultaneous confidence intervals for differences between the best treatment and the rest without presuming the best treatment is known, a priori. In our case, the parameters of interest for MCB are the relative economic inefficiency measures $u_i^*=\alpha_i-\alpha_{[1]}$, $i=1,\ldots,I$. The MCB technique facilitates the construction of simultaneous confidence intervals for u_i^* without knowing which bank is the best-practice one, which is implicitly assumed in the point estimates of α_i and u_i^*. Second, the so-derived simultaneous confidence intervals offer joint statements about which banks are fully efficient and which are off the efficient frontier at a pre-specified confidence level. Therefore, it is quite possible that the MCB intervals reveal more than one best-practice bank. However, the point estimates of EE imply that all but one bank are fully efficient, excluding the possibilities of ties in the sample for the best. Lastly, since MCB is based on fixed-effect specification, distributional assumptions on u_i^* are unnecessary.

Let $\hat{\Omega}$ be the covariance matrix of the vector parameter estimates $\hat{\alpha} = (\hat{\alpha}_1, \ldots, \hat{\alpha}_I)'$, in which each element is denoted by $\hat{\omega}_{ij}$ $(i,\ j = 1, \ldots, I)$. Selecting arbitrarily bank j as the control and letting λ be a pre-specified level of significance, the lower and upper bounds of simultaneous $(1-\lambda)$ 100% confidence intervals for the deviation of the ith bank from the pre-selected bank j will take the form

$$LB_i^j = \hat{\alpha}_i - \hat{\alpha}_j - h_{ji} \tag{6}$$

$$UB_i^j = \hat{\alpha}_i - \hat{\alpha}_j + h_{ji} \tag{7}$$

where $i,\ j = 1, \ldots, I$, but $i \neq j$ and $h_{ji} = d_j^*(\hat{\omega}_{ii} + \hat{\omega}_{jj} - 2\hat{\omega}_{ij})^{1/2}$. Notation d_j^* is the solution to

$$\text{Prob}\left(\max_{1\leq i \leq I-1} |Z_i| \leq d_j^*\right) = 1 - \lambda \tag{8}$$

where Z_i is an $I-1$ dimensional random vector distributed as an $(I-1)$-variate t distribution with degrees of freedom $I(T-1)-K$ and an appropriate covariance matrix can be deduced as follows.

Define the following notation

$$S = \{i | UB_j^i \geq 0 \quad \forall j \neq i\} = \{i | \hat{\alpha}_i \leq \hat{\alpha}_j + h_{ij} \quad \forall j \neq i\} \tag{9}$$

$$LB_i = \max\left[0, \min_{j\in S} LB_i^j\right] = \max\left[0, \min_{j\in S} \hat{\alpha}_i - (\hat{\alpha}_j + h_{ji})\right] \tag{10}$$

$$UB_i = \max\left[0, \min_{j\neq i} UB_i^j\right] = \max\left[0, \max_{j\neq i} \hat{\alpha}_i - (\hat{\alpha}_j - h_{ji})\right] \tag{11}$$

The $(1-\lambda)$ 100% MCB confidence intervals on u_i^* can then be expressed as

$$\text{Prob}\{[1] \in S \text{ and } LB_i \leq u_i^* \leq UB_i \quad i = 1, \ldots, I\} \geq 1 - \lambda \tag{12}$$

Readers are suggested to see Edwards and Hsu (1983) for the proof. Equation 12 states that with probability at least $(1-\lambda)$, the relative economic inefficiency of bank i lies between LB_i and UB_i, when the true identity of the most efficient bank [1] is not known with certainty. It should be noted that some signs and elements shown in Equations 9–11 deviate from those of the production frontier, e.g. Horrace and Schmidt (1996, 2000).

An MCB procedure divides the entire sample into three subsamples: banks in set S having $LB_i = 0$; banks not in S, but having $0 = LB_i < UB_i$; and banks not in S having $0 < LB_i < UB_i$. When S contains a single index it must be the most efficient bank having the least value of $\hat{\alpha}_i$. It is noteworthy that the MCB intervals are not centered on the point estimates $\hat{u}_i^*$, recognizing the bias inherent in the 'min' operation. The joint confidence intervals for u_i^* are frequently converted into joint confidence intervals for the values of $\text{EE}_i = \exp(-u_i^*)$. In doing so, the transformed lower and upper bounds have to be interchanged and the probability statement becomes:

$$\text{Prob}\{[1] \in S \text{ and } \exp(-UB_i) \leq \exp(-u_i^*) \leq \exp(-LB_i)u \quad i = 1, \ldots, I\} \geq 1 - \lambda \tag{13}$$

IV. Data and Empirical Results

Data description and parameter estimates

The sample period spans 1981–2001, containing 22 of Taiwan's domestic banks for each year. One of the public banks started business in 1982, making the total number of observations to be 461. The output categories include investments (q_1), which consist of all government and corporate securities and loans (q_2), which contain short- and long-term loans. The input categories are classified as all deposits and borrowed money (X_1), the number of full-time equivalent employees (X_2) and physical capital net of depreciation (X_3). The input prices of individual banks are obtained by taking the ratio of the incurred outlays for each input to the corresponding input quantities. Sample statistics are shown in Table 1.

Table 1. Sample statistics

Variable name	Mean	SD
Real actual expenditure (E)*	20 787.33	22 072.59
Real investments (q_1)*	48 438.11	65 694.47
Real loans (q_2)*	233 174.67	265 123.68
Price of deposits and borrowed money (w_1)	0.0597	0.0222
Real wage of labour (w_2)*	0.8033	0.3226
Price of capital (w_3)	0.5333	0.5417

Notes: *Millions of new Taiwan's dollars.
Base year: 1996. Number of observations: 461.

Table 2. Parameter estimates of the cost frontier

Variable name	Coefficient estimates	SE	Bank number	Fixed-effect estimates	SE
$\ln q_1$	0.2441***	0.0778	1	1.6740***	0.4414
$\ln q_2$	0.5386***	0.1305	2	1.9779***	0.4441
$\ln w_1$	0.5115***	0.0251	3	2.4840***	0.4319
$\ln w_2$	0.3511***	0.0154	4	2.1639***	0.4431
$\ln q_1 \times \ln q_1$	0.0725***	0.0138	5	2.3072***	0.4321
$\ln q_2 \times \ln q_2$	0.0954***	0.0256	6	2.5142***	0.4318
$\ln q_1 \times \ln q_2$	−0.0801***	0.0181	7	2.5330***	0.4356
$\ln w_1 \times \ln w_2$	−0.0757***	0.0039	8	2.5100***	0.4364
$\ln w_2 \times \ln w_3$	−0.0276***	0.0021	9	2.5273***	0.4360
$\ln w_1 \times \ln w_3$	−0.0370***	0.0036	10	2.2197***	0.4449
$\ln q_1 \times \ln w_1$	0.0095**	0.0044	11	2.0069***	0.4459
$\ln q_1 \times \ln w_2$	0.0007	0.0028	12	2.0274***	0.4470
$\ln q_2 \times \ln w_1$	0.0338***	0.0052	13	1.8390***	0.4453
$\ln q_2 \times \ln w_2$	−0.0325***	0.0033	14	2.2578***	0.4388
t	0.0871***	0.0152	15	2.0867***	0.4469
t^2	0.0004	0.0004	16	2.1067***	0.4466
$t \times \ln q_1$	0.0062***	0.0015	17	2.0940***	0.4470
$t \times \ln q_2$	−0.0109***	0.0022	18	1.9968***	0.4446
$t \times \ln w_1$	−0.0018***	0.0005	19	2.0162***	0.4437
$t \times \ln w_2$	−0.0052***	0.0004	20	1.7756***	0.4276
			21	1.5672***	0.4268
			22	1.7763***	0.4432
Log-likelihood	2185.81				

Notes: *Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

The extra terms of t (linear trend), t^2 (square of t) and all the cross effects between t and the other variables are considered in the regression model, to take care of possible technical change over time. Equations 5 and 3 are estimated simultaneously and the parameter estimates are shown in Table 2.

Most of the estimates reach statistical significance. The regularity conditions mentioned in Section II are checked using the parameter estimates for each sample observation. It is found that most of the sample points are in accord with standard micro-economic theory, indicating that these point estimates are consistent with the behaviour of cost minimization.

Economic efficiency and confidence intervals

In Table 2 it is seen that all of the fixed-effect estimates reach statistical significance at the 1% level. The significance of the α_i provides no information on the precision of the differences between pairs of α_i. The relative economic inefficiency measures and the corresponding confidence intervals of relative EE measures at the 75 and 95% confidence levels are shown in Table 3. Due to space restriction, I shall present the MCB results only.

The distribution of $\hat{u}_i^*$ is quite dispersed, which lies between zero and about 0.966. The average EE measures are calculated to be 0.603. This evidence suggests that on average an efficient bank requires nearly 60% of resources currently being used to produce the same level of outputs. The 95% (75%) critical values, d_j^*, required for MCB are simulated by the GAUSS programming language through 1 000 000 replications and the results range from 2.646 to 2.918.

The 95% MCB confidence intervals describe a sharply different picture than the point estimates of α_i listed in Table 2. Those intervals are fairly narrow, indicating that the differences $u_i^* = \alpha_i - \alpha_{[1]}$ and their transformation $\exp(-u_i^*)$ are precisely estimated. As a result, multiple best-practice banks are identified by the MCB confidence intervals. It includes two banks in the best set, S, i.e., banks 1 and 21.

All banks in group S should have an upper bound equal to unity, while there are banks with MCB upper bounds equal to unity, but not in S, which are classified in the second best group. They are potentially efficient at the 95% level, i.e., they will be economically efficient 95 times out of 100. The model identifies another two such banks as banks 20 and 22. The remaining 18 banks belong to the last group, devoid of EE at the 95% confidence level.

Table 3. The MCB confidence intervals

Bank number	$\hat{u}_i^*$	75% Lower bound	75% Upper bound	95% Lower bound	95% Upper bound
1	0.1068	0.7954	1.0	0.7587	1.0
2	0.4107	0.5896	0.7820	0.5634	0.7961
3	0.9168	0.3413	0.4842	0.3210	0.4980
4	0.5967	0.4884	0.6493	0.4662	0.6610
5	0.7399	0.4112	0.5716	0.3882	0.5865
6	0.9470	0.3322	0.4671	0.3128	0.4811
7	0.9657	0.3308	0.4522	0.3132	0.4627
8	0.9428	0.3384	0.4627	0.3205	0.4735
9	0.9600	0.3331	0.4542	0.3156	0.4645
10	0.6525	0.4663	0.6163	0.4468	0.6282
11	0.4396	0.5778	0.7640	0.5539	0.7792
12	0.4602	0.5765	0.7595	0.5566	0.7781
13	0.2718	0.6994	0.9215	0.6766	0.9454
14	0.6905	0.4397	0.5919	0.4179	0.6028
15	0.5194	0.5396	0.7113	0.5196	0.7273
16	0.5395	0.5319	0.7007	0.5133	0.7176
17	0.5267	0.5386	0.7095	0.5197	0.7265
18	0.4295	0.6026	0.7948	0.5849	0.8179
19	0.4490	0.5942	0.7843	0.5779	0.8086
20	0.2083	0.7731	1.0	0.7541	1.0
21	0	0.9651	1.0	0.9236	1.0
22	0.2090	0.7467	0.9863	0.7230	1.0

S (75%) = {1, 21}. S (95%) = {1, 21}.

V. Summary and Conclusion

The current article distinguishes itself from previous studies by the fact that its empirical study on the construction of MCB confidence intervals extends the single output production frontier to the multi-product dual cost frontier. After estimating the simultaneous equations by generalized least squares procedure for a panel of banks in Taiwan, we find the presence of large variations among the point estimates of relative economic efficiency. The mean EE measure is equal to roughly 0.60. These potentially bias results arise partially from involving the 'min' operator in the calculations of the point estimates and partially from the inability of the point estimates alone to provide a guide to the precision of them. Consequently, one should be very careful and even conservative when drawing inferences based solely on the point estimates. Using the MCB technique, the data reveal that 4 out of 22 banks may be efficient at the 95% confidence level.

References

Atkinson, S. E. and Cornwell, C. (1994) Parametric estimation of technical and allocative inefficiencies with panel data, *International Economic Review*, **35**, 231–43.

Edwards, D. G. and Hsu, J. C. (1983) Multiple comparisons with the best treatment, *Journal of the American Statistical Association*, **78**, 965–71; Corrigenda (1984), *Journal of the American Statistical Association*, **79**, 965.

Fraser, I. and Horrace, W. C. (2003) Technical efficiency of Australian wool production: point and confidence interval estimates, *Journal of Productivity Analysis*, **20**, 169–90.

Horrace, W. C. and Schmidt, P. (1996) Confidence statements for efficiency estimates from stochastic frontier models, *Journal of Productivity Analysis*, **7**, 257–82.

Horrace, W. C. and Schmidt, P. (2000) Multiple comparisons with the best, with economic applications, *Journal of Applied Econometrics*, **15**, 1–26.

Kumbhakar, S. C. (1997) Modelling allocative inefficiency in a translog cost function and cost share equations: an exact relationship, *Journal of Econometrics*, **76**, 351–6.