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Research Article

Productivity Evaluation for Banking System in Developing Countries: DEA Malmquist Productivity Index Based on CCR, BCC, CCR-BCC (A Case Study)

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Keywords

Data envelopment analysis,
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Banking system,
CCR-BCC.

Abstract

The main goal of this paper is to evaluate bank productivity over 2015-2019 with Data Envelopment Analysis (DEA) for 30 banks from eight developing countries. The primary purpose of this study is to compare the productivities with Malmquist Productivity Index (MPI). Applying MPI can be beneficial for managers to expand their comparison and evaluation. To find the superior model, we use Charnes, Cooper and Rhodes model (CCR), or Banker, Charnes and Cooper model (BBC), combine the two aforementioned models starting with CCR model (CCR-BCC). The results indicate that the CCR-BCC model has the most productive effect during all periods compare with other suggested models in MPI. Meanwhile, BCC and CCR models are in the second and third places, respectively. We consider input-oriented for the suggested models This study overcomes with some data and methodology issues in measuring the productivity of developing countries banks and highlights the importance of inspiring increased productivity through the banking industry comparing four suggested models and the new results. The dataset was obtained from BankFocus-Bureau van Dijk database. From each country we choose the three or four biggest banks based on the total assets.

1. Introduction

Despite the unprecedented growth in the banking industry in developing countries, research on the performance and efficiency of this industry is almost challenging. Therefore, one of the aims of this study is measuring productivity levels at the banks, which are an essential topic for administrators, stockholders, and customers.

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Svitalkova [1] shows that non-parametric methods are more acceptable than parametric ones for ranking decision-making units (DMUs). Based on Wanke et al. [2], DEA is a critical non-parametric method presently applied for efficiency and productivity evaluation. This method, technologically advanced by Charnes et al. [3], is founded by a scientific way of measuring efficiency. DEA classifies the most efficient DMUs and specifies what inefficient units must do to become efficient. To clarify more, DEA shows the best observe to be recognized from an efficiency frontier [4].

Over time, it has correspondingly progressed to develop more diverse with highlighting on product diversity through novel blends and valuable formulation developments instead of cooperating quality to live only as a low-cost common substitute.

The primary purpose of this paper is based on the evaluation of productivity with MPI. We have applied the three following models to find the superior one:

- CCR_{IO} (CCR Input Oriented),
- BCC_{IO} (BCC Input Oriented),
- $CCR_{IO} - BCC_{IO}$ (CCR-BCC Input Oriented)

The rest of the paper clarifies as follows:

Part 2 distributes a careful evaluation of literature related to the calculation of productivity and stipulates the potential role of the current study. Part 3 discusses the four steps of research methodology, and evaluation of each step (step1: CCR, BCC, CCR-BCC, step2: Inputs and outputs description, step3: Evaluation in MPI, step4: Process of workshops' productivity with MPI, followed by a discussion and conclusion of the experimental consequences in part 4 and 5 respectively.

2. Background and Literature Review

Banks are crucial foundations in a country's budget and economy. Based on Tsolas and Charles [5], the banking part plays an essential role in each country; consequently, difficulties in this area are the central part of the numerous papers. Based on the importance of economic institutes, many previous articles have pursued to assess the performance of banks in various countries [6-13]. Berger and Humphrey [14], in an outstanding study, surveyed 130 pieces of training that examined 21 multiple countries to evaluate bank efficiency base on parametric and non-parametric approaches, which shows the importance of education on efficiency evaluation in bank sectors. The main purposes are to recapitulate and intially analysis experiential evaluations of financial organization efficiency and try to attain at a consent view. They find that the numerous efficiency approaches do not essentially yield constant outcomes and propose some methods that these ways might be improved to bring about results that are more accurate, and useful.

The banking industry plays a critical role in the budget and, consequently, the difficulties associated with bank performance are the focus of our literature. Most papers are inspired by aforementioned concerns, encouraged by the recent financial crisis. As such, it aims to incorporate risk into the bank efficiency and to provide a snapshot of the efficiency outline of the banking industry and, accordingly, to evaluate the banking crisis. It is perceived that various DEA models are commonly utilized in different studies to compare, rank, and evaluate energy efficiency. Thus, a comprehensive comparison of several efficiencies delivers insight into the bank's performance. This comparison is of considerable significance to banking practitioners who desire to assess productivity and efficiency at a proper step of its progression. Other related studies which mostly include DEA can be addressed through various computational and rating methods [15-25] [39,40].

In this study a unique comparing exclusive four models in MPI is applied, which eventually results in comparing several productive and unproductive DMUs. Finally, finding the superior model provide valuable information for bank managers to select the best model. Meanwhile, comparing various bank's companies from different developing countries is one of the novelties of our research, which considers large laboratories at the same time. Thus, it can be beneficial for managers to have superior evaluating, remove unrelated data, and more effective processes.

3. Research Methodology

The objective of this study is to compare companies' efficiency effectively. Using a comparative DEA with MPI is established to determine the features of banks in terms of some DMUs with four suggested models. Finally, the entire progression can be divided into four steps, as follows:

3.1. Models

3.1.1. CCR Model

The CCR models show a constant return to scale (CRS), which means that relative progress in all inputs is equal to the increase in outputs. The efficiency of an assumed DMU is calculated based on the CCR_{IO} model as follows:

$$
\begin{aligned}
& Min\theta \\
& St. \\
& \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p \qquad , i = 1, \dots\dots, m \\
& \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp} \qquad , r = 1, \dots\dots, s \\
& \lambda_j \geq 0 \qquad , j = 1, \dots, n
\end{aligned}
\tag{1}
$$

where θ_p specifies the technical efficiency score of units DMU, λj indicates the dual variables that categorize the benchmarks for inefficient parts. If θ_p is equal to one, then the DMU shows a technically efficient unit.

It is on the efficiency frontier, which collected from the set of efficient units. DEA calculates the efficiency of each observation based on the frontier that covers all the views. Inefficient DMUs can be improved (moved to the efficient frontier) with strategic directions for precision, which are the points along the frontier. The distance to the efficiency frontier distributes an amount of efficiency.

3.1.2. BCC Model

The BCC model changed the Constant Return to Scale (CRS) impression to Variable Return to Scale (VRS). The DMU controls under VRS, and it is observed that growth in inputs does not result in a relative change in the outputs. The BCC model divides Technical Efficiency (TE) based on the CCR model into two parts:

- *Pure Technical Efficiency (PTE):* PTE provides the effect of scale size by just connecting a DMU to a unit of comparable scale and procedures on how a DMU develops its bases under the outer region.
- *Scale Efficiency (SE):* SE, shows how the scale size has positive or negative influences on efficiency. If after using both CRS and VRS models on similar data, there is a change in the two technical efficiencies, and based on these tags, DMU has a scaling efficiency and can be designed by:

$$SE = TE/PTE \tag{2}$$

The BCC_{IO} is represented as follows:

$$Min\theta$$

$$St. \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p \qquad ,i = 1, \dots \dots, m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp} \qquad ,r = 1, \dots \dots, s$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0 \qquad ,j = 1, \dots, n$$

3.1.3. CCR-BCC Model

Consider manufacturing technology where if it produces $X_0$and Y_0then λX_0can produce λY_0only when we have $\lambda \leq 1$. We make a set of production possibilities that include observations and apply the principles of convexity and feasibility. This series will be introduced as follows.

$$T_{CCR-BBC} = T_{NI} = \{(X, Y) | X \geq \sum_{j=1}^{n} \lambda_j X_j \ \&Y \leq \sum_{j=1}^{n} \lambda_j Y_j \ \& \sum_{j=1}^{n} \lambda_j \leq 1\& \ \lambda \geq 0\} \tag{4}$$

Suppose the purpose of evaluating the DMU with input X and output Y concerning the abovementioned technology will be the following definition:

T is defined as the set of possible production

The main goal in the input-oriented method is to find a virtual unit in which the input θX_0 is not more than X_0, and the minimum production should be Y_0. In fact:

$$Min\theta$$

$$St. \tag{5}$$

$$(\theta X_0, Y_0) \in T_{ND}$$

Based on the T_{ID} structure for $CCR_{IO} - BCC_{IO}$:

$$Min\theta$$

$$St. \tag{6}$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p \qquad ,i = 1, \dots \dots, m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp} \qquad ,r = 1, \dots \dots, s$$

$$\sum_{j=1}^{n} \lambda_j \leq 1$$

$$\lambda_j \geq 0 \qquad ,j = 1, \dots, n$$

3.2. Inputs and Outputs Description

As soon as the six suggested models, the orientation, and the DMUs were established, the next step was to create which variables would be involved in the model. This is the most important step in applying DEA. After applying the DMU j (j=1. . .n) which are financial institutes in eight selected developing countries or decision-making units, we propose the following three inputs and two outputs in our study:

- Xij (i= 1. . . m): Fixed assets
- Ncj (C= 1. . . c): Personnel expenses
- Qoj (O= 1. . . o): Total deposits
- Yrj (r = 1. . . s): Total loans
- Mhj (H = 1. . . h): Total profits

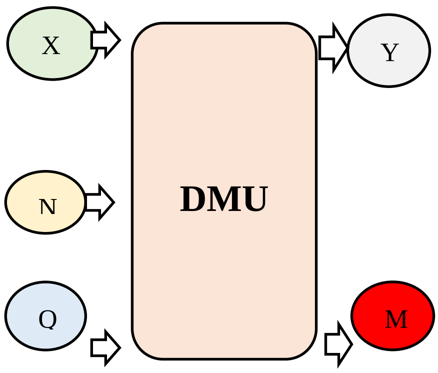

Figure1. Three inputs and two outputs for the three suggested models

Drake et al. [26] divide the selecting variables for financial institutes, into two following parts:

- **Production:** Based on Benston [27], banks are mainly measured to be service providers for customers. The inputs involve physical variables such as staff, capital, and materials. The outputs are generally related to the services available to customers, which may include deposits and loans
- **Intermediation:** Based on Sealey and Lindley [28], the critical role of banks is to gather assets and change them into investments and other profitable assets. The bank is chiefly playing an essential intermediary among extra managers and a lack of managers.

The production approach is more appropriate for assessing agencies, while the intermediation method is more suggested for bank evaluation. Several papers such as Svitalkova [1], Liu et al. [10] Zimkova [29], and Assaf et al. [30] have used the same inputs in our study. However, these papers measured the number of employees instead of personnel expenses.

Concerning the outputs, many papers used the total loans as the output such as Drake et al. [26], Liu et al. [10], Assaf et al [30] and Yilmaz and Güneş [31]. Numerous papers used the intermediation method also used total loan output, like in our study, based on the primary duty of banks, is to take deposits and to lend money. We consider the total profits in our study as a second output too.

The data analysis was directed applying R language and the Benchmarking package, which makes many DEA models available.

Finally, $CCR_{IO}(CCR\ Input\ Oriented)$ and $BCC_{IO}(BBC\ Input\ Oriented)$ for the single and dual-stage proposed model are widely discussed below:

3.2.1 Linear Model in CCR_{IO}

$$Max = \sum_{r=1}^{s} u_r y_{rp} + \sum_{h=1}^{H} e_h m_{hp} \tag{7}$$

$St.$

$$\sum_{i=1}^{m} v_i x_{ip} + \sum_{c=1}^{C} f_c n_{cp} + \sum_{o=1}^{O} k_o q_{op} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} + \sum_{h=1}^{H} e_h m_{hj} - \sum_{i=1}^{m} v_i x_{ij} - \sum_{c=1}^{C} f_c n_{cj} - \sum_{o=1}^{O} k_o q_{oj} \leq 0$$
$$u_r, e_h, v_i, f_c, k_j \geq 0 \ \ , j = 1, \dots, n$$

3.2.2 Dual Model in CCR_{IO}

$$Min\ \theta \tag{8}$$

$St.$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p x_{ip}$$

$$\sum_{j=1}^{n} \lambda_j n_{cj} \leq \theta_p n_{cp}$$

$$\sum_{j=1}^{n} \lambda_j q_{oj} \leq \theta_p q_{op}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp}$$

$$\sum_{j=1}^{n} \lambda_j m_{hj} \geq m_{hp}$$

$$\lambda_j \geq 0 \quad \theta_p\ free$$

3.2.3 Linear Model in BCC_{IO}

$$Max = \sum_{r=1}^{s} u_r y_{rp} + \sum_{h=1}^{H} e_h m_{hp} + w \tag{9}$$

$St.$

$$\sum_{i=1}^{m} v_i x_{ip} + \sum_{c=1}^{C} f_c n_{cp} + \sum_{o=1}^{O} k_o q_{op} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} + \sum_{h=1}^{H} e_h m_{hj} - \sum_{i=1}^{m} v_i x_{ij} - \sum_{c=1}^{C} f_c n_{cj} - \sum_{o=1}^{O} k_o q_{oj} + w \leq 0$$

$$u_r, e_h, v_i, f_c, k_o \geq 0 \ \ , j = 1, \dots, n$$

3.2.4 Dual Model in BCC_{IO}

$$Min\ \theta \tag{10}$$

$St.$

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p x_{ip}$$

$\sum_{j=1}^{n} \lambda_j n_{cj} \leq \theta_p n_{cp}$

$\sum_{j=1}^{n} \lambda_j q_{oj} \leq \theta_p q_{op}$

$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp}$

$\sum_{j=1}^{n} \lambda_j m_{hj} \geq m_{hp}$

$\sum_{j=1}^{n} \lambda_j = 1$

$\lambda_j \geq 0 \quad \theta_p \ free$

3.2.5 Linear Model in $\mathrm{CCR_{IO}} - \mathrm{BCC_{IO}}$

$$Max = \sum_{r=1}^{s} u_r y_{rp} + \sum_{h=1}^{H} e_h m_{hp} \tag{11}$$

$St.$

$\sum_{i=1}^{m} v_i x_{ip} + \sum_{c=1}^{C} f_c n_{cp} + \sum_{o=1}^{O} k_o q_{op} \leq 1$

$\sum_{r=1}^{s} u_r y_{rj} + \sum_{h=1}^{H} e_h m_{hj} + \sum_{v=1}^{V} g_v d_{vj} - \sum_{i=1}^{m} v_i x_{ij} - \sum_{c=1}^{C} f_c n_{cj} - \sum_{o=1}^{O} k_o q_{oj} \leq 0$

$u_r, e_h, v_i, f_c, k_j \geq 0 \ , j = 1, \dots, n$

3.2.6. Dual Model in $\mathrm{CCR_{IO}} - \mathrm{BCC_{IO}}$

$Min\ \theta$

$St.$ (12)

$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_p x_{ip}$

$\sum_{j=1}^{n} \lambda_j n_{cj} \leq \theta_p n_{cp}$

$\sum_{j=1}^{n} \lambda_j q_{oj} \leq \theta_p q_{op}$

$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{rp}$

$\sum_{j=1}^{n} \lambda_j m_{hj} \geq m_{hp}$

$\sum_{j=1}^{n} \lambda_j \leq 1$

$\lambda_j \geq 0 \quad \theta_p \ free$

3.3 Malmquist Productivity Index (MPI)

The MPI is measured to assess productivity growth based on the reference technology. The following two main topics are used in the calculation of MPI development:

- The first issue is the quantity of productivity change over the period.
- On the other hand, second is to decompose changes in productivity into what are generally denoted as a catching-up result or technical efficiency change (TEC) and a frontier shift result or technological change (TC).

MPI measures the total factor productivity change of a DMU between two periods. The idea of productivity typically denoted as labor productivity. This idea is related to TFP, defined as the product of efficiency change (catch-up) and technological change (frontier-shift). If TFP value is more than one, this specifies a progressive TFP growth from period (t) to period (t+1). However, a value of less than one designates a reduction in TFP development or performance relative to the preceding year. In fact:

$$Malmquist\ Productivity\ Index\ (MPI) = TEC \times TC \tag{13}$$

The MPI can be stated through distance function(E) based on the two following equations applying the reflections at time t and t+1[32].

$$MPI^t{}_I = \frac{E^t{}_I(x^{t+1} + y^{t+1})}{E^t{}_I(x^t + y^t)} \tag{14}$$

$$MPI^{t+1}{}_I = \frac{E^{t+1}{}_I(x^{t+1} + y^{t+1})}{E^{t+1}{}_I(x^t + y^t)} \tag{15}$$

The geometric mean of two MPI in Eq. (7) and Eq. (8) provides the Eq. (9):

$$MPI^G{}_I = (MPI^t{}_I MPI^{t+1}{}_I)^{1/2} = [\left(\frac{E^t{}_I(x^{t+1} + y^{t+1})}{E^t{}_I(x^t + y^t)}\right).\left(\frac{E^{t+1}{}_I(x^{t+1} + y^{t+1})}{E^{t+1}{}_I(x^t + y^t)}\right)]^{1/2} \tag{16}$$

Since we want to apply CCR_{IO} (CCR Input Oriented), BCC_{IO}, the input oriented geometric mean of MPI can be disintegrated using the abovementioned input-oriented TC and input oriented TEC as follows:

$$MPI^G{}_I = (TC_I)(TEC^G{}_I)^{1/2} = \frac{E^{t+1}{}_I(x^{t+1} + y^{t+1})}{E^t{}_I(x^t + y^t)}[\left(\frac{E^t{}_I(x^t + y^t)}{E^{t+1}{}_I(x^t + y^t)}\right).\left(\frac{E^t{}_I(x^{t+1} + y^{t+1})}{E^{t+1}{}_I(x^{t+1} + y^{t+1})}\right)]^{1/2} \tag{17}$$

MPI specified by equations (14) and (15) can be well-defined applying DEA, such as distance function. These are the elements of MPI which can be driven from the assessment of distance functions defined on frontier technology. So, the abovementioned MPI is the most common method between the numerous techniques that have been established to evaluate a production technology [33]. So, there are a large number of optimization methods have been proposed in various papers such as expert systems [34-37] and stochastic programming [38].

4. Discussion and Results

4.1. Discussion in the MPI Model

4.1.1. Discussion in MPI-CCR Model

The data covers in this study are five years from 2015 to 2019 for 30 banks in the developing countries. The number of DMUs is N or 30, and the period is T or 5.

The average MPI-CCR for all banks over 2015-2019 is given in Table 1 and Figure 2.

Table 1. Productivity measurement results based on MPI-CCR for 30 banks over 2015-2019

Banks	MPI	Rank	Banks	MPI	Rank
1	0.91	21	16	0.45	30
2	1.12	16	17	1.91	1
3	0.85	23	18	0.87	22
4	1.31	12	19	1.61	7
5	0.77	25	20	1.89	2
6	1.60	8	21	1.01	18
7	1.22	13	22	0.59	28
8	0.92	20	23	1.06	17
9	1.81	4	24	1.13	15
10	0.75	26	25	1.33	11
11	1.21	14	26	0.81	24
12	1.50	9	27	1.78	5
13	1.45	10	28	1.74	6
14	1.00	19	29	1.88	3
15	0.65	27	30	0.51	29

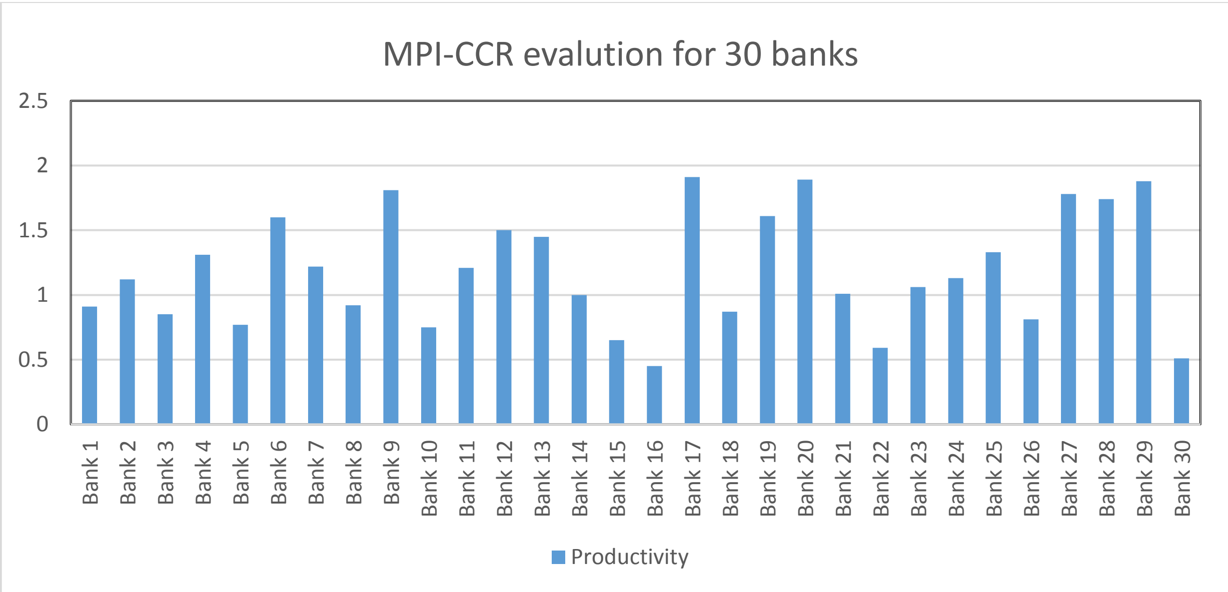

Figure 2. Average productivity for MPI-CCR over 5-year periods for 30 DMUs

4.1.2 Discussion in MPI-BCC Model

The average MPI-BCC for all banks over 2015-2019 is given in Table 2 and Figure 3.

4.1.3 Discussion in MPI-CCR-BCC Model

The average MPI-CCR-BCC for all banks over 2015-2019 is given in Table 3 and Figure 4.

Table 2. Productivity measurement results based on MPI-BCC for 30 banks over 2015-2019

Banks	MPI	Rank	Banks	MPI	Rank
1	0.92	21	16	0.46	30
2	1.13	16	17	1.92	1
3	0.86	3	18	0.88	22
4	1.32	12	19	1.64	7
5	0.78	25	20	1.90	2
6	1.61	8	21	1.02	18
7	1.24	13	22	0.61	28
8	0.93	20	23	1.07	17
9	1.83	4	24	1.14	15
10	0.76	26	25	1.36	11
11	1.22	14	26	0.82	24
12	1.52	9	27	1.79	5
13	1.46	10	28	1.75	6
14	1.01	19	29	1.89	3
15	0.66	27	30	0.53	29

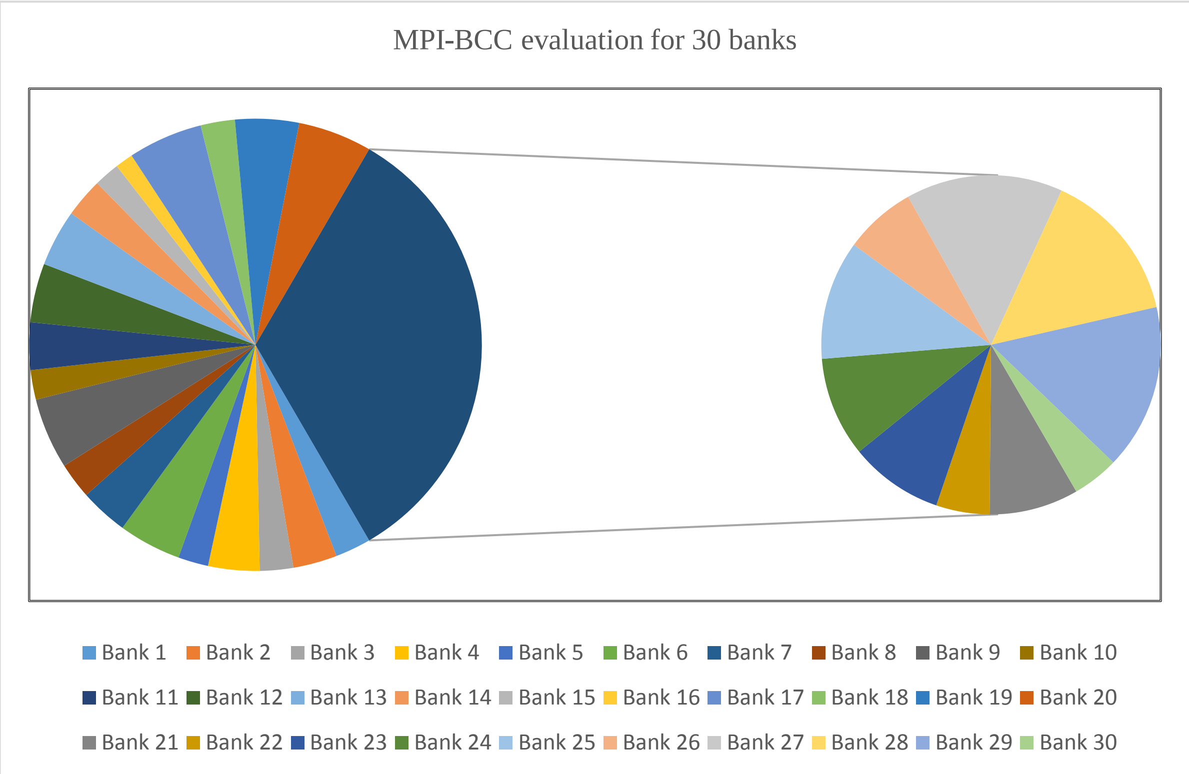

Figure 3. Average productivity for MPI-BCC over 5-year periods for 30 DMUs

Table 3. Productivity measurement results based on MPI-CCR-BCC for 30 banks over 2015-2019

Banks	MPI	Rank	Banks	MPI	Rank
1	0.93	21	16	0.47	30
2	1.14	16	17	1.93	1
3	0.87	23	18	0.89	22
4	1.33	12	19	1.67	7
5	0.79	25	20	1.91	2
6	1.62	8	21	1.03	18
7	1.26	13	22	0.63	28
8	0.94	20	23	1.08	17
9	1.85	4	24	1.15	15
10	0.77	26	25	1.39	11
11	1.23	14	26	0.83	24
12	1.54	9	27	1.80	5
13	1.47	10	28	1.76	6
14	1.02	19	29	1.90	3
15	0.67	27	30	0.55	29

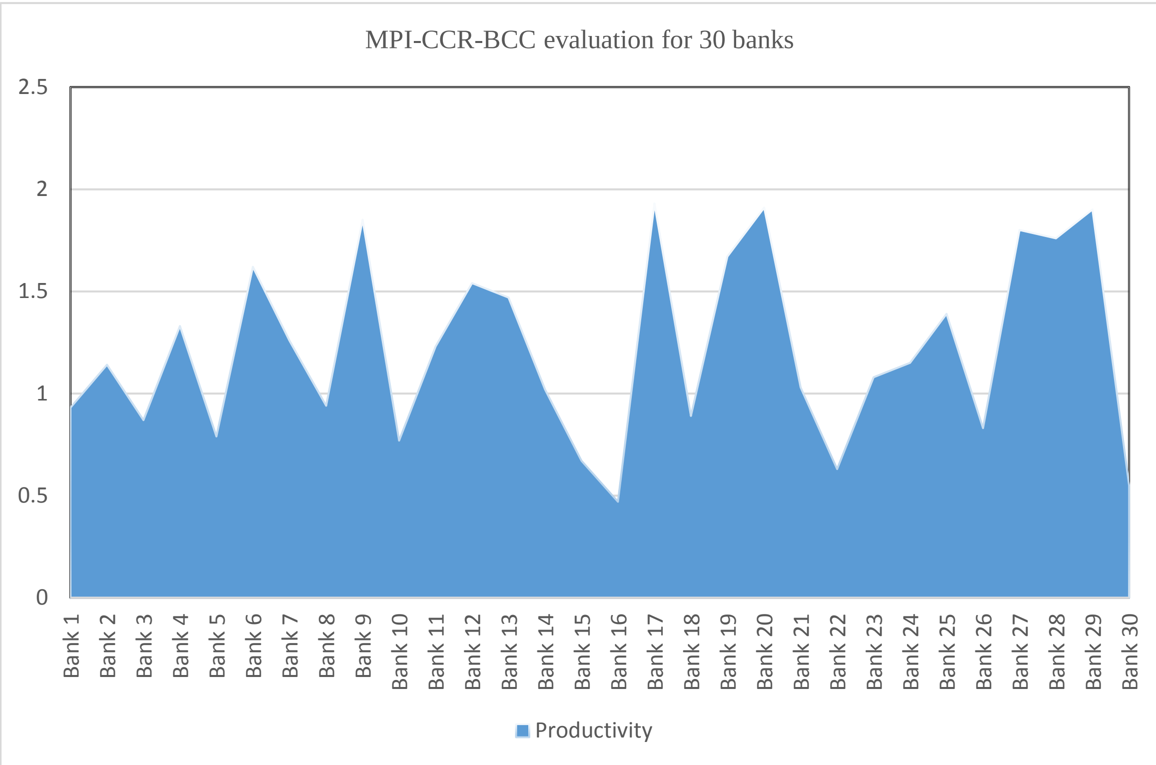

Figure 4. Average productivity for MPI-CCR-BCC over 5-year periods for 30 DMUs

4.2. Results

It can be concluded from (Table 1 and Figure 2), (Table 2 and Figure 3), (Table 3 and Figure 4):

- CCR-BCC model has the fourth average efficiency score over 5-years period for 30 DMUs
- BCC model has the fifth average efficiency score over 5-years period for 30 DMUs
- CCR model has the last and the sixth average efficiency score over 5-years period for 30 DMUs

So CCR-BCC model is the best fit model for our evaluation.

According to the evaluation of MPI in six suggested models in table 1,2,3 for 30 banks with quantified input and output principles:

Based on the CCR model in table 1 and Figure 2:

- The 17th bank has the 1st or the highest MPI with a productivity score of 1.91.
- The 20th and 29th banks are in the 2nd and 3rd places with productivity scores of 1.89 and 1.88, respectively.
- The 16th bank has the 30th and the lowest MPI with a productivity score of 0.45.
- The 22nd and 30th banks are in the 28th and 29th places with productivity scores of 0.59 and 0.51, respectively.

Based on the BCC model in table 2 and Figure 3:

- The 17th bank has the 1st or the highest MPI with a productivity score of 1.92.
- The 20th and 29th banks are in the 2nd and 3rd places with productivity scores of 1.90 and 1.89, respectively.
- The 16th bank has the 30th and the lowest MPI with a productivity score of 0.46.
- The 22nd and 30th banks are in the 28th and 29th places with productivity scores of 0.61 and 0.53, respectively.

Based on the CCR-BCC model in table 3 and Figure 4:

- The 17th bank has the 1st or the highest MPI with a productivity score of 1.93.
- The 20th and 29th banks are in the 2nd and 3rd places with productivity scores of 1.91 and 1.90, respectively.
- The 16th bank has the 30th and the lowest MPI with a productivity score of 0.47.
- The 22nd and 30th banks are in the 28th and 29th places with productivity scores of 0.63 and 0.55, respectively.

Although the difference between efficiency scores among the six suggested models is negligible, CCR-BCC model has the highest rank. BCC and CCR models are in the 2nd and 3rdplaces, respectively. Finally, the following relation is applicable for all DMUs in all MPIs and all years:

$$\text{CCR-BCC} > \text{BCC} > \text{CCR} \tag{18}$$

5. Conclusion

In this study, we describe how banks operate in the presence of similar banks. Therefore, those banks which have a higher score can improve their productivity. The more taking available information, the higher accurate and accessible data will be available. Each bank needs a productivity measurement to know its current status. So, productive companies are the best reference for increasing the productivity of unproductive banks. The CCR-BCC model has a more positive impact on efficiency score compare with other suggested models. The proposed approach, geometric average, results, and predictions derived from the period and productivities in MPI can help the practitioner to compare the efficiency of uncertain cases and instruct accordingly. Since the proposed window analysis method is based on a moving average, it is useful for finding per efficiency trends over time Meanwhile, using fuzzy and random data for MPI will be interesting as a final comparison. So, the results and predictions can be helpful for managers of these banks and other managers who benefit from this approach to achieve a higher relative productivity score. Besides, managers can compare the efficiency of the current year with other similar companies over the past years. For the future work, we will deal with extending the research by applying some methods such as but not limited to [41-52].

Conflict of Interest Statement

The authors declare no conflict of interest.

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