行政院國家科學委員會專題研究計畫 成果報告

應用共同邊界隨機方向距離函數探討東歐國家銀行業生產效率

研究成果報告(精簡版)

計 畫 類 別 ： 個別型
計 畫 編 號 ： NSC 100-2410-H-004-072-
執 行 期 間 ： 100 年 08 月 01 日至 101 年 07 月 31 日
執 行 單 位 ： 國立政治大學金融系

計 畫 主 持 人 ： 黃台心

報 告 附 件 ： 出席國際會議研究心得報告及發表論文

公 開 資 訊 ： 本計畫涉及專利或其他智慧財產權，1 年後可公開查詢

中 華 民 國 101 年 08 月 15 日

中 文 摘 要 ： 本研究在隨機邊界架構下，建立共同邊界隨機方向距離函數，此函數不同於 Battese et al. (2004) and O’Donnell et al. (2008) 所建構的確定性邊界函數。估計此共同邊界隨機方向距離函數後，可以計算出各群組的技術缺口比率值，進而在相同基礎上相互比較；技術缺口比率也能與環境變數相互連結。收集 17 個中、東歐國家銀行業的資料，並將非意欲產出—不良放款—納入模型中，實證分析結果發現若迴規模型忽略此非意欲產出，傾向低估技術效率與技術缺口比率值。另一方面，發現各國的技術缺口比率估計值高於技術效率值，顯示樣本銀行應優先採用先進生產技術，致力提升生產技術水準。

中文關鍵詞： 共同邊界方向距離函數； 技術效率； 環境變數； 非意欲產出；

英 文 摘 要 ： This paper first establishes a new metafrontier directional technology distance function (MDDF) under a stochastic framework, rather than a deterministic setting like the one proposed by Battese et al. (2004) and O’Donnell et al. (2008). The new MDDF allows for calculating comparable technical efficiencies for banks under different technologies relative to the potential technology available to the industry across nations. The inefficiency term of the new MDDF is further associated with relevant environmental variables of the form proposed by Battese and Coelli (1995). The new MDDF is then applied to examine and compare bank efficiencies of 17 Central and Eastern European countries. Non-performing loans (NPLs) are regarded as an undesirable, jointly produced with various loans, and the omission of them tends to underestimate technical inefficiency scores. Evidence is found that the estimated technology gap dominates technical efficiencies. Bank managers are suggested to swiftly adopt new financial innovations with an eye to shift the group frontier closer to the metafrontier.

英文關鍵詞： metafrontier directional distance function；technical efficiencies； environmental variables；undesirable output；

行政院國家科學委員會補助專題研究計畫 成果報告

應用共同邊界隨機方向距離函數探討東歐國家銀行業生產效率

計畫類別：☑個別型計畫　□整合型計畫
計畫編號：NSC 100－2410－H－004－072－
執行期間： 100 年 8 月 1 日至 101 年 7 月 31 日

執行機構及系所：國立政治大學金融學系

計畫主持人：　黃台心
共同主持人：　無
計畫參與人員：蔡釗旻、邱郁芳

成果報告類型(依經費核定清單規定繳交)：☑精簡報告　□完整報告

本計畫除繳交成果報告外，另須繳交以下出國心得報告：
□赴國外出差或研習心得報告
□赴大陸地區出差或研習心得報告
☑出席國際學術會議心得報告
□國際合作研究計畫國外研究報告

處理方式：除列管計畫及下列情形者外，得立即公開查詢
□涉及專利或其他智慧財產權，☑一年□二年後可公開查詢

中　華　民　國　101　年　8　月　14　日

中文摘要

本研究在隨機邊界架構下，建立共同邊界隨機方向距離函數，此函數不同於 Battese et al. (2004) and O'Donnell et al. (2008) 所建構的確定性邊界函數。估計此共同邊界隨機方向距離函數後，可以計算出各群組的技術缺口比率值，進而在相同基礎上相互比較；技術缺口比率也能與環境變數相互連結。收集 17 個中、東歐國家銀行業的資料，並將非意欲產出—不良放款—納入模型中，實證分析結果發現若迴規模型忽略此非意欲產出，傾向低估技術效率與技術缺口比率值。另一方面，發現各國的技術缺口比率估計值高於技術效率值，顯示樣本銀行應優先採用先進生產技術，致力提升生產技術水準。

關鍵詞： 共同邊界方向距離函數; 技術效率; 環境變數; 非意欲產出;

Abstract

This paper first establishes a new metafrontier directional technology distance function (MDDF) under a stochastic framework, rather than a deterministic setting like the one proposed by Battese et al. (2004) and O'Donnell et al. (2008). The new MDDF allows for calculating comparable technical efficiencies for banks under different technologies relative to the potential technology available to the industry across nations. The inefficiency term of the new MDDF is further associated with relevant environmental variables of the form proposed by Battese and Coelli (1995). The new MDDF is then applied to examine and compare bank efficiencies of 17 Central and Eastern European countries. Non-performing loans (NPLs) are regarded as an undesirable, jointly produced with various loans, and the omission of them tends to underestimate technical inefficiency scores. Evidence is found that the estimated technology gap dominates technical efficiencies. Bank managers are suggested to swiftly adopt new financial innovations with an eye to shift the group frontier closer to the metafrontier.

Key Words: metafrontier directional distance function; technical efficiencies; environmental variables; undesirable output;

目　　錄

1. Introduction 3

2. Literature Review 5

3. New Metafrontier Directional Distance Function

3.1 Directional Technology Distance Function 7

3.2 Metafrontier Directional Distance Function (MDDF) 9

4. Data Description……………………………………………...13

5. Empirical results

5.1 Coefficient Estimates of Group Frontiers 14

5.2 Group-specific Technical Inefficiency………………………15

5.3 Empirical Results of the MDDF……………………………16

6. Concluding Remarks 18

References 20

Table 1 26

Table 2 27

Table 3 28

Figure 1~2 29

Figure 3…………………………………………………………..30

國科會補助專題研究計畫成果報告自評表 31

1. Introduction

Following Koutsomanoli-Filippaki et al. (2009), this paper applies the stochastic frontier DDF to investigate bank efficiencies in 17 CEE countries. The advantages of using this DDF are as follows. First, it characterizes the joint production of desirable outputs with undesirable outputs and allows for a bank to increase desirable outputs and concurrently decrease inputs and undesirables. This differs from either the input- or the output-oriented distance function that permits either input savings or output expansion, but not both, and is incapable of handling undesirable outputs. Second, the DDF is specified as if the translog form without the need to take the natural logarithm. This flexible functional form can lessen the potential error of functional specification and the sample with variables taking a zero value can hold. Finally, the inefficiency term can be linked with a set of environmental variables that influence a bank's production effeciency.

In the banking industry, non-performing loans may be viewed as an undesirable, by-product jointly produced with various loans. According to Färe and Grosskopf (2005), desirable outputs are said to be null-joint with undesirable outputs, if there are no bad outputs produced, then only zero good output can be produced. Furthermore, undesirables are assumed to be weakly disposed, i.e., the disposal of them needs to consume resources and is not costless. Consequently, the exclusion of undesirables from the model is apt to overestimate the technical efficiency score. For example, suppose that banks A and B are producing the same level of outputs, but bank A employs less number of workers than bank B to screen out its applicants for loans. This would result in the amount of bank A's non-performing loans to exceed bank B's. Taking an output-oriented distance function as an example, it is very likely that bank A's efficiency score is greater than bank B's, since the former hires less labor than the latter to yield the same output quantities. If the bad output, satisfying the foregoing properties of null jointness and weak disposability, is explicitly taken into account, then the rank of the efficiency scores of the two banks may be reversed. This is because bank A has to consume some resources to deal with the bad output, lowering the output oriented technical efficiency measure.

To validly conduct a cross-country comparison, a researcher has to design a procedure that takes care of heterogeneous technologies, on the one hand, and that the performance of banks should be assessed on the same benchmark for different countries, on the other. This requires the use of the newly developed metafrontier model by Battese et al. (2004) and O'Donnell et al. (2008), which proceeds in a two-step procedure. In the first step, the stochastic frontier of each country (or group) is estimated to yield technical efficiency scores for all banks within the individual countries. In the second step, one estimates the metafrontier to obtain the technology gap ratios (TGRs) between the (deterministic) metafrontier and the group frontiers for each bank, using the linear or quadratic programming technique that allows for easily imposing the tangency restriction between the metafrontier and the group frontiers. Bos and Schmiedel (2007) apply this model to examine banking efficiency in 15 Western European countries accounting for potential differentials among country-specific banking technologies.

We extend the stochastic frontier DDF of Koutsomanoli-Filippaki et al. (2009) to the new metafrontier DDF (MDDF), which allows for estimating and comparing bank efficiency across 17 CEE countries. The idea of the new MDDF is first proposed by Huang et al. (2011), exemplified by a production function. It differs considerably from Battese et al. (2004) and O'Donnell et al. (2008) mainly in the second step, aiming at establishing the (stochastic) metafrontier. Our new MDDF is constructed under the stochastic frontier framework, instead of relying on mathematical programming techniques. The primary difficulties of programming techniques are that they are deterministic, similar to the DEA, such that the estimation results are easily confounded with random shocks, and that no statistical inferences can be made, because the statistical properties of the estimates are unknown. Both difficulties can be disentangled by the employment of the new MDDF, to be thoroughly discussed in Section 3.

The purpose of this paper is three-fold. First, we attempt to build a new MDDF under the stochastic frontier framework. The new MDDF is recommended and possibly preferable, because the resulting estimates of TGRs are free from the influence of random shocks. Second, the TGRs can be further specified as a function of an array of exogenous variables characterizing the environments in which production takes place. This approach is akin to Battese and Coelli (1995). In this manner, one is able to study the determinants of the TGRs and, more importantly, banks from different countries can be compared under similar condisitons. Third and finally, the new MDDF is applied to estimate and compare bank efficiencies of 17 CEE countries, as banks in these transition nations tend to adopt heterogeneous technologies due to systematic, cultural, regulatory, and endowment differences, and the financial systems in these countries have experienced various series of financial reforms during the past two decades.

The rest of this paper is organized as follows. Section 2 briefly reviews relevant literature on the DDF and MDDF. Section 3 establishes the new MDDF. Section 4 describes the data. Section 5 analyzes the empirical results, while the last section concludes the paper.

2. Literature Review

Battese et al. (2004) first propose a two-step approach to construct a metafrontier function suitable for estimating and comparing the technical efficiency of firms belonging to various technology groups. In the second step, they suggest using either a linear programming or quadratic programming technique, which permits the imposition of inequality constraints and forces the group frontier to be below (or above) the metafrontier, in order to compute the technology gap ratio for each firm in different groups. Following the same procedure, O'Donnell et al. (2008) compare the technical efficiency of agricultural production across 97 countries spanning 1986 to 1990. Huang et al. (2010) extend the above model to the metafrontier Fourier flexible cost function and compare technical efficiencies for banks in 16 Western European countries. A relatively technically efficient bank is found to be possibly technologically efficient and vice versa.

Huang et al. (2011) initiate a new metafrontier to estimate technical efficiency (TE) scores for firms in different groups. Their approach diverges from Battese et al. (2004) and O'Donnell et al. (2008) mainly in the second step, where a stochastic frontier model is formulated and estimated by the maximum likelihood to obtain the parameter estimates of the metafrontier, instead of relying on programming techniques. In this manner, the so-derived estimators have the desirable statistical properties and enable some relevant statistical inferences to be drawn.

The use of a metafrontier is preferable in that it allows researchers to assess the TGR for firms from different groups with respect to the common metafrontier. Therefore, these TGRs are comparable among firms of different groups, which are the salient features under the metafrontier framework. This present article intends to exploit such advantages and to explore banks' performance among CEE countries. It is noteworthy that a study on cross-country efficiency measure comparisons in transition countries' banking industry has largely increased recently without relying on the metafrontier. See, for example, Allen and Rai (1996), Altunbas et al. (2001), and Weill (2004), Bonin et al. (2005), Fries and Taci (2005), Rossi et al.

(2005),Yildirim and Philippatos, (2007), and Huang et al. (2011) to mention a few. However, Bos and Schmiedel (2007) and Huang, Chiang, and Chen (2011) perform the cross-country comparisons in the context of the metafrontier, proposed by Battese et al. (2004).

3. New Metafrontier Directional Distance Function

3.1 Directional Technology Distance Function

Input quantities are denoted by $x = (x_1, ..., x_N)' \in R_+^N$, output quantities are denoted by $y = (y_1, ..., y_M)' \in R_+^M$, and the undesirable vector is signified by $b = (b_1, ..., b_J)' \in R_+^J$. Following O'Donnell et al. (2008), the *k*th (*k* = 1,…, *K*) group's technology set is defined as:

$$T^k = \{(x, y, u) : x \text{ can be used by firms in group } k \text{ to produce } (y, b)\}.$$

A directional vector is expressed as $g = (g_x', g_y', g_u')'$, in which $g_x \in R_+^N$, $g_y \in R_+^M$, and $g_b \in R_+^J$.

We now define the directional technology distance function (DDF) for group *k* as:

$$\vec{D}_T^k(x, y, b; g) = \sup\{\beta : (x - \beta g_x, y + \beta g_y, b - \beta g_b) \in T^k\} \qquad (1)$$

It expands outputs in the direction g_y and contracts inputs and undesirables in the directions g_x and g_b, respectively, in order to be able to produce on the group frontier. The DDF translates the (*x*, *y*, *b*) vector in the direction g onto the boundary of the technology.

Since (*x*, *y*, *b*) is usually interior to technology T^k, the value of the distance function is non-negative. A firm having a value of $\vec{D}_T^k(x, y, b; g) = 0$ implies that it is already producing at the frontier, while a value of $\overrightarrow{D}_T^k(x,y,b;g)>0$ reveals that the firm's actual (*x*, *y*, *b*) locates underneath the frontier. Following Koutsomanoli-Filippaki et al. (2009), the directional vector herein is specified as *g* = (1,1,1), which means that a firm can produce at the efficient frontier if it simultaneously reduces its input quantities and undesirables by β units and increases outputs by β units along with the direction (1,1,1).

The DDF is commonly expressed as a flexible quadratic functional form allowing for a non-neutral technical change. The translation property is used to transform the DDF into an estimable regression equation. See, for example, Färe and Grosskopf (2005). We arbitrarily choose $\xi = x_1$ to translate the quadratic DDF into:

$$
\begin{aligned}
-x_1 &= \overrightarrow{D}^{k*}(x-x_1, y+x_1, b-x_1; 1,1,1,t,\theta) + v - u \\
&= \alpha_0 + \sum_{n=2}^{N}\alpha_n(x_n - x_1) + \sum_{m=1}^{M}\beta_m(y_m + x_1) + \sum_{j=1}^{J}\lambda_j(b_j - x_1) + \frac{1}{2}\sum_{n=2}^{N}\sum_{n'=2}^{N}\alpha_{nn'}(x_n - x_1)(x_{n'} - x_1) \\
&\quad + \frac{1}{2}\sum_{m=1}^{M}\sum_{m'=1}^{M}\beta_{mm'}(y_m + x_1)(y_{m'} + x_1) + \frac{1}{2}\sum_{j=1}^{J}\sum_{j'=1}^{J}\lambda_{jj'}(b_j - x_1)(b_{j'} - x_1) \\
&\quad + \sum_{n=2}^{N}\sum_{m=1}^{M}\gamma_{mn}(y_m + x_1)(x_n - x_1) + \sum_{n=2}^{N}\sum_{j=1}^{J}a_{jn}(b_j - x_1)(x_n - x_1) + \sum_{m=1}^{M}\sum_{j=1}^{J}c_{jm}(b_j - x_1)(y_m + x_1) \\
&\quad + \delta_1 t + \frac{1}{2}\delta_2 t^2 + \sum_{n=2}^{N}\psi_n t(x_n - x_1) + \sum_{m=1}^{M}\mu_m t(y_m + x_1) + \sum_{j=1}^{J}c_j t(b_j - x_1) + \varepsilon \qquad (2)
\end{aligned}
$$

where $\theta = (\alpha, \beta, \lambda, \gamma, a, c, \delta, \psi, \mu, c)$ is a vector of parameters to be estimated and $\varepsilon = v - u$ is the composed error term. Here and henceforth, $\overrightarrow{D}^*(\cdot)$ signifies the translated DDF that will be estimated later in our empirical study. In addition, $u = \overrightarrow{D}_T^*(x,y,b;1,1,1,t,\theta)$ is treated as a non-negative random variable, reflecting technical inefficiency of the firm under consideration, and v is a two-sided, normally distributed error with a mean of zero and a constant variance σ_v^2, which is traditionally assumed to be independent of *u*. The DDF of (2) must also satisfy the symmetrical conditions, i.e., $\alpha_{nn'} = \alpha_{n'n}$, $\beta_{mm'} = \beta_{m'm}$ and $\lambda_{jj'} = \lambda_{j'j}$.[1]

Similar to Battese and Coelli (1995) and Koutsomanoli-Filippaki et al. (2009), inefficiency term u is further specified as:

$$u = \alpha' z + w \geq 0 \tag{3}$$

Here, z is a set of environmental variables, α is the corresponding unknown parameters, and w is assumed to be $w \sim N\left(0, \sigma_w^2\right)$. A set of bank-level factors will be selected as the environmental variables to describe banks' technical inefficiency. Equation (3) implies that $w \geq -\alpha' z$. Equation (2) can be estimated by the maximum likelihood (ML). After obtaining all of the parameter estimates, one is able to compute the conditional expectation that serves as a point estimator for u, representing technical inefficiency, i.e.:

$$E\left(u \mid \varepsilon\right) = \alpha' z + \mu_* + \sigma_* \frac{\phi\left(\dfrac{-\alpha' z - \mu_*}{\sigma_*}\right)}{1 - \Phi\left(\dfrac{-\alpha' z - \mu_*}{\sigma_*}\right)}, \tag{4}$$

where $\mu_* = -\varepsilon \sigma_w^2 / \sigma^2$, $\sigma_*^2 = \sigma_v^2 \sigma_w^2 / \sigma^2$, $\sigma^2 = \sigma_v^2 + \sigma_w^2$, and $\varepsilon = v - w$.[2] The conditional expectation of (4) is non-negative by construction. The higher the value of $E\left(u \mid \varepsilon\right)$ is, the less technically efficient the firm is.

3.2 Metafrontier Directional Distance Function (MDDF)

A metafrontier technology set is defined by:

---

[1] A DDF must also satisfy the following three properties (the superscript k is dropped for simplicity):

(i) If $x' \geq x$, then $\vec{D}_T(x', y, b; g) \geq \vec{D}_T(x, y, b; g)$.

(ii) If $y' \geq y$, then $\vec{D}_T(x, y', b; g) \leq \vec{D}_T(x, y, b; g)$.

(iii) If $b' \geq b$, then $\vec{D}_T(x, y, b'; g) \geq \vec{D}_T(x, y, b; g)$.

[2] It can readily be shown that the conditional distribution of $w \mid \varepsilon$ is a truncated normal distribution at zero from below with a mean of μ_* and a variance of σ_*^2.

$T^m = \{(x, y, b) : x \geq 0, y \geq 0, b \geq 0,\ x$ can produce (y, b) for all firms under study$\}$.

The MDDF is then expressed as:

$$\vec{D}^m(x, y, u; g_x, g_y, g_u) = \sup\{\beta^m : (x - \beta^m g_x, y + \beta^m g_y, u - \beta^m g_u) \in T^m\} \quad (5)$$

This has similar implications to (1), but the reference set of T^k has to be replaced by T^m. O'Donnell et al. (2008) show that there exist four properties between group frontiers and the metafrontier, in which

$\vec{D}^{k*}(x - x_1, y + x_1, b - x_1; g) \leq \vec{D}^{m*}(x - x_1, y + x_1, b - x_1; g)$, for all $k = 1,\dots, K$, requires that the translated metafrontier envelops translated group frontiers. Hence, the value of group k's DDF has to be less than or equal to that of the metafrontier DDF along the prespecified direction vector g.[3] Based on this property, we refer their difference to the technology gap difference (TGD), i.e.:

$$\vec{D}^m(x, y, b; g) = \vec{D}_T^k(x, y, b; g) + TGD, \quad (6)$$

which shows that the overall inefficiency $\vec{D}^m(x, y, b; g)$, i.e., the firm's production technical inefficiency with respect to the metafrontier production technology, is equal to the sum of the firm's production technical inefficiency with respect to the group-k production technology and TGD. Term TGD displays the gap between the translated metafrontier and translated group-k frontier and is non-negative by construction. It depends on the accessibility and extent of adoption of the available potential production technology. The larger the value of TGD is, the less advanced the technology is adopted by firms of group k, and vice versa. It is crucial to note that since the overall inefficiency measures of firms are evaluated against the metafrontier, common to all firms in different groups, they are comparable for firms operating

[3] The other theee properties are: (i) if $(x, y, b) \in T^k$ for any k, then $(x, y, b) \in T^m$; (ii) if $(x, y, b) \in T^m$, then $(x, y, b) \in T^k$ for some k; (iii) $T^m = \{T^1 \cup T^2 \cup \dots \cup T^k\}$.

under different technologies.

We are now attempting to establish a new, stochastic metafrontier based on the stochastic frontier approach (SFA), which avoids the aforementioned problems and has the desired statistical properties. Recall that the new metafrontier of Huang et al. (2011) is developed for a production function. Their model has to be modified to adapt for the case of the DDF. Using the translation property, equation (6) can be re-formulated as:

$$\vec{D}^{k^*}(x-x_1, y+x_1, b-x_1; g) = \vec{D}^{m^*}(x-x_1, y+x_1, b-x_1; g) - TGD\,. \tag{7}$$

Although the true group-*k* frontier of $\vec{D}^{k^*}(\cdot)$ is unknown, its fitted value of $\hat{\vec{D}}^{k^*}(\cdot)$ can be obtained after estimating (2) by the ML, which leads to:

$$\vec{D}^{k^*}(x-x_1, y+x_1, b-x_1; g) = \hat{\vec{D}}^{k^*}(x-x_1, y+x_1, b-x_1; g) + \tilde{V}^m, \tag{8}$$

where $\tilde{V}^m = \hat{\varepsilon} - \varepsilon$ denotes a random error arising from the estimation error of the translated group frontier from (2), which can be shown to have a mean of zero with a non-constant variance.[4] This arises from the fact that the residual $\hat{\varepsilon}$ is affected by the set of variables in the group frontiers.

Substituting (8) into (7) we yield the following estimable stochastic metafrontier:

$$\hat{\vec{D}}^{k^*}(x-x_1, y+x_1, b-x_1; g) = \vec{D}^{m^*}(x-x_1, y+x_1, b-x_1; g) + V^m - U^m, \tag{9}$$

where $V^m = -\tilde{V}^m$, $V^m - U^m$ forms the composed errors, and U^m is nothing but the TGD that is treated as if it is the inefficiency term. The presence of V^m is important, since it makes (9) in a stochastic, rather than a deterministic, context.

---

4 On the ground of (2), the following relationship must be true:

$$-x_1 = \vec{D}^{k^*}(\cdot) + \varepsilon = \hat{\vec{D}}^{k^*}(\cdot) + \hat{\varepsilon}$$

where a "^" on the top of a variable denotes the estimated value by the ML. It follows that

$$\vec{D}^{k^*}(\cdot) = \hat{\vec{D}}^{k^*}(\cdot) + \hat{\varepsilon} - \varepsilon$$

and $\hat{\varepsilon} - \varepsilon$ vanishes as the sample size goes to infinity.

According to the previous paragraph, V^m (or $\tilde{V}^m$) is not independently and identically distributed (i.i.d.) and is obviously correlated with ε of the group frontier. The presence of heteroscedasticity does not influence consistency property of the ML estimators, but biases the estimated covariance matrix of the coefficients. The method developed by White (1982) should be applied to correct for the estimated covariance matrix and the so-derived estimates are referred to as quasi-maximum likelihood estimates in the literature. Also see, for example, Johnston and DiNardo (1992), page 428-430. We will show both original and corrected standard errors of the parameter estimates of the metafrontier in Section V.

Note that U^m can also be linked with a set of environmental variables like (3), which is infeasible if the programming technique is adopted as suggested by Battese et al. (2004) and O'Donnell et al. (2008). To appropriately characterize the differences of the TGR among countries, we will choose country-level factors as the environmental variables, as opposed to bank-level factors relating to *u*'s of group frontiers. This implicitly assumes that U^m of the metafrontier is unrelated with *u* of the group frontier. The assumption appears to be reasonable due to the fact that the two measures have distinct attribute. Recall that U^m represents the gap between the metafrontier, fromed by all groups, and group frontiers, while *u* evaluates managerial incapabilities of banks of a particular group.

The functional form of the translated MDDF ($\overrightarrow{D}^{m*}$) in (9) is analogously specified to (2) and the TGD is estimated by formula (4). It is interesting to note that our approach permits the estimated group frontier to exceed the metafrontier, i.e.: $\hat{\overrightarrow{D}}^{k*}(x-x_1, y+x_1, b-x_1; g) \geq \overrightarrow{D}^{m*}(x-x_1, y+x_1, b-x_1; g)$, due to the presence of the error (V^m) from estimating $\overrightarrow{D}^{k*}(x-x_1, y+x_1, b-x_1; g)$. However, the metafrontier must always exceed the true group frontier, i.e.,

$\overrightarrow{D}^{k*}(x - x_1, y + x_1, b - x_1; g) \leq \overrightarrow{D}^{m*}(x - x_1, y + x_1, b - x_1; g)$.

Figure 1 illustrates the MDDF model. At given input and output levels, say, x_1 and y_1, the observed point A relative to the projected metafrontier point A‴ consists of three components: the technology gap difference, $TGD = \overrightarrow{D}^{m*}(\cdot) - \overrightarrow{D}^{k*}(\cdot)$, the firm's technical inefficiency between points A and A′, estimated by $E(u \mid \varepsilon)$ of (4), and the random noise component *v* of (2) between points A′ and A″, i.e.:

$$A = A''' - TGD - v - u, \quad (10)$$

or equivalently:

$$A''' - A = TGD + u + v. \quad (11)$$

It should be emphasized that, although both the technology gap difference TGD and the firm's production inefficiency are non-negative, the translated metafrontier $\overrightarrow{D}^{m*}$ does not necessarily envelop all firms' observed production at point A. The unrestricted difference in (11) distinguishes the metafrontier model using the SFA from the DEA due to the presence of the random noise component *v*.

[Insert Figure 1 Here]

4. Data Description

We compile unbalanced panel data covering 1995-2008 from 17 CEE countries from the accounting statements of the Bankscope database.[5] The sample contains 1466 banks with a total of 6770 bank-year observations. All variables are measured in millions of US dollars and deflated by the individual consumer price indices of the sample countries with base year 2005.

According to the intermediation approach, we identify three inputs and three outputs. The input categories consist of labor (x_1), physical capital (x_2), and

[5] We exclude three countries, i.e., Albania, Belarus, and Montenegro, due to severe data unavailability.

borrowed funds (x_3).[6] Total loans (y_1) and other earning assets (y_2) are regarded as the conventional outputs. Non-interest revenue (y_3) is considered as an additional output, reflecting a bank's degree of product diversification and constituting a crutial source of revenue for modern universal banks. The inclusion of y_3 enables us to correctly describe a bank's production process and its capability at diversifying the output spectrum. Furthermore, the item of loan loss reserves is defined as the single undesirable, mainly because this item co-exists with various loans granted, which meet the property of null jointness. Appendix 1 gives detailed variable definitions together with some environmental variables.

This paper classifies the environmental variables into micro- and macro-environmental variables to reflect the different atmospheres confronted by banks. The former variables are used to explain technical inefficiencies for the group frontiers and the latter to explain technology gap differences. Following Berger et al. (1993), Mester (1993), Allen and Rai (1996), Lozano-Vivas et al. (2002), and Huang et al. (2011), we identify four micro-level variables: the ratio of equity to total assets (ETA), average ROA per year (AROA), ownership dummies, and an unlisted dummy. Three macro-level variables are defined: real GDP per capita (RGDP), population density (PD), and the Herfindahl-Hirschman Index (HHI).[7]

5. Empirical Results

5.1 Coefficient Estimates of Group Frontiers

To validate the use of MDDF, it is crucial to test the null hypothesis that the

[6] The entry for the number of employees is missing for many sample banks. Although the item of personnel expense is available, it is missing entirely in Bosnia and Bulgaria for 1995-1997, in Serbia for 1995-1999, and in Poland for 1995-1996. In addition, some countries have merely a few (less than three) observations on this variable for several years. The item of total assets net of fixed assets is instead used as a proxy for the number of employees. Altunbas et al. (2000, 2001), Weill (2004), and Fries and Taci (2005), to mention a few, utilize the same definition for labor.

[7] The variable of density of demand for deposits is used by several previous works. Unfortunately, this variable is not available in Serbia and hence is overlooked here.

banking systems among countries undertake the same technology. If the hypothesis is not rejected, then researchers can simply pool the data from different countries and estimate a common frontier. There is no need to establish a MDDF.

Following Battese et al. (2004), the likelihood-ratio (LR) test statistic $L = -2\{\ln(L_1) - \ln(L_2)\}$ is computed, where $\ln(L_1)$ = -30120 is the value of the likelihood function for the stochastic DDF estimated by pooling the data for all groups, and $\ln(L_2)$ = -22664 is the sum of the values of the likelihood functions for the 17 country frontiers. The value of the LR statistic is equal to 14912 and the hypothesis is decisively rejected at the 1% level of significance with 706 degrees of freedom. Banks of different countries are indeed operating under heterogenous technologies.

5.2 Group-specific Technical Inefficiency

Table 1 presents average inefficiency scores for each country over time, and mean inefficiency scores are in the last column. These measures tell us how many units of outputs and inputs (undesirables), on average, should be increased and reduced, respectively, in order to be able to produce on the efficient group frontier. A higher inefficiency score of a bank implies that the observed input-output mix of the bank deviates farther away from the group-specific frontier and that the bank is less technically efficient. It is worth mentioning that these average inefficiency scores across countries are not comparable since they are gauged against heterogeneous frontiers.

Average technical inefficiency scores in Macedonia and Estonia are the lowest and equal to 0.38 and 0.97, respectively. Macedonian banks should simultaneously decrease 0.38 units (millions of US dollars) of both inputs and the undesirable and increase 0.38 units of outputs in order to attain the efficient frontier. The measure of

0.97 for Estonian banks can be analogously explained. On the contrary, average technical inefficiency scores for Polish and Romanian banks are the highest and equal to 4.11 and 5.94, respectively.

[Insert Table 1 Here]

5.3 Empirical Results of the MDDF

Table 2 presents the parameter estimates of the MDDF, in which more than one half of the parameters are significantly estimated at least at the 10% level, based on uncorrected standard errors.[8] Only one of the three macro-environmental variables, i.e., HHI, is significantly estimated. Its negative coefficient estimate reflects that banks in more concentrated markets are more technically efficient. Koutsomanoli-Filippaki et al. (2009) yield similar evidence. This result can be justified using the contestable theory, proposed by Baumol (1982). When those markets under consideration become more concentrated, incumbent banks behave competitively to discourage entry; otherwise higher prices and profits will induce potential competitors to enter and to share the market. A number of works investigating transition countries, such as Mamatzakis et al. (2008), Fries and Taci (2005), and Yildirim and Philippatos (2007) reach similar findings.

[Insert Table 2 Here]

We next use the parameter estimates to compute the conditional mean of U^m in (10), which is exactly the TGD estimate. Table 3 presents the average TGD measures over time and various mean inefficiency measures for each sample country. Moreover, Figure 2 draws the trend of these average TGD measures. The measure falls from 1996 to 1998 and then rises until 2003, or the year before some of the sample countries joined the EU. The measure goes down in the first two years after entering

[8] There are merely 15 estimates attain statistical significance on the ground of corrected standard errors. This confirms that the composed error is indeed heteroskedastic, which causes the original standard errors to be underestimated and then the t-statistics tend to lie in the critical region.

the EU, followed by three years of slight increases. Generally speaking, a representative bank's TGD measure in the CEE countries slightly worsens during the sample period, and enrollment in the EU prompts an increase in an average bank's technology somewhat.

[Insert Table 3 Here]

[Insert Figure 2 Here]

The average TGD measure is equal to 5.32, which gauges the difference between the metafrontier and the group-specific frontier. An average bank is able to produce 5.32 million US dollars of more desirables and less undesirable, respectively, and to employ 5.32 million US dollars of fewer inputs, if it adopts the potential technology to provide financial products. Latvia has the lowest mean TGD (2.68), followed by Slovenia (2.79) and Moldova (3.00), while Czech Republic (17.77), Serbia (13.91), and Romania (10.47) are at the other end of the spectrum. It is noticeable that most of the countries have higher average TGDs than their average technical inefficiency measures, with the exception of Slovenia. This implies that the main source of inefficiency comes from the failure of our sample banks to undertake the potential technology, instead of managerial inabilities. Bank managers are suggested to adopt new innovations swiftly to enhance their production technology in such a way as to be able to produce on the metafrontier. By doing so, their outputs can be largely increased, accompanied by a decrease in both inputs and the undesirable output.

Figure 3 depicts the scatter diagram for each country with the horizontal and vertical axes being the mean values of the group-specific technical inefficiency score and TGD, respectively. Countries located at the lower-left quadrant reflect that their banks outperform those of the remaining countries in the other three quadrants on average, because the former have a smaller average inefficiency score and a narrower average technology gap. In this regard, banks in Latvia, Bosnia, Bulgaria, Estonia, Croatia, Hungary, Lithuania, Moldova, Macedonia, Slovakia, and Ukraine perform relatively well.

The average technical inefficiency of Romania's banks stands the highest, along with the third highest average TGD, indicating that their managerial abilities and production technology have large room for improvement. Banks in Poland, Russia, and Slovenia have worse technical efficiency measures, but adopt advanced production technology, while the reverse is true for banks in Czech Republic and Serbia. The two countries' banks have better managerial abilities, but undertake less sophisticated technology.

[Insert Figure 3 Here]

6. Concluding Remarks

The current paper has applied the MDDF to compute and compare production efficiencies of banks in 17 CEE countries, in which the banking industry of each country is assumed to have potential access to the same technology, but each bank chooses to operate on a different part of technology frontier. The directional distance function appears to be a better choice for estimating banking efficiency, since it allows for gauging a bank's efficiency from the orientations of inputs, outputs, and undesirables at the same time. As the undesirables - loan loss reserves - are jointly produced with some desirables - various loans - and the disposal of the undesirables requires the use of resources and adversely affects the production of desirables, it is suggested that researchers include the undesirables in their econometric models in order to appropriately characterize a bank's production process, as well as to correctly measure its technical efficiency. Moreover, the employment of the MDDF enables the technology gap to be evaluated for banks under different technologies relative to the potential technology available to the industry as a whole in the framework of the stochastic frontier approach, as opposed to the programming technique proposed by Battese et al. (2004). One of the advantages of our MDDF is that the technology gap can be further related to a group of environmental variables, which is infeasible in the context of programming techniques.

Evidence is found to verify that the banking industries of the 17 CEE countries do indeed adopt different technologies. This justifies the validity of the MDDF in the comparison of technical efficiencies among groups. Some of the environmental variables are found to have significant impacts on the group frontiers and the metafrontier, confirming the usefulness of the stochastic metafrontier model.

Our empirical study shows that the average TGDs substantially vary across countries and exceed average technical inefficiency scores in most countries, while those mean TGDs present no clear trend during the sample period. Bank managers should promote their production technology by quickly responding to financial innovations in such a way as to shift their group frontiers closer to the metafrontier. As the average technical inefficiency score is relatively small to the average TGD of the same country, managerial inability appears to be less of an issue.

The production of undesirables is almost inevitable in many industries, such as manufacturing and banking sectors, and it requires the disposing of consuming resources. The exclusion of undesirables from the model is apt to mislead the subsequent results. Therefore, using the directional distance function by the current paper is more preferable. This is confirmed in Subsection 5.4, where the model ignoring the undesirables tends to underestimate the technical inefficiency scores.

For future research studies, our MDDF can be extended to measure and compare productivity change for banks in different countries under the framework of the Luenberger productivity indicator. Since these indicators of different groups are evaluated relative to the same metafrontier, they are comparable and able to provide insightful information, or more specifically, whether productivity change is driven by technical efficiency change or technological change has different implications to managers, business consultants, and regulatory authorities.

References

〔1〕 Allen, L. and A. Rai (1996). Operational efficiency in banking: an international comparison, *Journal of Banking and Finance* 20, 655-672.

〔2〕 Altunbas, Y., Gardener, E. P. M., Molyneux, P., and Moore, B. (2001), Efficiency in European Banking. *European Economic Review* 45, 1931-1955.

〔3〕 Ariss, R. T. (2010). On the implications of market power in banking: Evidence from developing countries. *Journal of Banking & Finance* 34, 765-77.

〔4〕 Battese, G. E., and Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics* 20, 325-332.

〔5〕 Battese, G. E. and Rao, D. S. P. (2002). Technology gap, efficiency, and a stochastic metafrontier function. *International Journal of Business and Economics* Vol. 1, No. 2, 87-93.

〔6〕 Battese, G. E., Rao, D. S. P., and O'Donnell, C. J. (2004). A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. *Journal of Productivity Analysis* 21, 91-103.

〔7〕 Baumol, W. J. (1982). Contestable Markets: An Uprising in the Theory of Industry Structure, *American Economic Review*, 72, 1-15.

〔8〕 Berger, A. N., G. A. Hancock, and D. B. Humphrey (1993). Bank efficiency derived from the profit function, *Journal of Banking and Finance* 17, 317-347.

〔9〕 Berger, A. N., Hasan, I., and Zhou, M. (2009). Bank ownership and efficiency in China: What will happen in the world's largest nation? *Journal of Banking & Finance* 33, 113-130.

〔10〕Bolt, W., Humphrey, D. (2010). Bank competition efficiency in Europe: A frontier approach. *Journal of Banking and Finance* 34, 1808–1817.

〔11〕Bonin, J., Hassan, I., Wachtel, P. (2005). Bank performance, efficiency and ownership in transition countries. *Journal of Banking and Finance* 29, 31-53.

〔12〕Bos, J.W.B., Schmiedel, H. (2007). Is there a single frontier in a single European banking market? *Journal of Banking and Finance* 31, 2081–2102.

〔13〕Caner, S., Kontorovich, V. (2004). Efficiency of the Banking Sector in the Russian Federation with International Comparison. *Экономический журнал ВШЭ* 3, 357-375.

〔14〕Chen, X., Skully, M., and Brown, K. (2005). Banking efficiency in China: Application of DEA to pre- and post-deregulation eras: 1993-2000. *China Economic Review* 16, 229-245.

〔15〕Chung, Y. H., Färe, R., and Grosskopf, S. (1997). Productivity and undesirable outputs: A directional distance function approach. *Journal of Environmental Management* 51, 229-240.

〔16〕Cohen, W.M. and Levinthal, D.A. (1989). Innovation and learning: The two faces of R&D. *Economic Journal* 99, 569–596.

〔17〕Färe, R., Grosskopf, S. (2000). Theory and application of directional distance functions. *Journal of Productivity Analysis* 13, 93–103.

〔18〕Färe, R., Grosskopf, S. (2004). Modeling undesirable factors in efficiency evaluation: Comment. *European Journal of Operational Research* 157, 242-245.

〔19〕Färe, R. and S. Grosskopf (2005). New directions: efficiency and productivity. Kluwer Academic Publishers, Boston, U.S.A.

〔20〕Färe, R., Grosskopf, S., and Carl A. Pasurka, Jr. (2001). Accounting for air pollution emissions in measures of state manufacturing productivity growth. *Journal of Regional Science* 41: 3*,* 381-409.

〔21〕Färe, R., Grosskopf, S., and Hernandez-Sancho, F. (2004). Environmental performance: an index number approach. *Resource and Energy Economics* 26, 343-352.

〔22〕Färe, R., Grosskopf, S., Lovell, C. A. K., and Yaisawarng, S. (1993). Derivation of shadow prices for undesirable outputs: A distance function approach. *The Review of Economics and Statistics* 75: 2, 374-380.

〔23〕Färe, R., S. Grosskopf, and W. Weber (1997), The effect of risk-based capital requirements on profit efficiency in banking, Discussion paper series No. 97-12, Department of Economics, Southern Illinois University at Carbondale.

〔24〕Färe, R., Grosskopf, S., Noh, D., Weber, W. (2005). Characteristics of a polluting technology. *Journal of Econometrics* 126, 469-492.

〔25〕Fries, S., Taci, A. (2005). Cost efficiency of banks in transition: Evidence from 289 banks in 15 post-communist countries. *Journal of Banking and Finance* 29, 55-81.

〔26〕Fukuyama, H., Weber, W. L. (2008). Japanese banking inefficiency and shadow pricing. *Mathematical and Computer Modelling* 48, 1854-1867.

〔27〕Fu, X., Heffernan, S. (2009). The effects of reform on China's bank structure and performance. *Journal of Banking & Finance* 3, 39-52.

〔28〕Garcia-Herrero, A., Gavila, S., and Santabarbara, D. (2009). What explains the low profitability of Chinese banks? *Journal of Banking & Finance* 33*,* 2080-2092.

〔29〕Hasan, I., Koetter, M., and Wedow, M. (2009). Regional growth and finance in Europe: Is there a quality effect of bank efficiency? *Journal of Banking &*

Finance 33, 1446-1453.

〔30〕Hasan, I., Marton, K. (2003). Development and efficiency of the banking sector in a transitional economy: Hungarian experience. *Journal of Banking & Finance* 27, 2249-2271.

〔31〕Hayami, Y. (1969). Sources of agricultural productivity gap among selected countries. *American Journal of Agricultural Economics* 51, 564-575.

〔32〕Hayami, Y., Ruttan, V. W. (1970). Agricultural productivity differences among countries. *The American Economic Review* 60, 895-911.

〔33〕Hayami, Y., Ruttan, V. W. (1971). *Agricultural Development: An International Perspective*, Baltimore: Johns Hopkins University Press.

〔34〕Huang, T. H., Chiang, L. C. and Chen, K. C. (2011). An Empirical Study of Bank Efficiencies and Technology Gaps in European Banking. *The Manchester School*, 79, 839-860.

〔35〕Huang, C. J., Huang, T. H. and Liu, N. H. (2011). A New Approach to Estimating the Metafrontier Production Function Based on a Stochastic Frontier Framework. Manuscript.

〔36〕Huang, T. H., Shen, C. H., Chen, K. C. and Tseng, S. J. (2011). Measuring Technical and Allocative Efficiencies for Banks in the Transition Countries Using the Fourier Flexible Cost Function. *Journal of Productivity Analysis* 35, 143-157.

〔37〕Isik, I. and Hassan, M. (2003). Efficiency, ownership and market structure, corporate control and governance in the Turkish banking industry. *Journal of Business Finance and Accounting* 30, 1363−1421.

〔38〕Johnston, J. and DiNardo, J. (1992). *Econometric Methods*, fourth edition, McGraw-Hill companies, Inc., New York.

〔39〕Kaneko, S., Managi, S. (2007). Environmental productivity in China.

Economics Bulletin 17, 1-10.

〔40〕Kontolaimou, A.and Tsekouras, K. (2010). Are cooperatives the weakest link in European banking? A non-parametric metafrontier approach. *Journal of Banking & Finance* 34, 1046-1057.

〔41〕Koutsomanoli-Filippaki, A., Margaritis, D., and Staikouras, C. (2009). Efficiency and productivity growth in the banking industry of Central and Eastern Europe. *Journal of Banking & Finance* 33, 557-567.

〔42〕Li, Y., Hu, J. L. and Liu, H. W. (2009). Non-performing Loans and Bank Efficiencies: An Application of the Input Distance Function Approach. *Journal of Statistics and Management Systems* 12, 435-450.

〔43〕Lin, X., Zhang, Y. (2009). Bank ownership reform and bank performance in China. *Journal of Banking & Finance* 33, 20-29.

〔44〕Lozano-Vivas, A., J. T. Pastor and J. M. Pastor (2002). An efficiency comparison of European banking systems operating under different environmental conditions, *Journal of Productivity Analysis* 18, 59-77.

〔45〕Mamatzakis, E., Staikouras, C., and Koutsomanoli-Filippaki, A. (2008). Bank efficiency in the new European Union member states: Is there convergence? *International Review of Financial Analysis* 17, 1156-1172.

〔46〕McMullen, B. S., Noh, D. W. (2007). Accounting for emissions in the measurement of transit agency efficiency: A directional distance function approach. *Transportation Research Part D* 12, 1-9.

〔47〕Mester, L. J. (1993). Efficiency in the savings and loan industry, *Journal of Banking and Finance* 17, 267-286.

〔48〕O’Donnell, C. J., Rao, D. S. P., and Battese, G. E. (2008). Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. *Empirical Economics* 34, 231-255.

〔49〕Park, K. H., Weber, W. L. (2006). A note on efficiency and productivity growth in the Korean Banking Industry, 1992-2002. *Journal of Banking & Finance* 30, 2371-2386.

〔50〕Picazo-Tadeo, A. J., Reig-Martínez, E., and Hernández-Sancho, F. (2005). Directional distance functions and environmental regulation. *Resource and Energy Economics* 27, 131-142.

〔51〕Sathye, M. (2003). Efficiency of banks in a developing economy: The case of India. *European Journal of Operational Research* 148, 662-671.

〔52〕Santosh Kumar Das. (2010). Financial liberalization and banking sector efficiency: The Indian experience. 12th Money and Finance Conference, 11-12 12th March 2010 IGIDR, Mumbai.

〔53〕Staikouras, C., Mamatzakis, E., and Koutsomanoli-Filippaki, A. (2008). Cost efficiency of the banking industry in the South Eastern European region. *Int. Fin. Markets, Inst. and Money* 18, 483-497.

〔54〕Staub, R. B., Geraldo da Silva e Souza, and Tabak, B. M. (2010). Evolution of bank efficiency in Brazil: A DEA approach. *European Journal of Operational Research* 202, 204-213.

〔55〕Turk-Ariss, R. (2010). On the implications of market power in banking: Evidence from developing countries. *Journal of Banking and Finance* 34, 765-775.

〔56〕Watanabe, M., Tanaka, K. (2004). Efficiency analysis of Chinese industry: A directional distance function approach. *Energy Policy* 35, 6323–6331.

〔57〕Weill, L. (2004). Measuring cost efficiency in European banking: A comparison of frontier techniques. *Journal of Productivity Analysis* 21, 133-152.

〔58〕White, H. (1982). Maximum likelihood estimation of misspecified models.

Econometrica, 50, 1-16.

〔59〕Yildirim, S., Philippatos, G. (2007). Efficiency of banks: Recent evidence from the transition economies of Europe, 1993-2000. *European Journal of Finance* 13,123-143.

〔60〕Yu, M. M. (2004). Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environmental factors. *Journal of Air Transport Management* 10, 295-303.

Table 1. Average group-specific technical inefficiency over time

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Bosnia (BA)	NA	1.50	0.74	1.28	1.10	1.16	1.23	0.90
Bulgaria (BG)	0.95	0.86	2.07	1.30	1.37	1.66	1.52	0.91
Czech (CZ)	1.39	10.04	1.97	6.25	5.77	2.97	1.97	2.88
Estonia (EE)	0.96	1.48	0.82	1.01	0.70	1.01	0.47	0.71
Croatia (HR)	2.44	1.57	1.27	1.27	2.32	2.03	1.98	1.93
Hungary (HU)	3.75	2.71	2.21	1.94	1.53	1.41	1.08	0.70
Lithuania (LT)	0.83	1.60	1.12	1.22	1.40	0.80	1.01	0.80
Latvia (LV)	1.73	1.24	0.89	2.41	2.20	1.27	1.35	1.41
Moldova (MD)	2.71	2.82	2.58	2.83	2.54	2.61	2.49	2.75
Macedonia (MK)	0.58	0.26	0.15	0.34	0.31	0.35	0.44	0.27
Poland (PL)	1.57	1.06	2.79	2.98	3.39	3.83	8.44	18.00
Romania (RO)	29.08	11.37	0.51	0.96	9.48	2.79	5.17	4.38
Serbia (RS)	1.28	1.92	2.21	1.43	3.02	2.54	2.99	2.30
Russia (RU)	19.36	15.01	18.63	10.46	5.49	6.33	5.19	4.61
Slovenia (SI)	5.04	2.46	2.54	1.95	2.38	3.04	9.64	5.04
Slovakia (SK)	1.03	3.98	2.70	3.01	0.83	0.67	2.89	1.18
Ukraine (UA)	0.88	0.90	0.45	0.48	0.48	1.84	1.47	1.27
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**Mean**	
Bosnia (BA)	1.31	1.47	1.43	1.48	1.25	1.21	***1.24***	
Bulgaria (BG)	0.61	1.99	1.73	2.03	1.62	1.59	***1.53***	
Czech (CZ)	3.17	1.80	1.70	1.31	1.05	1.68	***2.90***	
Estonia (EE)	1.28	0.37	1.03	0.75	0.12	2.79	***0.97***	
Croatia (HR)	1.52	1.84	2.62	3.08	1.98	2.23	***1.98***	

Hungary (HU)	1.20	1.20	2.32	4.91	1.75	0	***2.13***
Lithuania (LT)	0.81	1.00	0.95	1.14	0.91	1.95	***1.09***
Latvia (LV)	1.47	1.46	0.98	0.86	1.69	3.84	***1.61***
Moldova (MD)	2.45	2.63	2.54	2.54	2.59	2.56	***2.58***
Macedonia (MK)	0.88	0.33	0.30	0.27	0.36	0.53	***0.38***
Poland (PL)	8.33	5.64	5.58	1.67	2.88	4.63	***4.11***
Romania (RO)	4.40	3.61	7.18	9.04	11.10	5.49	***5.94***
Serbia (RS)	3.23	2.48	2.48	2.09	2.67	3.97	***2.68***
Russia (RU)	4.74	3.13	2.72	2.99	3.51	3.80	***3.66***
Slovenia (SI)	5.41	7.71	3.18	3.43	3.07	3.77	***3.82***
Slovakia (SK)	0.61	1.45	1.94	1.26	1.30	1.35	***1.79***
Ukraine (UA)	1.24	1.73	2.40	2.22	2.21	4.36	***2.03***

Table 2. Parameter estimates of the MDDF

Variables	Parameter Estimates	Variables	Parameter Estimates	Variables	Parameter Estimates	Variables	Parameter Estimates
Intercept	1.78E-01 (1.00E+00) [1.81E-1]	x_2^2	-1.94E-05 (6.05E-06)*** [1.73E-05]	y_3x_2	4.36E-05 (1.84E-05)** [6.05E-05]	ty_2	1.73E-02 (4.89E-04)*** [3.21E-03]***
y_1	-3.90E-01 (8.08E-03)*** [4.66E-01]	x_3^2	3.04E-05 (6.40E-06)*** [3.03E-04]	y_3x_3	-1.12E-05 (1.46E-06)*** [3.60E-06]***	ty_3	-6.04E-04 (2.25E-03) [6.54E-03]
y_2	-3.85E-01 (2.68E-03)*** [2.23E-02]***	b^2	3.16E-05 (1.03E-06)*** [6.51E-05]	x_2x_3	1.14E-05 (7.02E-06)* [5.16E-05]	tx_2	2.25E-02 (1.07E-03)*** [1.10E-02]**
y_3	-2.39E-02 (8.75E-04)*** [6.42E-02]	y_1y_2	-2.37E-05 (4.61E-06)*** [9.71E-06]**	y_1b	-2.18E-05 (9.86E-07)*** [4.27E-05]	tx_3	-6.39E-03 (8.04E-04)*** [1.41E-02]
x_2	-1.74E-01 (2.04E-02)*** [1.03E-01]*	y_1y_3	8.65E-06 (8.76E-07)*** [2.32E-06]***	y_2b	1.88E-05 (4.24E-06)*** [5.97E-06]***	tb	2.59E-02 (1.09E-03)*** [1.24E-02]**
x_3	9.64E-02 (2.97E-02)*** [3.99E-01]	y_2y_3	1.90E-05 (5.86E-07)*** [7.77E-06]**	y_3b	2.17E-06 (1.50E-05) [5.05E-05]	Intercept	-3.50E+02 (1.00E+00)*** [3.12E-02]***
b	2.47E-05 (3.53E-06)*** [3.29E-05]	y_1x_2	-4.61E-05 (1.18E-05)*** [3.22E-05]	x_2b	-4.85E-05 (1.02E-05)*** [3.56E-05]	RGDP	-2.16E-01 (9.98E-01) [7.75E-01]

y_1^2	-2.66E-05	y_1x_3	9.44E-06	x_3b	1.39E-05	PD	1.72E-04
	(3.40E-06)***		(8.67E-06)		(9.73E-06)*		(2.03E-04)
	[1.23E-05]**		[3.45E-05]		[2.70E-05]		[2.18E-04]
y_2^2	2.00E-06	y_2x_2	-3.58E-05	t	6.43E-01	HHI	-2.46E-02
	(7.03E-06)		(1.01E-05)***		(9.04E-01)		(1.91E-03)***
	[1.68E-05]		[2.54E-05]		[2.62E+00]		[1.57E-02]
y_3^2	7.26E-07	y_2x_3	2.08E-05	t^2	-2.76E-02	σ^2	2.36E+03
	(1.31E-06)		(1.07E-06)***		(1.29E-03)***		(1.00E+00)***
	[7.76E-06]		[2.65E-05]		[3.58E-03]***		[3.64E+02]***
likelihood	-0.3292E+05			ty_1	1.55E-02	gamma	9.73E-01
					(8.68E-04)***		(1.33E-02)***
					[1.59E-02]		[4.28E-02]***

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.
Numbers in brackets are corrected standard errors suggested by White (1982).

Table 3. Average TGD over time and various inefficiency estimates across countries

Year	TGD	Country	TGD	Group-specific Ineff.	Overall Ineff.
1995	4.87	BA	7.58	1.24	8.82
1996	5.89	BG	5.65	1.53	7.18
1997	4.75	CZ	17.77	2.9	20.67
1998	3.21	EE	5.22	0.86	6.08
1999	3.77	HR	5.12	1.98	7.10
2000	4.44	HU	5.30	2.13	7.43
2001	5.06	LT	6.76	1.09	7.85
2002	4.56	LV	2.68	1.61	4.29
2003	6.43	MD	3.00	2.58	5.58
2004	5.45	MK	6.16	0.38	6.54
2005	4.92	PL	8.44	4.11	12.55
2006	5.29	RO	10.47	5.94	16.41
2007	5.64	RS	13.91	2.68	16.59
2008	6.09	RU	4.34	3.66	8.00
Average	5.32	SI	2.79	3.82	6.61
		SK	5.70	1.79	7.49
		UA	5.90	2.03	7.93

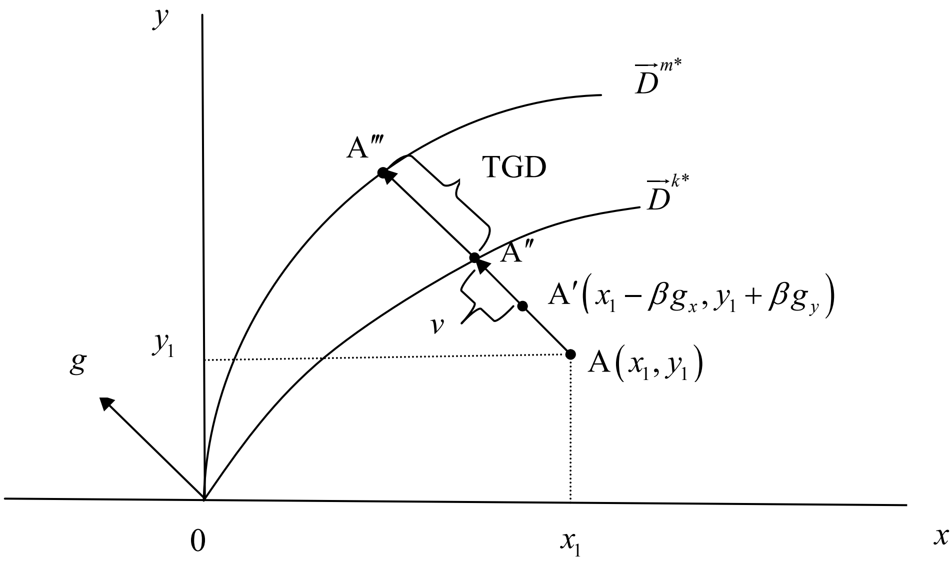

Figure 1. Metafrontier directional distance function

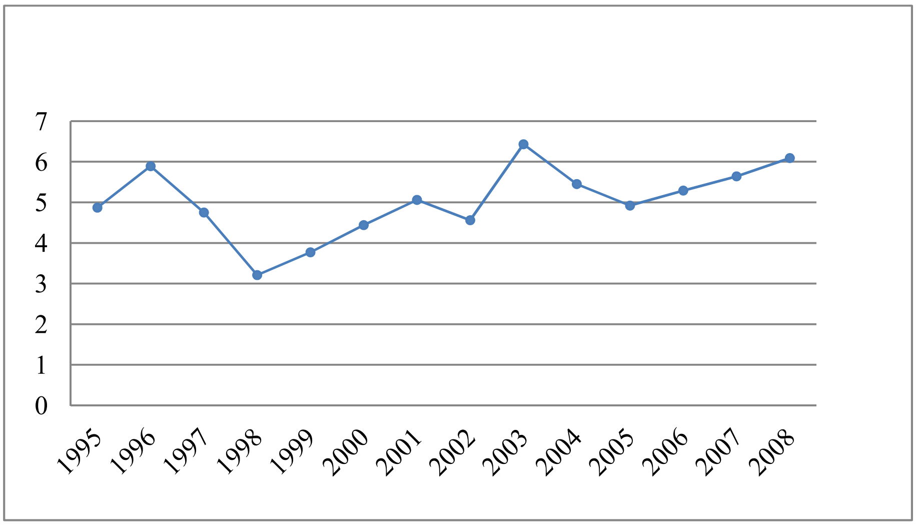

Figure 2. The trend of average TGD measures

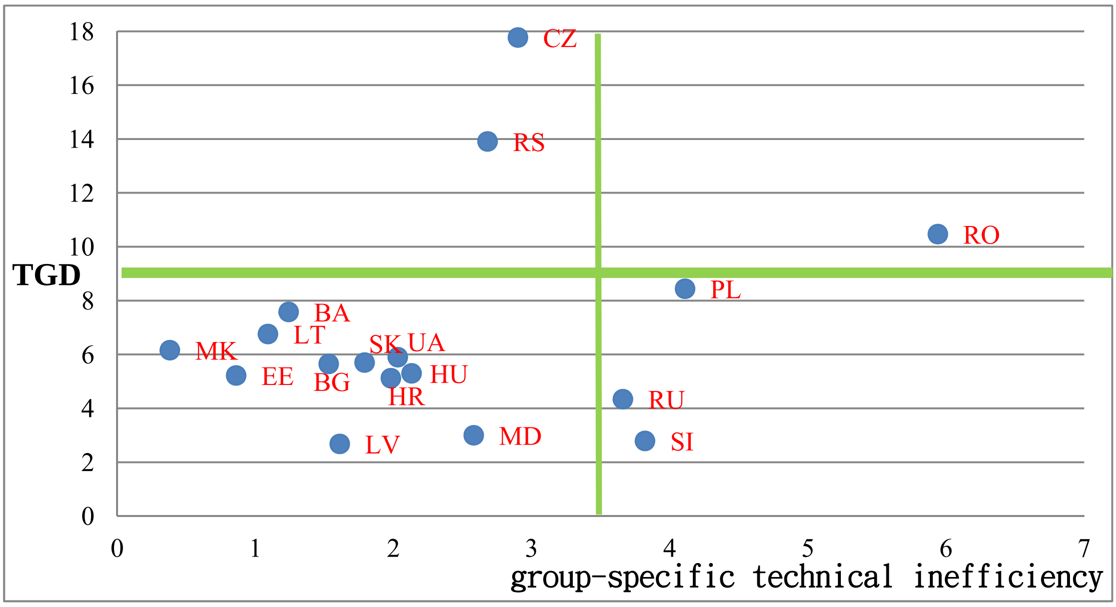

Figure 3. Scatter diagram

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

☐ ☑達成目標

☐ 未達成目標（請說明，以 100 字為限）

☐ 實驗失敗

☐ 因故實驗中斷

☐ 其他原因

說明：

本結案報告內容，與原計畫內容完全相符，且達成預期目標。例如，

(i) 為凸顯考慮非意欲產出的重要性，同時估計有無非意欲產出的方向距離函數，進而衡量和比較效率估計值的差異。

(ii) 使用 Bankscope 資料庫，收集中、東歐各國銀行業縱橫資料，樣本銀行家數高達 1466，總樣本數為 6770 筆。

(iii) 採用兩個階段估計步驟，第一階段運用 SFA 模型個別估計每個國家的群組邊界，得到迴歸係數與技術效率估計值。第二階段合併所有國家樣本資料以及迴歸係數估計值，仍然使用 SFA 模型得到共同邊界函數的估計值，從而可以計算技術缺口比率，做為計算和比較各國銀行業生產效率的依據。此時，技術缺口比率可與表為環境變數的函數，探討兩者間之關係。

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 ☑未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 □無

技轉：□已技轉 □洽談中 □無

其他：(以 100 字為限)

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

過去探討跨國間銀行業效率與生產力的實證研究，一者假設各國銀行廠商的生產技術相同，將各國銀行資料合併後進行估計，此做法忽略不同國家間之差異；或者雖假設各國銀行採用不同生產技術，但未能在相同基礎上進行比較。Battese et al. (2004) 提出的共同生產函數雖然成功的解決上述問題，但是，在第二階段使用數理規劃法，造成前後兩階段方法不一致。本研究針對第二階段從事改良，建構共同邊界隨機方向距離函數，使得前後兩階段方法趨於一致，技術缺口比率也可與環境變數連結，進一步探討影響技術缺口比率的因素有哪些。方向距離函數另一項優點，可將非意欲產出—不良放款--納入模型中，較能更正確反映銀行業實況。

針對中、東歐各國商業銀行近十四年的縱橫資料 (panel data)，深入分析和比較這各國銀行業生產效率。發現距離函數中若忽略環境變數，易造成低估技術效率和技術缺口比率。另外，迴歸模型中若忽略非意欲產出，也導致效率值的低估。如此，可以深入了解中、東歐各國商業銀行歷經民主化與自由化的洗禮，它們的生產效率是否有所提升，做為我國政府擬訂相關政策時的參考。

本研究之成果具有實證應用價值，經改寫後可投稿至國外學術性期刊，具有發表之潛力。

行政院國家科學委員會補助國內專家學者出席國際學術會議報告

101 年 8 月 8 日

報告人姓名	黃台心	服務機構及職稱	國立政治大學 金融學系
會議時間 地點	2006 年 7 月 24 – 27 日 泰國　曼谷	本會核定補助文號	併入專題研究計畫編號 NSC-100-2410-H-004-072
會議名稱	（中文） 2012 年亞太地區生產力國際學術研討會 （英文） 2012 Asian Pacific Productivity Conference (APPC2012)		
發表論文題目	（中文） 運用投入面距離函數衡量中國前100大會計師事務所的技術效率 （英文）An Evaluation of Technical Efficiencies for the Top 100 Public Accounting Firms in China Using Input Distance Functions		

報告內容應包括下列各項：

一、參加會議經過

全世界研究生產力與效率的領域，共有三大國際研討會，亞太地區國際生產力學術研討會為其中之一，每兩年在亞太地區各國輪流舉辦；另外兩個為歐洲地區和北美地區國際生產力學術研討會。前次 APPC2010 會議，在台灣由中央研究院經濟學研究所主辦。本次 APPC2012 研討會議，自 7 月 24 日至 7 月 27 日止，共計四天，第一天主要給博士生發表論文，由學術先進給與建議；後三天為正式研討會，共有超過 70 篇的論文於會議中宣讀，穿插三場 keynote session。

二、與會心得

參與發表之論文品質均十分優異，藉由參與這種大型國際學術研討會，一方面可掌握相同領域學者最新研究方向，相互切磋；另一方面，吸取他人之長處，激發新的研究方向。

本次主辦單位邀請的 keynote speaker 之一—Professor Nancy Chau，她的演講內容，將探討生產效率的方向距離函數結合國際貿易理論，是相當有開創性的研究，擴大效率與生產力領域的適用範圍，值得後進者跟進探討。

參與本次學術研討會過程中，也與來自日本學者討論 Network DEA 的相關研究和最新發展，獲益良多。

三、考察參觀活動(無是項活動者省略)

無

四、建議

泰國今年是第一次主辦 APPC 學術研討會，參加的學者還有成長空間。此外，曼谷市區的交通狀況也有大幅改善空間。

五、攜回資料名稱及內容

Book of Abstract

六、其他

無

接受函

From: APPC 2012 <appc2012@ymail.com>
To: wangmei@mail.sju.edu.tw
Date: Sun, 08 Apr 2012 17:41:13 +0100
Subject: Acceptance for oral presentation

Dear colleague,

I am pleased to inform you that your abstract "An Evaluation of Technical Efficiencies for the Top 100 Public Accounting Firms in China Using Input Distance Functions", reference 0144 has been accepted as an oral presentation at APPC 2012.

Guidelines for presentations will shortly be posted on the conference website. Please register for the conference to confirm your participation. Registration must be done online through the link on the conference website. May we remind you that early registration deadline is on May 31, 2012 while regular registration deadline is on June 22, 2012. Payment information will shortly be posted on the conference website. In addition, please book your accommodation immediately to reserve the room and special price. Booking form and instruction are available on the conference website.

We look forward to seeing you in KMITL, Bangkok, Thailand from 24-27 July 2012.

With best wishes,

Wirat Krasachat (KMITL, Bangkok, Thailand)
Lek Yaisawarng (Union College, New York, USA)

摘要

An Evaluation of Technical Efficiencies for the Top 100 Public Accounting Firms in China Using Input Distance Functions

Tai-Hsin Huang* Bao-Guang Chang** Hsiu-Mei Wang***

Abstract: This paper investigates the effect from a policy that expands a public accounting firm's size, enforced by China's government, on firms' technical efficiency and economies of scale. We apply and estimate a standard input distance frontier using data on the top 100 Chinese accounting firms covering 2008-2009. We find that the larger the firm size is, the more technically efficient it is, thus justifying policy enforcement. Economies of scale prevail in the top 100 accounting firms and are not exhausted, supporting that these firms keep extending their production scale to reduce their long-run average costs. Those sample firms experiencing a merger and acquisition (M&A) do not outperform firms without any merger and acquisition in terms of technical efficiency scores, possibly resulting from the short sample period, such that the beneficial effects from M&A have not been taken into account yet.

Key words: Chinese public accounting firms; input distance function; technical efficiency; returns to scale;

* Professor, Department of Money and Banking, National Chengchi University
** Professor, Department of Accounting, Tamkang University
*** Ph. D. Student, Graduate Institute of Management Sciences, Accounting Section, Tamkang University

無研發成果推廣資料

100 年度專題研究計畫研究成果彙整表

<table>
<tr><td colspan="3">計畫主持人：黃台心</td><td colspan="4">計畫編號：100-2410-H-004-072-</td></tr>
<tr><td colspan="7">計畫名稱：應用共同邊界隨機方向距離函數探討東歐國家銀行業生產效率</td></tr>
<tr><td colspan="3" rowspan="2">成果項目</td><td colspan="3">量化</td><td rowspan="2">單位</td><td rowspan="2">備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）</td></tr>
<tr><td>實際已達成數（被接受或已發表）</td><td>預期總達成數(含實際已達成數)</td><td>本計畫實際貢獻百分比</td></tr>
<tr><td rowspan="16">國內</td><td rowspan="4">論文著作</td><td>期刊論文</td><td>0</td><td>0</td><td>100%</td><td rowspan="3">篇</td><td></td></tr>
<tr><td>研究報告/技術報告</td><td>1</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>研討會論文</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>專書</td><td>0</td><td>0</td><td>100%</td><td></td><td></td></tr>
<tr><td rowspan="2">專利</td><td>申請中件數</td><td>0</td><td>0</td><td>100%</td><td rowspan="2">件</td><td></td></tr>
<tr><td>已獲得件數</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td rowspan="2">技術移轉</td><td>件數</td><td>0</td><td>0</td><td>100%</td><td>件</td><td></td></tr>
<tr><td>權利金</td><td>0</td><td>0</td><td>100%</td><td>千元</td><td></td></tr>
<tr><td rowspan="4">參與計畫人力（本國籍）</td><td>碩士生</td><td>1</td><td>0</td><td>100%</td><td rowspan="4">人次</td><td></td></tr>
<tr><td>博士生</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>博士後研究員</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>專任助理</td><td>1</td><td>0</td><td>100%</td><td></td></tr>
<tr><td rowspan="16">國外</td><td rowspan="4">論文著作</td><td>期刊論文</td><td>0</td><td>2</td><td>100%</td><td rowspan="3">篇</td><td></td></tr>
<tr><td>研究報告/技術報告</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>研討會論文</td><td>0</td><td>2</td><td>100%</td><td></td></tr>
<tr><td>專書</td><td>0</td><td>0</td><td>100%</td><td>章/本</td><td></td></tr>
<tr><td rowspan="2">專利</td><td>申請中件數</td><td>0</td><td>0</td><td>100%</td><td rowspan="2">件</td><td></td></tr>
<tr><td>已獲得件數</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td rowspan="2">技術移轉</td><td>件數</td><td>0</td><td>0</td><td>100%</td><td>件</td><td></td></tr>
<tr><td>權利金</td><td>0</td><td>0</td><td>100%</td><td>千元</td><td></td></tr>
<tr><td rowspan="4">參與計畫人力（外國籍）</td><td>碩士生</td><td>0</td><td>0</td><td>100%</td><td rowspan="4">人次</td><td></td></tr>
<tr><td>博士生</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>博士後研究員</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
<tr><td>專任助理</td><td>0</td><td>0</td><td>100%</td><td></td></tr>
</table>

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 ■未發表之文稿 □撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：（以 100 字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限）

過去探討跨國間銀行業效率與生產力的實證研究，一者假設各國銀行廠商的生產技術相同，將各國銀行資料合併後進行估計，此做法忽略不同國家間之差異；或者雖假設各國銀行採用不同生產技術，但未能在相同基礎上進行比較。Battese et al. (2004) 提出的共同生產函數雖然成功的解決上述問題，但是，在第二階段使用數理規劃法，造成前後兩階段方法不一致。本研究針對第二階段從事改良，建構共同邊界隨機方向距離函數，使得前後兩階段方法趨於一致，技術缺口比率也可與環境變數連結，進一步探討影響技術缺口比率的因素有哪些。方向距離函數另一項優點，可將非意欲產出—不良放款--納入模型中，較能更正確反映銀行業實況。

針對中、東歐各國商業銀行近十四年的縱橫資料 (panel data)，深入分析和比較這各國銀行業生產效率。發現距離函數中若忽略環境變數，易造成低估技術效率和技術缺口比率。另外，迴歸模型中若忽略非意欲產出，也導致效率值的低估。如此，可以深入了解中、東歐各國商業銀行歷經民主化與自由化的洗禮，它們的生產效率是否有所提升，做為我國政府擬訂相關政策時的參考。

本研究之成果具有實證應用價值，經改寫後可投稿至國外學術性期刊，具有發表之潛力。