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RESEARCH PAPER

Exploring the Role of Physical Space Facilities of Bank Branches in Malmquist Productivity Growth using DEA

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ABSTRACT
Increased productivity and efficiency are the most important sources of economic development. Pure efficiency, economies of scale, technology, rules and regulations are recent known factors affecting the Malmquist productivity index. This article focuses on the role of physical space facilities of bank branches as a factor affecting the decomposition of Malmquist productivity index. First, we will introduce a new model that applies weight restrictions in basic DEA models for constant returns to scale technologies. The weight restrictions are in the form of assurance region type I to enhance the distinctiveness power of the basic data envelopment analysis models. Then develop an extended Malmquist Index using the proposed model. It provides a new decomposition that explains the role of bank branches facilities in increasing or decreasing productivity. The validity of the proposed method is confirmed by actual data from 74 commercial bank branches in the two periods 2017 and 2018, and the results of the traditional and extended Malmquist indexes are analyzed.

KEYWORDS: *Data envelopment analysis; Malmquist productivity index; Physical space of bank branches.*

1. Introduction

In Data Envelopment Analysis (DEA), the efficiency of a supposed Decision Making Unit (DMU) is defined as the ratio of the weighted sum of the outputs to the weighted sum of inputs. Because the DMU has complete freedom to choose between input and output weights, some of the inputs / outputs may be ignored or assigned zero weights. Most of DEA's methodological enhancements have followed an application-oriented path as a result of applying this method to solve real problems. Incorporating restrictions on the attached weights of the inputs / outputs is one of the DEA's areas of development. One way to avoid this situation is to limit the weights. By imposing absolute upper and lower bounds, Assurance Region type I (ARI) and type II (ARII), or other predefined weight restrictions in related literature, the model becomes more realistic. See [1] for literature on different types of weight restrictions and value judgments in DEA. We note that ARI restrictions are imposed on input or output weights, but ARII sets relations between the weights of inputs and outputs. Weight constraints dictate the previous views of the manager or modeler or how to reflect information about the relative importance of individual inputs and outputs, or specific relationships between them, including cost and price considerations. There are other ways to improve the distinctiveness of DEA models, such as compromises, selective proportions, and the creation of unobserved DMUs [2].

Productivity growth is one of the major sources of economic development. Therefore, understanding the factors affecting productivity is very important. The productivity is considered as a key factor in the success and development of DMUs and its evaluation is more comprehensive than efficiency evaluation [3]. In recent years, productivity changes measurement during several time periods has attracted many researchers. The Malmquist Index (MI) is the primary index used to measure changes in productivity over time. In 1992, a DEA-based decomposition of the Malmquist index consisting of two components, Technology Change (TC) and Efficiency Change

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(EC), was developed over two time periods was developed called FGLR [4]. In 1994, the three-component version of the index regarding Constant and Variable Returns to Scale (CRS-VRS) technologies were introduced. It is called FGNZ decomposition [5]. FGNZ involves Pure Efficiency Changes (PEC), Scale Efficiency Changes (SEC), and technological changes. These decompositions were performed using the basic CRS and VRS models. In this regard, there are two other studies that use new technologies as a basis. Alirezaee and Afsharian [6] have introduced the Extended Malmquist Index (EMI), which uses trade-offs technology along two basic models to increase the importance of efficiency with expanded production possibility set. To take into account the impact of the imposed strategy on the behavior of the DMU, Alirezaee and Rajabi Tanha [7] proposed a balance model for assessing the DMU's balance factor and provided a further extended Malmquist index.

Many organizations have been trying new designs and techniques to construct office buildings, which can increase productivity, and attract more employees [8]. Many authors have noted that, the physical layout of the workspace, along with efficient management process, is playing a major role in boosting employees' productivity and improving organizational performance [9,10]. One of the challenges that banks are faced with is recognition and differentiation of customers and providing customized services to them [11]. The unprecedented growth of competition in the banking technology has raised the importance of retaining current customers and acquires new customers so that is important analyzing Customer behavior, which is based on bank databases [12]. We believe that branch physics can indirectly be ethical or immoral. Convenient counter, suitable furniture, parking, decoration, facilities for entering disabled persons or with wheelchair are samples of branch physical facilities and location. Changes in the physical spaces of banking establishments must be determined by "how such establishments want to be perceived" by customers [13]. One of the most important human needs is a working environment that helps people work in the most comfortable environment they can imagine. Buildings and air conditioning systems are carefully crafted [14]. The productivity of employees is determined excessively by the environment in which they work [15]. Changes in the physical spaces of banking establishments must be determined by "how such establishments want to be perceived" by customers [13]. A stressful work environment can lead to several disorders in physical health, mental health, and low job satisfaction [16].

The proposed Physical Space Facilities (PSF) model uses ARI weight constraints, and then defines the PSF factor of each branch to evaluate. When applying ARI restrictions, use the predefined PSF scores obtained during regular annual evaluations carried out by plan and program management of bank. Scores are treated as the relative value of the input of location index in multiplier form of DEA basic models. The proposed model is then used in extending an EMI to determine the role of PSF as a factor contributing to the growth or decline of productivity. EMI is divided into two components: Extended Efficiency Change (EEC) and Extended Technology Change (ETC). Regarding both new extended and CRS technologies, we define a new component of PSF factor change and propose the decomposition of three components including EC and ETC. Looking at VRS technology alongside the new advanced and CRS technologies also yields SEC, PEC, PSF factor changes, and the decomposition of four new components of EMI consisting of ETC. Note that the layer DEA model for a particular DMU can be used if there are DMUs with special data structures [17].

The rest of this article is organized as follows: Section 2 describes the proposed PSF model and defines the PSF factor of a supposed branch. Section 3 describes the enhanced MI and its various decompositions, including PSF changes. Section 4 uses real-world case study at the bank branch level to demonstrate the applicability and effectiveness of the proposed method of decomposing and calculating EMI. This section analyzes and compares MI and EMI over two time periods. The final note and future directions are shown in Section 5.

2. The Proposed PSF Model

Suppose that we have n DMUs with m inputs and s outputs denoted by $X_j=\left(X_{1j},\ldots,X_{ij},\ldots,X_{mj}\right)$ and $Y_j=\left(Y_{1j},\ldots,Y_{rj},\ldots,Y_{sj}\right)$ respectively for DMU$_j$, $j=1,\ldots,n$. It is assumed that $X_j\geq 0$ and $Y_j\geq 0$ with $X_j\neq 0$ and $Y_j\geq 0$ for all DMUs. The multiplier forms of basic input-oriented CRS and VRS models for measuring technical efficiency (TE) and pure efficiency (PE) for a given DMU$_k$ are defined as follows:

$$\theta_{CRS} = Max\sum_{r=1}^{s} u_r y_{rk}$$
$$s.t.\sum_{i=1}^{m} v_i x_{ik} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 1,\ j = 1,\ldots,n \qquad (1)$$
$$u_r \ge \varepsilon, v_i \ge \varepsilon, i = 1,\ldots,m, r = 1,\ldots,s$$

And

$$\theta_{VRS} = Max\sum_{r=1}^{s} u_r y_{rk} - u_0$$
$$s.t.\sum_{i=1}^{m} v_i x_{ik} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} - u_0 \le 1,\ j = 1,\ldots,n \qquad (2)$$
$$u_r \ge \varepsilon, v_i \ge \varepsilon, i = 1,\ldots,m, r = 1,\ldots,s$$
$$u_0 \text{ free}$$

where u_r and v_i are weights assigned to output r and input i, respectively, and $\varepsilon > 0$ is a non-Archimedean infinitesimal applied to avoid zero weights.

There are several related factors that affect employee job satisfaction and productivity [18]. Production efficiency is one of the most important aspects of bank branch performance. In the production approach, a branch generally provides services using human and physical resources as inputs and deposits, loans, etc. (number of transactions or document processing) as outputs [19]. According to DEA's production model, human resources and location indexes are considered as inputs, and deposits, loans and services as outputs. We will develop a new model based on this input / output structure, but one can add other inputs to the labor cost and location index, or consider other outputs.

The branch location index is an index that represents the status of a branch with respect to many quality and quantity factors. Factors fall into three categories: branch customer characteristics, branch physical location, and branch staff characteristics. The calculation of the location index of all branches of the bank was carried out as part of the research project "Model Design and Implementation of Maskan Bank Branches". 48902612 from July 13, 2011, created by the authors. This indicator is important both for assessing branches from a business perspective and as an indicator of the bank's potential capital associated with its geographic location. We use this index as input to evaluate the sector [6].

Plan and program management of bank assigns scores to each branch's physical location facilities by conducting periodic evaluations over a year. Consider P_j^{min} and P_j^{max} as the minimum and maximum PSF scores of DMU$_j$. All of the scores are nonnegative values between 0 and 1.

Here we introduce PSF model as

$$\theta_{PSF} = Max\sum_{r=1}^{s} u_r y_{rk}$$
$$s.t.\sum_{i=1}^{m} v_i x_{ik} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 1,\ j = 1,\ldots,n \qquad (3)$$
$$\frac{1}{P_k^{\max}} \le \frac{v_1}{v_2} \le \frac{1}{P_k^{\min}}$$
$$u_r \ge \varepsilon, v_i \ge \varepsilon, i = 3,\ldots,m, r = 1,\ldots,s$$

Model (3) takes into account the role of PSF in DEA evaluation by adding additional constraints and uses the relevant PSF value as the ratio of the input weights v_1 and v_2. Other inputs may or may not have weights in the model (3).

To explore the role of PSF in the Malmquist productivity index described in the next section, we define a new concept called PSF factor, as follows:

Definition 1. The PSF factor of a bank branch is equal to the ratio of θ_{PSF} to θ_{CRS} efficiency scores.

3. Expanding MI

This section, first outlines the traditional Malmquist index in 3.1 and then uses the proposed model in the previous section to develop EMI in 3.2.

3.1. MI and its decompositions

Let $\left(x_k^t, y_k^t\right)$ and $\left(x_k^{t+1}, y_k^{t+1}\right)$ be inputs and outputs of DMU$_k$ observed at two time periods, t and $t+1$. The (input-oriented) Malmquist productivity index can be expressed as

$$MI = \left[\frac{D^t\left(x_k^{t+1}, y_k^{t+1}\right)}{D^{t+1}\left(x_k^t, y_k^t\right)} \times \frac{D^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D^t\left(x_k^t, y_k^t\right)}\right]^{\frac{1}{2}} \qquad (4)$$

Calculation of MI requires two single-period and two mixed-period measures. The two single-period measures are $D^t\left(x_k^t, y_k^t\right)$ and $D^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)$, which refer to the distance of $\left(x_k^t, y_k^t\right)$ and $\left(x_k^{t+1}, y_k^{t+1}\right)$ from efficient frontiers of time periods, t and $t+1$ respectively. Also, the two mixed-period measures are $D^{t+1}\left(x_k^t, y_k^t\right)$ and $D^t\left(x_k^{t+1}, y_k^{t+1}\right)$, which refer to the distance of $\left(x_k^t, y_k^t\right)$ and $\left(x_k^{t+1}, y_k^{t+1}\right)$ from different efficient frontiers constructed in time periods , t and $t+1$ respectively. These four measures are called distance functions. All of the required distance functions in the MI formula can be obtained from DEA models.

Assuming input-oriented CRS technology, $D^t\left(x_k^{t+1}, y_k^{t+1}\right)$ could be obtained as follows:

$$
\begin{aligned}
& D^t\left(x_k^{t+1}, y_k^{t+1}\right) = Max \sum_{r=1}^{s} u_r^t y_{rk}^{t+1} \\
& s.t. \sum_{i=1}^{m} v_i^t x_{ik}^{t+1} = 1 \\
& \sum_{r=1}^{s} u_r^t y_{rj}^t - \sum_{i=1}^{m} v_i^t x_{ij}^t \leq 1, j = 1, \ldots, n \\
& u_r^t \geq \varepsilon, v_i^t \geq \varepsilon, i = 1, \ldots, m, r = 1, \ldots, s
\end{aligned} \tag{5}
$$

The other three distance functions can be computed similarly. FGLR two-component decomposition of MI, which presents EC and TC, is

$$
MI = \frac{D_{CRS}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{CRS}^t\left(x_k^t, y_k^t\right)} \left[\frac{D^t\left(x_k^{t+1}, y_k^{t+1}\right)}{D^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)} \times \frac{D^t\left(x_k^t, y_k^t\right)}{D^{t+1}\left(x_k^t, y_k^t\right)} \right]^{\frac{1}{2}} = EC \times TC \tag{6}
$$

Considering the two CRS and VRS technologies, the FGNZ decomposition uses the CRS and VRS models as in equations (1) - (2) to divide the MI into three components: PEC, SEC, and TC as in Eq. (7). Note that SE is defined as the ratio of efficiency values for CRS and VRS.

$$
MI = PEC \times SEC \times TC \tag{7}
$$

And

$$
PEC = \frac{PE^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{PE^t\left(x_k^t, y_k^t\right)}, SEC = \frac{SE^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{SE^t\left(x_k^t, y_k^t\right)}
$$

where

$$
PEC^t\left(x_k^t, y_k^t\right) = D_{VRS}^{t+1}\left(x_k^t, y_k^t\right), SE^t\left(x_k^t, y_k^t\right) = \frac{D_{CRS}^t\left(x_k^t, y_k^t\right)}{D_{VRS}^t\left(x_k^t, y_k^t\right)} \tag{8}
$$

And

$$
\begin{aligned}
& D_{VRS}^t\left(x_k^t, y_k^t\right) = Max \sum_{r=1}^{s} u_r^t y_{rk}^{t+1} - u_0^t \\
& s.t. \sum_{i=1}^{m} v_i^t x_{ik}^{t+1} = 1 \\
& \sum_{r=1}^{s} u_r^t y_{rj}^t - \sum_{i=1}^{m} v_i^t x_{ij}^t - u_0^t \leq 1, j = 1, \ldots, n \\
& u_r^t \geq \varepsilon, v_i^t \geq \varepsilon, i = 1, \ldots, m, r = 1, \ldots, s
\end{aligned} \tag{9}
$$

Note that for all the above decompositions, an amount of MI greater than, equal to, or less than 1 means that productivity increased, did not changed, or decreased during periods t and $t+1$. Similar results hold about its components.

3.2. EMI development based on PSF concept

Think of the PSF model as the basic technology of Eq. (6), so we have the new EMI as Eq. (10). The distance functions in (10) are defined in (11).

$$
EMI^{PSF} = \left[\frac{D_{PSF}^t\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{PSF}^{t+1}\left(x_k^t, y_k^t\right)} \times \frac{D_{PSF}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{PSF}^t\left(x_k^t, y_k^t\right)} \right]^{\frac{1}{2}} \tag{10}
$$

Where $\left(x_k^t, y_k^t\right)$ and $\left(x_k^{t+1}, y_k^{t+1}\right)$ are the observed inputs and outputs of DMU$_k$ in time periods t and $t+1$ respectively. $D_{PSF}^t = \left(x_k^{t+1}, y_k^{t+1}\right)$, is calculated by solving model (11). Other measures in Eq. (10) are calculated in a similar manner.

$$
\begin{aligned}
& D_{PSF}^t\left(x_k^{t+1}, y_k^{t+1}\right) = Max \sum_{r=1}^{s} u_r^t y_{rk}^{t+1} \\
& s.t. \sum_{i=1}^{m} v_i^t x_{ik}^{t+1} = 1 \\
& \sum_{r=1}^{s} u_r^t y_{rj}^t - \sum_{i=1}^{m} v_i^t x_{ij}^t \leq 1, j = 1, \ldots, n \\
& \frac{1}{P_k^{\max,t}} \leq \frac{v_1}{v_2} \leq \frac{1}{P_k^{\min,t}} \\
& u_r^t \geq \varepsilon, v_2^t \geq \varepsilon, i = 1, \ldots, m, r = 1, \ldots, s
\end{aligned} \tag{11}
$$

Now we can develop other versions of EMI decompositions regarding CRS and PSF technologies. Two-component EMI can be written as

$$EMI^{PSF} = EEC^{PSF} \times ETC^{PSF} \quad (12)$$

Where

$$EEC^{PSF} = \frac{D_{PSF}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{PSF}^{t}\left(x_k^{t}, y_k^{t}\right)}$$

And

$$ETC^{PSF} = \left[\frac{D_{PSF}^{t}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{PSF}^{t+1}\left(x_k^{t}, y_k^{t}\right)} \times \frac{D_{PSF}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{PSF}^{t}\left(x_k^{t}, y_k^{t}\right)}\right]^{\frac{1}{2}} \quad (13)$$

which are obtained by replacing CRS model of the with the PSF model in Eq. (6). Using the concept of PSF factor developed in Definition 1, a new three-component decomposition that determines the share of PSF Factor Changes (PSFFC) in productivity changes is developed as follows:

$$EMI^{PSF} = EC \times PSFFC \times ETC^{PSF} \quad (14)$$

where

$$EC = \frac{D_{CRS}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{CRS}^{t}\left(x_k^{t}, y_k^{t}\right)}$$

And

$$PSFFC = \frac{PSFF^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{PSFF^{t}\left(x_k^{t}, y_k^{t}\right)} = \left[\frac{D_{PSF}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)}{D_{CRS}^{t+1}\left(x_k^{t+1}, y_k^{t+1}\right)} \times \frac{D_{CRS}^{t}\left(x_k^{t}, y_k^{t}\right)}{D_{PSF}^{t}\left(x_k^{t}, y_k^{t}\right)}\right]$$

which is obtained from Eq. (12) according to the relation $D_{PSF}^{t}\left(x_k^t, y_k^t\right) = D\left(x_k^t, y_k^t\right) \times PSFF^t\left(x_k^t, y_k^t\right)$.

In addition, if we consider VRS technology in addition to CRS and PSF, other novel four-component decomposition of EMI will be obtained as follows:

$$EMI^{PSF} = PEC \times SEC \times PSFFC \times ETC^{PSF}$$

The components PEC and SEC were defined in Eq. (7).

4. Case study

In this section, as a practical case study, we will calculate and analyze the new EMI decompositions in the two periods 2017-2018 for 74 branches of the Maskan Bank of Iran in the western region of Tehran. It should be noted that Maskan Bank is the largest Iranian government bank operating in the housing sector. There are more than 1300 branches in 38 regions of Iran.

4.1. Input / output data

The robustness of DEA analysis results depends on the availability and quality of the data [20]. Table 1 shows descriptive statistics for the inputs / outputs for the two periods. The unit of measurement of labor cost is 1,000,000 Rial. The other indexes are normalized and have no units. Data is taken directly from bank planning and program management.

Tab. 1. Descriptive statics of data

	2017				2018			
	Min	Max	Mean	STD.	Min	Max	Mean	STD.
Inputs								
Personnel expenses	1384.62	13332.97	4364.46	2019.71	1898.48	18396.58	5870.05	2792.48
Location index	384	1212	926.8	164.64	384	1212	926.8	164.64
Outputs								
Deposits	86.8	5491	1524.86	1054.86	154.5	5620	1417.97	881.074
Loans	62.53	16127	1509.30	2063.145	111.9	18300	1648.76	2269.94
Services	69.05	18942	1404.53	2330.88	169.9	22045	1448.92	2649.23

Table 2 shows descriptive statistics for PSF values over the two periods.

Tab. 2. Descriptive statistics of PSF values

	2017				2018			
	Min	Max	Mean	STD.	Min	Max	Mean	STD.
PSF Min scores	0.007	0.339	0.090	0.064	0.009	0.419	0.082	0.058
PSF Max scores	0.028	1	0.352	0.224	0.034	1	0.320	0.183

4.2. Analyzing the results for EMI

EMI^{PSF} results were calculated for all branches according to Eq. (15). First, provide descriptive statistics for the results of EMI^{PSF} calculated from section 3 as are shown in Table 3.

Tab. 3. Descriptive statistics of EMI^{PSF} results

	Min(#branch)	Max(#branch)	Mean	STD.
ETC^{PSF}	0.35(71)	1.12(18)	0.57	0.12
PSFFC	0.99(18)	2.89(71)	1.32	0.34
EMI^{PSF}	0.55(36)	3.02(71)	0.93	0.33
EMI^{PSF}-MI	-0.34(60)	1.25(71)	0.15	0.18

Table 3 shows an average of 15% increase in EMI^{PSF} relative to MI. The largest reduction in EMI relative to MI is 0.34% which belongs to the 60th branch. The largest increase of 1.25% can be traced back to the 71st branch. The minimum and maximum ETC^{PSF} for branches 71 and 18 are equal to 0.35 and 1.12 respectively.

As with the previous subsection, consider only the branches with the highest and lowest values in difference between EMI^{PSF} and MI. Also, check the branches that changed little when switching from MI to EMI^{PSF}. A list of these branches is shown in Table 4.

Tab. 4. MI, EMI^{PSF}, and their components for selected branches

#	PSFFC	PEC	SEC	ETC^{PSF}	TC	MI	EMI^{PSF}
1	1.10	0.88	0.95	0.65	0.84	0.71	0.59
5	1.06	0.93	1.00	0.69	0.70	0.65	0.68
16	1.05	1.11	1.11	0.59	0.60	0.74	0.76
18	0.99	0.83	0.97	1.12	0.54	0.43	0.89
27	1.09	1.13	1.02	0.70	0.79	0.91	0.88
43	2.08	1.04	1.35	0.45	0.65	0.92	1.33
60	1.00	1.00	1.00	1.00	1.34	1.34	1.00
71	2.89	1.21	2.47	0.35	0.60	1.78	3.02
73	1.82	1.08	1.70	0.40	0.54	0.99	1.34
74	2.32	0.97	2.60	0.35	0.54	1.36	2.05

Due to the PSF factor consideration, the status of branches 43 and 73 has changed from non-productive branch to productive branch. Strong growth of PSFFC at branches 43, 71, 73, and 74 result in a significant increase in EMI^{PSF} compared to MI. Also, the ETC^{PSF} value for the branch 18 has almost doubled, which result in a double increase in EMI^{PSF} compared to MI. At branches 1 and 60, their EMI^{PSF} is lower than MI because ETC^{PSF} is reduced in relation to TC. Most branches in Table 4 do not show negative growth in PSFFC. All branches in Table 4 except branches 18 and 60 show negative growth in ETC^{PSF}.

5. Conclusion

Changes in productivity are affected by a variety of factors. The more factors involved in the measurement, the more accurate the productivity analysis. In addition to technology, efficiency and size, this paper contributes to the role of the physical facilities of bank branches in the calculation of the enhanced Malmquist Index. In this work, first we propose a new model called PSF to measure a new factor named physical space facilities factor. This model is used to calculate the distance functions of the extended Malmquist productivity index. The physical space facilities factor for each branch was defined as the ratio of the new extended model to the CRS efficiency value. The enhanced Malmquist Index's new three- and four-component decompositions are designed to provide useful information about the causes of increased or decreased productivity. The proposed method was applied to an actual case study of a bank.

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