An allocation productivity indicator: Application in Taiwanese banks

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Abstract

This study applies the non-parametric approach and combine the the Luenberger productivity indicator and the allocative efficiency (Chamber et al., 1996) to develop an allocation Luenberger indicator. The allocation Luenberger indicator can be decomposed into the allocative efficiency change and the allocative technical change. We also investigate whether there is a relationship in the proposed allocation indicator, profit Luenberger indicator (Juo et al., 2015) and the Luenberger productivity indicator. For the empirical application, we use the 31 Taiwanese banks to measure profit Luenberger productivity indicator, Luenberger productivity indicator and allocation Luenberger indicator, and also compare these indicators and their components by the financial holding company and non-financial holding company.

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1. Introduction

Financial institutions play an important role in the economy, especially for Banks, which maintain public and private savings and their intermediation activities to allocate investments that contribute to the development of a country (Oliveira, 2008). The Taiwanese banking market also experienced some changes: Government decided to allow overseas investors in 1991 into the local banking market. Different types of financial institutions, such as investment and trust Companies, credit unions, small and medium-sized enterprises are allowed to reinvent themselves as commercial Banks. The government cut its value-added tax rate from 5% to 2% and relax the rules on the merger of financial institutions and allowing the establishment of financial holding companies (FHCs). However, after these changes, are Taiwanese banks performing better or worse? Do their profits increase or decrease? This study will investigate the performance of Taiwanese banks by the efficiency and productivity.

Efficiency and productivity analysis of Decision Making Units (DMUs) have been applied in many fields since Charnes et al. (1978) introduced Data Envelopment Analysis (DEA) as a non-parametric model (Emrouznejad, et al., 2008). The widely used productivity-Malmquist productivity index introduced by Caves et al. (1982) and refined by Fare et al. (1992) is to measure the change in productivity over time, and it can be decomposed into technical change efficiency change. However, the Malmquist index should be made either an output or input orientation under the assumption of either revenue maximization or cost minimization (Boussemart et al, 2003). The Luenberger productivity indicator which is a difference-based indicator can well avoid the above limiting assumption (Chamber et al., 1996). From the Chambers et al.(2002), “these Luenberger indicators are novel because they are based on a translation representation of the technology and, thus, are all specified in difference (not ration) from.” It also provides a possibility of measuring productivity growth by the direction of input contractions and output expansions simultaneously within goal of profit maximization.

Juo et al. (2015) adapt the profit efficiency which defined by the Chamber et al. (2002) to replace the directional distance function within the Luenberger productivity indicator to develop a profit oriented Luenberger productivity indicator (*PLPI*) under the assumption that profit maximization and the prices of outputs and inputs are available. They decomposed the *PLPI* into the profit efficiency change (*PEC*) and profit technology change (*PTC*), and further decomposed the *PEC* and the *PTC* into the technical efficiency change (*TEC*), allocative efficiency change (*AEC*), the technical change (*TC*) and price effect (*PE*). The decomposition can be shown as follows:

$$PLPI = PEC + PTC$$
$$= TEC + AEC + TC + PE$$

In this study, following the study of Juo et al. (2015), a concept of an Allocation Luenberger indicator (*ALI*) is proposed and three types of Luenberger indicators with their relationships in the framework of organization management are discussed. The profit Luenberger productivity indicator can be decomposed into the Luenberger productivity indicator (*LPI*) and the Allocation Luenberger indicator (*ALI*). Our proposed Allocation Luenberger indicator and its decomposition of various components are based on the assumption of variable returns to scale. For an empirical illustration, this study applies the proposed Allocation indicator with the method of the data envelopment approach and uses 31 Taiwanese banks in the sample period of 2010-2014 to empirically measure and compare the productivity changes and profit Luenberger decomposition components.

Our main findings are that Taiwanese banks show on average positive profit productivity growth from 2010 to 2014. The growth mainly comes from the contribution of Luenberger productivity improvement which enough offset the decrease from the Allocation Luenberger. We also showed that the allocation Luenberger indicator of the Taiwanese banking industry regresses due to the allocation technology decreases. The allocation technology regress is more influential than the allocation efficiency increase to the allocation Luenberger indicator. Finally, we find the profit productivity growth in financial holding companies is faster than that in non-financial holding companies, however the former's allocation indicator is reducing and the.

The rest of the paper is organized as follows. The methodology is discussed in Section 2. In this section we also introduce the concept of Allocation Malmquist Index and its decomposition. Section 3 presents data and variables. Section 4 shows the results and discussion and Section 5 concludes this paper.

2. Methodology

2.1 Technology, profit functions and allocative inefficiency

This study considers the panel data of the j-th (j=1, 2,…, J) DMUs. Assume that the DMUs use the input vector x^t $(x^t \in R_+^N)$ to produce output vector y^t $(y^t \in R_+^M)$. For the j-th DMU, this study defines its production technology set as follow: $S^t = \{(x^t, y^t): x^t \ can \ produce \ y^t\}$ where S^t is assumed to be convex and closed.

This study follows Chambers et al. (1997) and defines the directional distance function (DDF) by

$$\overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right) = sup\left\{\beta: (x^t - \beta g_x^t, y^t + \beta g_y^t) \in S^t\right\} \quad (1)$$

Where the directional vector $g^t = (-g_x^t, \ +g_y^t)$, $g_x^t \in R_+^N$ and $g_y^t \in R_+^M$, denotes this function shifts by simultaneously contracting inputs and expanding outputs, so as to reach the production frontier. Thus, the $\overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)$ also represents the degree of the technical inefficiency (*TI*).

The profit function is defined for the technology S as

$$\pi^t\ (p,w) = sup\{p^t y^t - w^t x^t : (x,y) \in S^t\}. \tag{2}$$

The Eq. (2) implies

$$\pi^t\ (p,w) \geq p^t y^t - w^t x^t \quad \forall (x,y) \in S^t$$

Since

$y^t + \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)g_y^t$ is feasible within $x^t - \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)g_x^t$

$$\pi^t\ (p,w) \geq p^t\left[y^t + \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)g_y^t\right] - w^t\left[x^t - \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)g_x^t\right]$$

$$\pi^t\ (p,w) \geq p^t y^t - w^t x^t + (p^t g_y^t + w^t g_x^t)\overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right)$$

$$\pi I^t\ = \frac{\pi^t\ (p,w) - (p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} \geq \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right) \tag{3}$$

The profit inefficiency (πI) is defined as

$$\pi I^t\ = \frac{\pi^t\ (p,w) - (p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} \tag{4}$$

TheπI^t , the difference between the maximal profit and obversed profit normalized by the sum $\left(p^t g_y + w^t g_x\right)$ which means the firm size, is called the Nerlovian profit efficiency measured in Chambers et al. (1998). Thus, the πI^t is independent of the unit of measure.

The right hand side of Eq. (3) measures the technical inefficiency. The gap in the inequality Eq. (3) reflects the residual inefficiency of profit.

And the allocative inefficiency is defined as

$$AI^t\ = \frac{\pi^t\ (p,w) - (p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} - \overrightarrow{D^t}\left(x^t, y^t; -g_x^t, g_y^t\right) \tag{5}$$

The AI^t reflects the distance from the maximal profit to the actual profit. In general, AI^t <0 indicates the DMU under the assessment comparing with other DMUs, is allocatively inefficient, since its production is taken place in an inappropriate input-output mixed, given the input and output prices. If AI^t =0 indicates the DMU is allocative efficient, it have reached the maximal profit.

Rearranging the Eq. (5), the profit inefficiency can be decompose into the two sources as follows:

$$AI^t = \pi I^t - TI^t \tag{6}$$

From the above Eq. (6), it can be known that the allocative inefficiency is a difference of profit inefficiency and technical inefficiency. The allocative inefficiency results from the wrong output-input mix in light of their given prices.

2.2 The Luenberger productivity indicator

The Luenberger productivity index (LPI) that is introduced by Chambers et al. (1996) which used to evaluating a difference-based productivity change. This indicator is defined and calculated by the quantity distance function.

Following Chambers (1996), the Luenberger productivity indicator for t and t+1 as followed:

$$LPI = \frac{1}{2}\left[\vec{D}^t\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right) + \vec{D}^t\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right) - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right] \tag{7}$$

The productivity indicator is constructed as the arithmetic mean of the productivity change measured by the technology at t and the productivity change measured by the technology at t+1. It indicates the productivity change by positive value and negative value. Furthermore, it also can be decomposed into two components, namely technical efficiency change (*TEC*) and technical change (*TC*) as followed:

$$LPI = \vec{D}^t\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right) \qquad (TEC)$$

$$+\frac{1}{2}\left\{\left[\vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^t\left(x^t, y^t; -g_x^t, g_y^t\right)\right] + \left[\vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right) - \vec{D}^t\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right]\right\} \qquad (TC)$$

(8)

Where the $TEC = \vec{D}^t\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)$ denotes the change of the technical efficiency from t to t+1. The functions of *TEC* and *TC* are indicated by the positive values and negative values. For example, if *TEC*>0, it means an improved technical efficiency, *TEC*<0 indicates the technical efficiency decreases and *TEC*=0 shows a constant efficiency. In the Eq. (7), the *TC* which is in the second bracket means the shift of the production technology between period t and t+1. When *TC* >0, it means technical improve, *TC*<0 indicates technical regress and *TC*=0 is the technology is constant in t and t+1. This decomposition has been implemented in Chambers et al. (1996).

2.3 Profit-oriented Luenberger indicator

In the literature, the non-parametric profit Luenberger productivity indicator (*PLPI*) introduced by Juo et al. (2015) is measured in terms of maximum-profit boundaries. Compared with the conventional Luenberger productivity, they use the profit inefficiency to replace the technical inefficiency, and define it as followed:

$$PLPI = \frac{1}{2}\left\{\left[\frac{\pi^t\left(p^t, w^t\right) - \left(p^t y^t - w^t x^t\right)}{p^t g_y^t + w^t g_x^t} - \frac{\pi^t\left(p^t, w^t\right) - \left(p^t y^{t+1} - w^t x^{t+1}\right)}{p^t g_y^{t+1} + w^t g_x^{t+1}}\right] + \left[\frac{\pi^{t+1}\left(p^{t+1}, w^{t+1}\right) - \left(p^{t+1} y^t - w^{t+1} x^t\right)}{p^{t+1} g_y^t + w^{t+1} g_x^t} - \frac{\pi^{t+1}\left(p^{t+1}, w^{t+1}\right) - \left(p^{t+1} y^{t+1} - w^{t+1} x^{t+1}\right)}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}}\right]\right\} \quad (9)$$

This is measure a profit-oriented productivity. It is defined by the arithmetic means of two terms (brackets) that are composed of the own-period and cross-period profit inefficiencies defined by Fare and Primont (2003). Similarly, this profit productivity improvement also are indicated by positive values and negative values. If the value of profit productivity is less than 0, it means the profit productivity decreases, If the value of is great than 0, it indicates a improved profit productivity, if the value of is 0, it shows a constant productivity.

Furthermore, the profit-oriented Luenberger indicator also can be decomposed into the profit efficiency change (*PEC*) and profit technology change (*PTC*) as follows:

$$PLPI = \left[\frac{\pi^t\ (p^t,w^t)-(p^t y^t-w^t x^t)}{p^t g_y^t+w^t g_x^t} - \frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_y^{t+1}+w^{t+1}g_x^{t+1}}\right] \qquad (PEC)$$

$$+\frac{1}{2}\left\{\left[\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^t-w^{t+1}x^t)}{p^{t+1}g_y^t+w^{t+1}g_x^t} - \frac{\pi^t\ (p^t,w^t)-(p^t y^t-w^t x^t)}{p^t g_y^t+w^t g_x^t}\right] + \right.$$

$$\left.\left[\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_y^{t+1}+w^{t+1}g_x^{t+1}} - \frac{\pi^t\ (p^t,w^t)-(p^t y^{t+1}-w^t x^{t+1})}{p^t g_y^{t+1}+w^t g_x^{t+1}}\right]\right\} \qquad (PTC)$$

(10)

The *PEC* is the term in the first bracket, it shows the degree of catch-up with the profit boundary cross two periods. The *PTC* is the second term in the brace it is the profit technology change of the DMU between period t and t+1 and measures shift of the profit boundary from $\left(\mathrm{x}^t, y^t\right)$ to $\left(\mathrm{x}^{t+1}, y^{t+1}\right)$. The values of the *PEC* and *PTC* greater than 0 indicates the improvements, while the values less than 0 means recession. Moreover, the profit-oriented productivity can be further decomposed into changes in technical efficiency, allocative efficiency, technology change, and price effect.

2.4 Allocation Luenberger indicator

In the spirit of the works of Chambers et al. (1996a, 1996b), Chambers et al. (1998) and Juo et al. (2015), this study defines the allocation productivity indicator (*ALI*) as

$$ALI = \frac{1}{2}\left\{\left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^t-w^{t+1}x^t)}{p^{t+1}g_y^t+w^{t+1}g_x^t} - \vec{D}^t\ \left(x^{t+1},y^{t+1};-g_x^{t+1},g_y^{t+1}\right)\right) - \right.\right.$$

$$\left.\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_y^{t+1}+w^{t+1}g_x^{t+1}} - \vec{D}^{t+1}\left(x^{t+1},y^{t+1};-g_x^{t+1},g_y^{t+1}\right)\right)\right] +$$

$$\left[\left(\frac{\pi^t\ (p^t,w^t)-(p^t y^t-w^t x^t)}{p^t g_y^t+w^t g_x^t} - \vec{D}^t\ \left(x^t,y^t;-g_x^t,g_y^t\right)\right) - \left(\frac{\pi^t\ (p^t,w^t)-(p^t y^{t+1}-w^t x^{t+1})}{p^t g_y^{t+1}+w^t g_x^{t+1}} - \right.\right.$$

$$\left.\left.\left.\vec{D}^{t+1}\left(x^t,y^t;-g_x^t,g_y^t\right)\right)\right]\right\} \qquad (11)$$

This indicator in above Eq. (11) can be applied to make resource allocation management within the assumption the input and output prices are known. The value of the allocation

Luenberger indicator greater than 0 means progress, the value less than 0 indicates regress, and the value equals 0 shows constant.

Followed decomposition in the Chambers et al. (1996) and Juo et al. (2015), this allocation indicator also can be decomposed into the allocative efficiency change (*AEC*) and allocative technical change (*ATC*) as follows:

$$ALI = \left[\left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t}-w^{t}x^{t})}{p^{t}g_{y}^{t}+w^{t}g_{x}^{t}} - \vec{D}^{t}\ \left(x^{t},y^{t};-g_{x}^{t},g_{y}^{t}\right)\right) - \left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_{y}^{t+1}+w^{t+1}g_{x}^{t+1}} - \vec{D}^{t+1}\left(x^{t+1},y^{t+1};-g_{x}^{t+1},g_{y}^{t+1}\right)\right)\right] \quad (AEC)$$

$$+\frac{1}{2}\left\{\left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t}-w^{t+1}x^{t})}{p^{t+1}g_{y}^{t}+w^{t+1}g_{x}^{t}} - \vec{D}^{t}\ \left(x^{t+1},y^{t+1};-g_{x}^{t+1},g_{y}^{t+1}\right)\right) - \left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t+1}-w^{t}x^{t+1})}{p^{t}g_{y}^{t+1}+w^{t}g_{x}^{t+1}} - \vec{D}^{t+1}\left(x^{t},y^{t};-g_{x}^{t},g_{y}^{t}\right)\right)\right] + \left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_{y}^{t+1}+w^{t+1}g_{x}^{t+1}} - \vec{D}^{t+1}\left(x^{t+1},y^{t+1};-g_{x}^{t+1},g_{y}^{t+1}\right)\right) - \left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t}-w^{t}x^{t})}{p^{t}g_{y}^{t}+w^{t}g_{x}^{t}} - \vec{D}^{t}\ \left(x^{t},y^{t};-g_{x}^{t},g_{y}^{t}\right)\right)\right]\right\} \quad (ATC)$$

(12)

The *AEC* is the change of the allocative efficiency between period t and t+1. It indicates the extent of catch-up with the optimum output-input mix over time.

$$AEC = \left[\left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t}-w^{t}x^{t})}{p^{t}g_{y}^{t}+w^{t}g_{x}^{t}} - \vec{D}^{t}\ \left(x^{t},y^{t};-g_{x}^{t},g_{y}^{t}\right)\right) - \left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_{y}^{t+1}+w^{t+1}g_{x}^{t+1}} - \vec{D}^{t+1}\left(x^{t+1},y^{t+1};-g_{x}^{t+1},g_{y}^{t+1}\right)\right)\right] \quad (13)$$

The *ATC* is the shift of the allocation technology of the DMU between period t and t+1, and measures the change of the production boundary evaluated at $\left(x^{t}, y^{t}\right)$ and $\left(x^{t+1}, y^{t+1}\right)$, and profit boundary evaluated at the prices $\left(p^{t}, w^{t}\right)$ and $\left(p^{t+1}, w^{t+1}\right)$.

$$ATC = \frac{1}{2}\left\{\left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t}-w^{t+1}x^{t})}{p^{t+1}g_{y}^{t}+w^{t+1}g_{x}^{t}} - \vec{D}^{t}\ \left(x^{t+1},y^{t+1};-g_{x}^{t+1},g_{y}^{t+1}\right)\right) - \left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t+1}-w^{t}x^{t+1})}{p^{t}g_{y}^{t+1}+w^{t}g_{x}^{t+1}} - \vec{D}^{t+1}\left(x^{t},y^{t};-g_{x}^{t},g_{y}^{t}\right)\right)\right] + \right.$$

$$\left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_y^{t+1}+w^{t+1}g_x^{t+1}}-\vec{D}^{t+1}(x^{t+1},y^{t+1};-g_x^{t+1},g_y^{t+1})\right)-\right.$$

$$\left.\left(\frac{\pi^{t}\ (p^{t},w^{t})-(p^{t}y^{t}-w^{t}x^{t})}{p^{t}g_y^{t}+w^{t}g_x^{t}}-\vec{D}^{t}\ (x^{t},y^{t};-g_x^{t},g_y^{t})\right)\right]\Bigg\} \quad (14)$$

The term of the *ATC* is in the study of Juo et al. (2015) defined as the price effect. Here, we prefer to call this term as the allocation-technology change. The values of *AEC* and *ATC* greater than 0 denote improvement, while the values less than 0 indicate the deterioration.

The Luenberger productivity indicator, profit Luenberger productivity indicator and allocation Luenberger indicator and their decompositions are illustrated in Figure 1. As shown in Juo et al. (2015), the profit Luenberger productivity indicator and its following decomposition are estimated under the assumption of variable returns to scale (VRS).

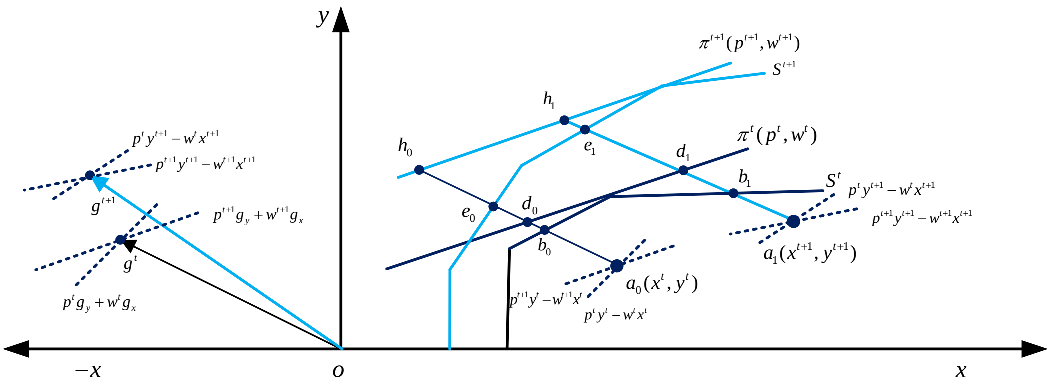

Fig.1 The decomposition of the indicators *LPI, ALI, PLPI*

The allocation Luenberger indicator can be presented in terms of the distances as follows:

$$API=\frac{1}{2}[(b_0d_0/0g-e_0h_0/0g)+(b_1d_1/0g-e_1h_1/0g)]$$

$$AEC=(b_0d_0/0g-e_1h_1/0g)$$

$$ATC=\frac{1}{2}[(b_1d_1/0g-b_0d_0/0g)+(e_1h_1/0g-e_0h_0/0g)]$$

The profit-oriented Luenberger indicator can be presented in terms of the distances as follows:

$$PLPI = \frac{1}{2}[(a_0 d_0/0g - a_1 d_1/0g) + (a_0 h_0/0g - a_1 h_1/0g)]$$

$$PEC = (a_0 d_0/0g - a_1 h_1/0g)$$

$$PTC = \frac{1}{2}(d_0 h_0/0g + d_1 h_1/0g)$$

The Luenberger indicator can be presented in terms of the distances as follows:

$$LPI = \frac{1}{2}[(a_0 b_0/0g - a_1 b_1/0g) + (a_0 e_0/0g - a_1 e_1/0g)]$$

$$TEC = (a_0 b_0/0g - a_1 e_1/0g)$$

$$TC = \frac{1}{2}[(a_0 e_0/0g - a_0 b_0/0g) + (a_1 e_1/0g - a_1 b_1/0g)]$$

2.5 Relationship of *LPI, ALI, PLPI*

It is well known that any DMU should have a good management with best use of production and resource, for obtaining a maximum-profit, therefore, it has to use available resources efficiently. Now, we will show the relationships among the *LPI, ALI, PLPI* in the framework of organization management.

According to Chambers et al. (1996), the profit inefficiency can be decomposed into technical inefficiency and allocative inefficiency: $\pi I = TI + AI$. Combined with Eq. (7)-(14), the relationship in, *LPI, ALI, PLPI* that is, *LPI+ ALI=PLPI* is shown as

$$PLPI = \frac{1}{2}\left\{\left[\frac{\pi^t\ (p^t,w^t)-(p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} - \frac{\pi^t\ (p^t,w^t)-(p^t y^{t+1} - w^t x^{t+1})}{p^t g_y^{t+1} + w^t g_x^{t+1}}\right] + \right.$$

$$\left.\left[\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^t - w^{t+1} x^t)}{p^{t+1} g_y^t + w^{t+1} g_x^t} - \frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^{t+1} - w^{t+1} x^{t+1})}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}}\right]\right\} =$$

$$\frac{1}{2}\left[\vec{D}^t\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right) + \vec{D}^t\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right) - \right.$$

$$\left.\vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right] + \frac{1}{2}\left\{\left[\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^t - w^{t+1} x^t)}{p^{t+1} g_y^t + w^{t+1} g_x^t} - \right.\right.\right.$$

$$\vec{D}^t\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)) - \left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^{t+1} - w^{t+1} x^{t+1})}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}} - \right.$$

$$\vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right))\Big] + \Big[(\frac{\pi^t\ (p^t,w^t)-(p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} - \vec{D}^t\ \left(x^t, y^t; -g_x^t, g_y^t\right)) -$$

$$(\frac{\pi_h^t (p^t,w^t)-(p^t y^{t+1} - w^t x^{t+1})}{p^t g_y^{t+1} + w^t g_x^{t+1}} - \vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right))\Big]\Big\} = LPI + ALI \qquad (15)$$

Furthermore, these indicators' component's also have the relationship:

$$PEC = \left[\vec{D}^t\ \left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right] +$$

$$\left[\left(\frac{\pi^t\ (p^t,w^t)-(p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} - \vec{D}^t\ \left(x^t, y^t; -g_x^t, g_y^t\right)\right) -\right.$$

$$\left.\left(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^{t+1} - w^{t+1} x^{t+1})}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}} - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right)\right]$$

$$= TEC + AEC \qquad (16)$$

Therefore, it can be conducted:

$$PTC = \frac{1}{2}\left\{\left[\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^t - w^{t+1} x^t)}{p^{t+1} g_y^t + w^{t+1} g_x^t} - \frac{\pi^t\ (p^t,w^t)-(p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t}\right] +\right.$$

$$\left.\left[\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^{t+1} - w^{t+1} x^{t+1})}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}} - \frac{\pi^t\ (p^t,w^t)-(p^t y^{t+1} - w^t x^{t+1})}{p^t g_y^{t+1} + w^t g_x^{t+1}}\right]\right\}$$

$$= \frac{1}{2}\left\{\left[\vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right) - \vec{D}^t\ \left(x^t, y^t; -g_x^t, g_y^t\right)\right] +\right.$$

$$\left.\left[\vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right) - \vec{D}^t\ \left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)\right]\right\}$$

$$+ \frac{1}{2}\Big\{\Big[(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^t - w^{t+1} x^t)}{p^{t+1} g_y^t + w^{t+1} g_x^t} - \vec{D}^t\ \left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)) -$$

$$(\frac{\pi^t\ (p^t,w^t)-(p^t y^{t+1} - w^t x^{t+1})}{p^t g_y^{t+1} + w^t g_x^{t+1}} - \vec{D}^{t+1}\left(x^t, y^t; -g_x^t, g_y^t\right))\Big] +$$

$$\Big[(\frac{\pi^{t+1}(p^{t+1},w^{t+1})-(p^{t+1} y^{t+1} - w^{t+1} x^{t+1})}{p^{t+1} g_y^{t+1} + w^{t+1} g_x^{t+1}} - \vec{D}^{t+1}\left(x^{t+1}, y^{t+1}; -g_x^{t+1}, g_y^{t+1}\right)) -$$

$$(\frac{\pi^t\ (p^t,w^t)-(p^t y^t - w^t x^t)}{p^t g_y^t + w^t g_x^t} - \vec{D}^t\ \left(x^t, y^t; -g_x^t, g_y^t\right))\Big]\Big\}$$

$$= TEC + AEC \qquad (17)$$

The profit Luenberger indicator can be further decomposed as follows:

PLPI=*PEC*+*PTC*

= (*AEC*+*TEC*) + (*TC*+*ATC*)

= (*TEC*+*TC*) + (*AEC*+ *ATC*)

$= LPI + ALI$ (18)

Where:

PEC= profit efficiency change

PTC= profit technology change

AEC= allocative efficiency change

TEC= technical efficiency change

TC= technical change

ATC= allocation-technology change

2.6 Implementing the decomposition

In order to implement the decomposition of the profit Luenberger productivity indicator, we use the DEA approach within the directional distance functions, depending on the measure of the Nerlovian profit inefficiency. Suppose that in the time period t (t =1,2,...,T), the j^{th} (j =1,2,...,J) DMU in the employs a vector of N inputs $x_j^t = (x_{j1}^t, x_{j2}^t, \cdots, x_{jN}^t)$ to generate a vector of M outputs $y_j^t = (y_{j1}^t, y_{j2}^t, \cdots, y_{jM}^t)$. For the j^{th} DMU in the h^{th} group, we assume its directional vector in each time period is a vector that equals the values of the DMU's own outputs and inputs each year, namely, $g^t = (-g_x^t, +g_y^t) = (-x_j^t, y_j^t)$. Technical inefficiency gives the expansion in outputs and contraction in inputs in terms of the directional vector.

The group-specific distance function $\vec{D}_j^t(x_j^t, y_j^t; -g_x^t, g_y^t)$ can be computed by using only the group's observations from the following mathematical programming:

$$\vec{D}_j^t(x_j^t, y_j^t; -x_j^t, y_j^t) = max\beta_j^t$$

$$\sum_{j=1}^{J} \lambda_{hj}^t y_{hj}^t \geq y_{jm}^t - \beta_j^t y_j^t \qquad m = 1, \dots, M$$

$$\sum_{j=1}^{J} \lambda_j^t x_j^t \geq x_{jn}^t - \beta_j^t x_j^t \qquad n = 1, \dots, N$$

$\sum_{j=1}^{J} \lambda_j^t = 1$

$\lambda_j^t \geq 0; j = 1, \dots, J$ (19)

Here, $\vec{D}_j^t(x_j^t, y_j^t; -x_j^t, y_j^t)$ represents this directional distance function in the j th DMU in the h[th] group seeking the maximum ratio of the increase in outputs and the decrease in inputs. This will produce a projected point on the surface of the production frontier along the direction of the expansion of outputs and the contraction of inputs. The constraint, $\sum_{j=1}^{J} \lambda_j^t = 1$, imposes a variable returns to scale (VRS) technology in the above linear programming problem. We now compute the cross-period directional distance function as follows:

$\vec{D}_{hj}^t(x_j^{t+1}, y_j^{t+1}; -x_j^{t+1}, y_j^{t+1}) = max\ \beta_j^{t,t+1}$

$\sum_{j=1}^{J} \lambda_j^t y_j^t \geq y_{jm}^{t+1} + \beta_j^{t,t+1} y_j^{t+1} \quad m = 1, \dots, M$

$\sum_{j=1}^{J} \lambda_j^t x_j^t \geq x_{jn}^{t+1} - \beta_j^{t,t+1} x_j^{t+1} \quad n = 1, \dots, N$

$\sum_{j=1}^{J} \lambda_j^t = 1$

$\lambda_j^t \geq 0; j = 1, \dots, J$ (20)

The other directional distance functions, $\vec{D}_j^{t+1}(x_j^{t+1}, y_j^{t+1}; -g_x^{t+1}, g_y^{t+1})$ and $\vec{D}_j^{t+1}(x_j^t, y_j^t; -g_x^t, g_y^t)$, can be computed using the above two linear programs by interchanging the time periods *t* and *t+1*. For DMU j, we denote the observed profit in period *t* at the prevailing output price and input price vectors, $p_{jm}^t = (p_{j1}^t, p_{j2}^t, \cdots, p_{jM}^t)$ and $w_{jn}^t = (w_{j1}^t, w_{j2}^t, \cdots, w_{jN}^t)$, as $p^t y^t - w^t x^t = \sum_{m=1}^{M} p_{jm}^t y_{jm}^t - \sum_{n=1}^{N} w_{jn}^t x_{jn}^t$. Similarly, we denote the other observed profits as: $p^{t+1} y^{t+1} - w^{t+1} x^{t+1} = \sum_{m=1}^{M} p_{jm}^{t+1} y_{jm}^{t+1} - \sum_{n=1}^{N} w_{jn}^{t+1} x_{jn}^{t+1}$, $p^{t+1} y^t - w^{t+1} x^t = \sum_{m=1}^{M} p_{jm}^{t+1} y_{jm}^t - \sum_{n=1}^{N} w_{jn}^{t+1} x_{jn}^t$ and $p^t y^{t+1} - w^t x^{t+1} = \sum_{m=1}^{M} p_{jm}^t y_{jm}^{t+1} - \sum_{n=1}^{N} w_{jn}^t x_{jn}^{t+1}$. Because $g^t = (-x_{hj}^t, y_{hj}^t)$., the normalized factors denote proxies for the firm production size, and they are defined as $p^t g_y^t + w^t g_x^t = \sum_{m=1}^{M} p_{jm}^t y_{jm}^t + \sum_{n=1}^{N} w_{jn}^t x_{jn}^t$ and. $p^{t+1} g_y^{t+1} + w^{t+1} g_y^{t+1} = \sum_{m=1}^{M} p_{jm}^{t+1} y_{jm}^{t+1} + \sum_{n=1}^{N} w_{jn}^{t+1} x_{jn}^{t+1}$

We then compute the maximum profit $\pi_{hj}^t(p_{hj}^t, w_{hj}^t)$ for DMU j in group h from the following linear programming model:

$$\pi_j^t(p_j^t, w_j^t) = max(p_j^t y_m - w_j^t x_n)$$

$$\sum_{j=1}^{J} \lambda_j^t y_j^t \geq y_m \qquad m = 1, \dots, M$$

$$\sum_{j=1}^{J} \lambda_j^t x_j^t \geq x_n \qquad n = 1, \dots, N$$

$$\sum_{j=1}^{J} \lambda_j^t = 1$$

$$\lambda_j^t \geq 0; j = 1, \dots, J \qquad (21)$$

Imposing VRS, $\sum_{j=1}^{J} \lambda_j^t = 1$, in this model implies a non-perfectly competitive market, and hence profit-maximum may not be zero. Given the price vector and the technology, the maximal profit (benchmark) is computed by the choosing quantity vector of outputs and inputs (x_n, y_m). We also compute $\pi_j^{t+1}(p_j^{t+1}, w_j^{t+1})$ using the above linear program by interchanging the time periods *t* and *t+1*.

3. Data and variables

The sample data consist of 31 Taiwanese banks over the period 2010-2014. The data set in this study has been extracted from the "Condition and Performance of Domestic Banks" published by the Central Bank of China (Taiwan) and the Taiwan Economic Journal (TEJ)[2].

This study follows the intermediation approach for the specification of inputs and

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[2] The "Condition and Performance of Domestic Banks" was downloaded from http://www.cbc.gov.tw/ct.asp?xItem=1062&ctNode=535&mp=2.

outputs. This approach assumes that the bank collects deposits to transform them with labor and capital into loans and other earning assets. According to Berger and Humphrey (1997), this study considers two outputs: financial investments (y1) and total loans (y2). The investments are defined as other earning assets, Including financial assets, securities, and equity investments. The corresponding unit price of the investments (p1) is the ratio of the income from investments to the investments. Total loans consist of all types of loans issued that generate a given amount of interest income. The corresponding unit price of loans (p2) is the ratio of the raised amounts of interest income to the total loans.

Table 1 specification of the variables

Variable	Name	Definition
Input variables		
x1	Financial funds	Including deposits and borrowed funds (unit: millions of NTD)
x2	Labour	Number of employees
x3	Physical capital	Net amount of fixed assets (unit:millions of NTD)
Output variables		
y1	Investments	Including financial assets,securities,and equity investments (unit:millions of NTD)
y2	Loans	Including loans and discounts (unit:millions of NTD)
Input price variables		
w1	Price of fund	Interest expenses divided by total deposit
w2	Price of labour	personal expenses divided by number of
w3	Price of physical capital	Total operational expenses net of personal expenses divided by fixed asset
Output price variables		
p1	Price of investment	Revenue from investments divided by investment
p2	Price of loan	Revenue from loans divided by loans

This study specifies three inputs to model the costs. The input vector includes financial funds (x1), labor (x2), and physical capital (x3). Financial funds are defined as deposits

Table 2 Summary statistics of inputs and outputs, 2010-2014

Variables		2010	2011	2012	2013	2014
Y1: Investments	Mean	187,961	181,994	194,437	214,921	230,035
	S.D.	207,176	206,563	206,074	218,922	230,185
Y2: Loans	Mean	572,290	613,507	637,418	669,197	708,287
	S.D.	533,507	565,061	577,935	596,871	622,293
X1 : Financial funds	Mean	771,830	811,660	845,805	903,346	952,879
	S.D.	702,142	721,346	745,922	812,084	830,734
X2: Labour	Mean	3,879	3,958	3,969	4,037	4,104
	S.D.	2,450	2,507	2,529	2,657	2,667
X3: Physical capital	Mean	12,588	13,471	13,454	13,560	13,938
	S.D.	14,697	18,112	18,291	18,192	18,436
P1 : Price of investment	Mean	0.0334	0.0303	0.0215	0.0167	0.0151
	S.D.	0.0551	0.0395	0.0169	0.0130	0.0090
P2 : Price of loan	Mean	0.0206	0.0229	0.0242	0.0238	0.0237
	S.D.	0.0040	0.0042	0.0044	0.0042	0.0035
W1: Price of financial fund	Mean	0.0057	0.0071	0.0077	0.0073	0.0076
	S.D.	0.0011	0.0012	0.0013	0.0012	0.0012
W2: Price of labour	Mean	1.1521	1.1932	1.2222	1.3088	1.3785
	S.D.	0.2943	0.3008	0.2726	0.3255	0.3542
W3: Price of physical capital	Mean	0.4115	0.4418	0.4926	0.4606	0.4902
	S.D.	0.40993	0.46588	0.49122	0.4846	0.5414

and borrowed funds. This input always accounts for the highest percentage of banks' total costs, while it also generates interest and other financial expenses. Thus, the corresponding unit price (w1) is calculated as the ratio of financial expenses to financial funds. Labor is defined as the number of employees, while the corresponding unit price (w2) is calculated as a ratio of personal expenses to the total number of employees. The last input, physical capital, corresponds to the bank's fixed assets, whose unit price (W3) is obtained as a ratio of associated costs (non-labor operational expenses, which are non-interest expenses minus personal expenses). Tables 1 define all the variables and present summary statistics and Table 2 presents summary statistics of all variables for Taiwanese banks from 2010 to 2014.

Table 2 shows that Taiwanese banks have slowly increase for the outputs and inputs. The share of the loans (y2) to the investments (y1) nearly is 3:1. It means the Taiwanese banks focus their business in the Loans. In terms of the prices, there is an opposite change for the output prices, the price of investment (p1) experiences a decrease from 0.0334 to 0.0151, and the price of the loan (p2) shows a slightly increase from 0.0206 to 0.0237. For the input prices, although they all show a growth over all sample period, the input prices of financial fund (w1) and physical capital (w3) have a sudden decrease between 2012 and 2013.

4. Results and discussion

Table 3 firstly presents the relationship among the profit-oriented Luenberger indicator (*PLPI*), Luenberger (*LPI*) and allocation Luenberger indicator (*ALI*) in the Taiwanese banks. It can be conducted that the Taiwanese banking industry have a profit performance growth between 2010 and 2014. This is because of the positive contributions in Luenberger indicator (0.0493) can offset the negative contributions in the allocation indicator (-0.0208). From the value of the median, it is conducted that the most of the Taiwanese banks have a positive improvement among *PLPI*, *LPI* and *ALI*, respectively with 0.0233, 0.0189 and 0.0049. We also find that the allocation indicator dominates Luenberger indicator for all banks. For the managers in the banks whose profit performance is negative, the most important job is to adjust their operating input-output mixes to boost their profits.

In the following, we use the decomposition in the Eq. (18) to explain the reasons behind the productivity changes of the *PLPI*, *LPI* and *ALI* in Taiwanese banks. Table 4 which presents the average productivity changes of the *PLPI*, *LPI* and *ALI*, and their decomposed components over the periods of 2010-2014. From the mean value, it can be seen the *PLPI*, *LPI* and *ALI* have a relationship as follows:

$$\begin{aligned} 0.0285 &= 0.3078 + (-0.2794) \\ &= (0.0145+0.2574) + [0.0347 + (-0.2782)] \\ &= (0.0145+0.0347) + [(0.2574 + (-0.2782)) \\ &= 0.0493 + (-0.0208) \end{aligned} \tag{22}$$

This is in line with the Eq. (18).

From the profit management point of view, the reason of the improved profit productivity of the Taiwanese banks can be considered at the profit efficiency change and the profit technology shift. It also is because the profit efficiency growth (0.2078) can offset the profit technology reduction (-0.2794). Furthermore, from the decomposition PEC=TEC + AEC and PTC=TC+ATC, the profit efficiency growth comes from the increases in the technical efficiency and allocative efficiency, and the reduction in the profit technology is because the positive contribution in the technology cannot offset the negative shift in the allocation technology.

Table 3 the *PLPI, LPI and ALI* in Taiwanese banks from 2010 to 2014

DMU	Bank	*PLPI*	*LPI*	*ALI*
DMU 1	Bank of Taiwan	-0.0293	0.2514	-0.2807
DMU 2	First Bank	-0.0457	0.1233	-0.1690
DMU 3	Hua Nan Bank	0.0006	0.0337	-0.0330
DMU 4	Mega Bank	0.0395	0.2121	-0.1726
DMU 5	Bank SinoPac	-0.0575	0.0606	-0.1182
DMU 6	E. Sun Bank	-0.0267	0.0909	-0.1176
DMU 7	Taishin Bank	0.1504	0.0633	0.0871
DMU 8	China Trust Bank	-0.0015	0.0149	-0.0163
DMU 9	Taipei Fubon Bank	0.0727	0.1863	-0.1136
DMU 10	Cathay United Bank	0.1338	0.0372	0.0966
DMU 11	Shin Kong Bank	0.0924	-0.0072	0.0996
DMU 12	Jih Sun Bank	0.0233	0.0075	0.0158
DMU 13	Yuan Ta	0.0790	0.0188	0.0602
DMU 14	Bank of Kaohsiung	0.0029	-0.0090	0.0119
DMU 15	Land Bank	-0.0242	0.0246	-0.0487
DMU 16	Chang Hwa Bank	0.0346	0.0075	0.0272
DMU 17	Citibank Taiwan	0.1462	0.1631	-0.0170
DMU 18	Shanghai Bank	0.0588	-0.0295	0.0883
DMU 19	Union Bank	0.1031	0.0189	0.0842
DMU 20	Far Eastern Bank	-0.1125	0.1465	-0.2590
DMU 21	Ta Chong Bank	0.0255	-0.0019	0.0274
DMU 22	EnTie Bank	0.0308	0.0347	-0.0038
DMU 23	Sunny Bank	0.0102	-0.0020	0.0122
DMU 24	Bank of Panhsin	0.0100	-0.0023	0.0123
DMU 25	Taiwan Business Bank	0.0019	-0.0111	0.0130
DMU 26	Standard Chartered Bank (Taiwan)	0.0539	0.0545	-0.0006
DMU 27	Taichung Bank	0.0386	-0.0106	0.0491
DMU 28	King's Town Bank	0.0740	0.0313	0.0427
DMU 29	HWATAI Bank	-0.0101	0.0053	-0.0154
DMU 30	COTA Bank	0.0041	-0.0009	0.0049
DMU 31	Bank of Taipei	0.0040	0.0155	-0.0115
	Mean	0.0285	0.0493	-0.0208
	Median	0.0233	0.0189	0.0049
	Max	0.1504	0.2514	0.0996
	Min	-0.1125	-0.0295	-0.2807

Table 4 The indicators of *PLPI, LPI and ALI* for Taiwanese banks from 2010 to 2014

	$PLPI = LPI + ALI$								
	$PLPI = PEC + PTC$			$LPI = TEC + TC$			$ALI = AEC + ATC$		
DMU	*PL*	*PEC*	*PTC*	*L*	*TEC*	*TC*	*AL*	*AEC*	*ATC*
DMU 1	-0.0293	0.0616	-0.0909	0.2514	0.0000	0.2514	-0.2807	0.0128	-0.2935
DMU 2	-0.0457	0.0663	-0.1120	0.1233	0.0000	0.1233	-0.1690	-0.0140	-0.1550
DMU 3	0.0006	0.0926	-0.0920	0.0337	0.0263	0.0074	-0.0330	-0.0404	0.0074
DMU 4	0.0395	0.0443	-0.0049	0.2121	0.0000	0.2121	-0.1726	0.0000	-0.1726
DMU 5	-0.0575	0.1021	-0.1596	0.0606	0.0002	0.0604	-0.1182	-0.0664	-0.0517
DMU 6	-0.0267	0.1628	-0.1895	0.0909	0.0420	0.0489	-0.1176	-0.0730	-0.0446
DMU 7	0.1504	0.5168	-0.3664	0.0633	0.0803	-0.0170	0.0871	0.1674	-0.0803
DMU 8	-0.0015	0.1321	-0.1336	0.0149	-0.0654	0.0802	-0.0163	0.1177	-0.1341
DMU 9	0.0727	0.0947	-0.0220	0.1863	0.0000	0.1863	-0.1136	0.0304	-0.1440
DMU 10	0.1338	-0.0822	0.2160	0.0372	0.0237	0.0135	0.0966	0.3371	-0.2406
DMU 11	0.0924	1.0166	-0.9242	-0.0072	-0.0052	-0.0020	0.0996	1.0477	-0.9482
DMU 12	0.0233	0.1447	-0.1214	0.0075	0.0235	-0.0161	0.0158	0.1708	-0.1550
DMU 13	0.0790	0.3329	-0.2539	0.0188	0.0000	0.0188	0.0602	0.2613	-0.2011
DMU 14	0.0029	0.1597	-0.1568	-0.0090	-0.0052	-0.0038	0.0119	0.0134	-0.0015
DMU 15	-0.0242	0.0216	-0.0458	0.0246	0.0000	0.0246	-0.0487	-0.0121	-0.0366
DMU 16	0.0346	0.1216	-0.0870	0.0075	0.0321	-0.0247	0.0272	0.0250	0.0021
DMU 17	0.1462	0.0512	0.0950	0.1631	0.1439	0.0192	-0.0170	0.1087	-0.1257
DMU 18	0.0588	0.0489	0.0098	-0.0295	0.0084	-0.0379	0.0883	0.1488	-0.0606
DMU 19	0.1031	2.3786	-2.2755	0.0189	0.0080	0.0109	0.0842	2.3947	-2.3105
DMU 20	-0.1125	0.0661	-0.1786	0.1465	-0.0130	0.1595	-0.2590	-0.2593	0.0003
DMU 21	0.0255	0.3338	-0.3082	-0.0019	0.0000	-0.0019	0.0274	0.0220	0.0055
DMU 22	0.0308	0.6281	-0.5973	0.0347	0.0080	0.0267	-0.0038	0.2805	-0.2843
DMU 23	0.0102	0.5120	-0.5018	-0.0020	-0.0009	-0.0011	0.0122	0.5506	-0.5384
DMU 24	0.0100	0.5434	-0.5334	-0.0023	-0.0003	-0.0020	0.0123	0.7149	-0.7026
DMU 25	0.0019	0.1048	-0.1029	-0.0111	-0.0054	-0.0057	0.0130	0.0011	0.0119
DMU 26	0.0539	0.1712	-0.1173	0.0545	0.1260	-0.0715	-0.0006	-0.0503	0.0497
DMU 27	0.0386	0.2340	-0.1954	-0.0106	0.0042	-0.0148	0.0491	0.1728	-0.1237
DMU 28	0.0740	0.7171	-0.6431	0.0313	0.0214	0.0099	0.0427	1.4389	-1.3962
DMU 29	-0.0101	0.3426	-0.3527	0.0053	-0.0023	0.0076	-0.0154	0.1156	-0.1310
DMU 30	0.0041	0.1959	-0.1918	-0.0009	0.0000	-0.0009	0.0049	0.1182	-0.1133
DMU 31	0.0040	0.2275	-0.2235	0.0155	0.0000	0.0155	-0.0115	0.2459	-0.2574
MEAN	0.0285	0.3078	-0.2794	0.0493	0.0145	0.0347	-0.0208	0.2574	-0.2782

From the indicator measurement point of view, the profit indicator increases is due to the positive impact of Luenberger indicator is greater than the negative effect of the allocation indicator.

It is turn to the production management point of view, the Luenberger productivity of the Taiwanese banking industry increases from 2010 to 2014 is due to both technical efficiency increases (0.0145) and the technical growth (0.0347). The contribution in technical growth is more influential than the technical efficiency to the Luenberger productivity.

When it comes to the resource allocation management, the allocation indicator of the banking industry regress is mainly resulted from the allocation technology regress (-0.2782) though the allocative efficiency progress (0.2574) offers a positive contribution to the allocation indicator.

Specifically for the DMUs, like DMU 1, it have a negative profit productivity from 2010 to 2014. By the decomposition in the profit indicator, it can be explained that the negative effect in profit technology is more functional than the profit efficiency increasing effect. For the productivity management of the DMU 1, it can be known that it have an increasing productivity which mainly comes from the contribution in the production technology progress, however, from the allocation indicator management, it have an adverse effect in allocation ability. Although the allocative efficiency increases from 2010 to 2014, the reduction in allocation technology severely limits the ability to the resource allocation, yielding the allocation indicator regresses. Therefore, for DMU 1, the top priority is to manage the input-output allocation, and improve the profit technology. Regarding to the DMU 4, it have a positive profit productivity. This is due to the contribution in the productivity can offset the impact in the negative allocation. In other words, the function of the productivity is more than that of the resource allocation, yielding the profit growth.

Table 5 Decomposition of *PLPI, LPI and ALI* for Taiwanese banks by types

		2010-2011	2011-2012	2012-2013	2013-2014	2010-2014
PLPI	FHC	-0.0209	0.0377	0.0025	0.0138	0.0083
	NFHC	-0.0039	0.0181	0.0044	0.0064	0.0063
	OVERALL	-0.0110	0.0264	0.0036	0.0095	0.0071
PEC	FHC	0.0866	0.0588	0.0246	0.0366	0.0516
	NFHC	0.1136	0.1697	0.0162	0.0815	0.0952
	OVERALL	0.1023	0.1232	0.0197	0.0627	0.0770
PTC	FHC	-0.1074	-0.0210	-0.0222	-0.0228	-0.0434
	NFHC	-0.1174	-0.1516	-0.0118	-0.0751	-0.0890
	OVERALL	-0.1132	-0.0968	-0.0161	-0.0532	-0.0698
LPI	FHC	0.0679	0.0136	-0.0092	0.0117	0.0210
	NFHC	0.0194	0.0059	0.0004	-0.0016	0.0060
	OVERALL	0.0398	0.0091	-0.0036	0.0040	0.0123
TEC	FHC	0.0169	-0.0036	0.0043	-0.0079	0.0024
	NFHC	0.0125	0.0034	0.0029	-0.0008	0.0045
	OVERALL	0.0144	0.0005	0.0035	-0.0038	0.0036
TC	FHC	0.0510	0.0172	-0.0135	0.0197	0.0186
	NFHC	0.0069	0.0024	-0.0024	-0.0008	0.0015
	OVERALL	0.0254	0.0086	-0.0070	0.0078	0.0087
ALI	FHC	-0.0888	0.0241	0.0117	0.0021	-0.0127
	NFHC	-0.0233	0.0123	0.0039	0.0080	0.0002
	OVERALL	-0.0507	0.0172	0.0072	0.0055	-0.0052
AEC	FHC	0.0696	0.0624	-0.0264	0.0445	0.0375
	NFHC	0.1011	0.1662	-0.0146	0.0823	0.0837
	OVERALL	0.0879	0.1227	-0.0196	0.0665	0.0644
ATC	FHC	-0.1584	-0.0383	0.0381	-0.0425	-0.0503
	NFHC	-0.1243	-0.1540	0.0186	-0.0743	-0.0835
	OVERALL	-0.1386	-0.1055	0.0268	-0.0609	-0.0696

As a result, we also can conclude that the ratio of the profit loss is not only from the productivity, but also from the resource allocation management. For any DMU, especially for the moribund DMU, it is important to focus on the allocation and production management.

Table 5 shows the panel results of the *PLPI*, *LPI* and *ALI* between 2010 and 2014. For overall baking industry, the average change of the profit performance due to the changes in productivity and resource allocation increases by 0.0071 over the period 2010-2014. The profit efficiency change is the positive source (0.0770) and the profit technology change is the negative and dominant source (-0.0698). From the productivity point of view, for the industry, we find that the Luenberger productivity of the Taiwanese banking industry have an increase with 0.0060. This is due to both of the technical efficiency progress and technical growth. However, from the allocation management point of view, although the allocative efficiency increases from 2010 to 2014, the allocation technology reduces severely, yielding the decrease in the allocation indicator. For the corporate structure, the financial holding company (FHC) and non-financial holding company (NFHC) have a positive profit productivity growth. The profit growth in FHC is faster than that in NFHC, maybe this is the FHC have a divergent investment or a more profit increasing point. By the decomposition of the profit indicator, it is found that the profit effect growth in the NFHC is greater than that in the FHC, and the profit technology

4. Conclusion

In this paper, following the study of Juo et al. (2004), a concept of an allocation Luenberger is proposed. Three kinds of productivity indicators of production, profit and allocation with their relationships in the framework of organization management are discussed. It is shown that the profit Luenberger productivity indicator (PLPI) can be decomposed into the Luenberger productivity indicator (LPI) and allocation Luenberger indicator (ALI). The LPI can further be decomposed into the technical change (TC) and technical efficiency change (TEC), and the ALI also can further be decomposed into the allocative efficiency change (AEC) and the allocative technology change (ATC). To illustrate an application of the proposed indicators, we adopt an empirical experiment within Taiwanese banking industry. This study employs panel data from 31 Taiwanese banks during the period 2010-2014 to measure the profit t Luenberger productivity indicator, Luenberger productivity indicator and allocation Luenberger indicator.

The empirical evidence here finds that Taiwanese banks show on average positive profit productivity growth. The growth mainly comes from the contribution of Luenberger productivity improvement which enough offset the decrease from the Allocation Luenberger. This indicates that production productivity is the main source for reducing any profit loss for Taiwanese banks. In terms of productivity change, the decompositions of the three types of Luenberger indicators illustrate the reasons of the productivity change of the Taiwanese banking industry from 2010 to 2014. We found that the profit Luenberger productivity of the Taiwanese banking industry progresses since the value of the profit efficiency increase is more influential than the value of the profit technology regress, the profit efficiency growth is the main factor to cause the profit productivity growth. We also showed that the allocation Luenberger indicator of the Taiwanese banking industry regresses due to the allocation technology decreases. The allocation technology regress is more influential than the allocation efficiency increase to the allocation Luenberger indicator. Finally, we find the profit productivity growth in financial holding companies is faster than that in non-financial holding companies, however the former’s allocation indicator is reducing and the latter’s is increasing.

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