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RISK-ADJUSTED PRODUCTIVITY CHANGE OF TAIWAN'S BANKS IN THE FINANCIAL HOLDING COMPANIES

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After financial holding company act was implemented in 2001, taiwan's banks have experienced structural changes. This study employs the risk-adjusted profit productivity indicator to investigate whether the banks in the financial holding companies (fhcs) could operate with higher productivity growth than those without establishing or joining fhcs. Equity capital which is regarded as a risk factor in this study. The data of taiwan's banks over the period 2010-2016 were taken for the above comparison.

***Keywords**: data envelopment analysis (dea); productivity change; risk; profit*

1. Introduction

As well known to us, the resources of individual financial institutions and cross sector financial mergers, such as between banks and securities and insurance companies, can be consolidated within a FHC. Rather than compete against homogenous financial products, banks can diversify their business scope under the FHCs. Therefore, the aim of commercial banks establishing or joining FHCs is to seek a greater business scope and resource share so as to obtain the optimal capital and cost reduction. It should be interesting to investigate whether establishing or joining FHCs can improve banks' operating efficiency and productivity in terms of profit.

A lot numbers of previous papers indicate that DEA has been widely applied to evaluating banks' operating performance. Most of them pay attention to technical efficiency and productivity change. If the input prices are available, a researcher can find the cost benchmark (the minimum cost) to measure a bank's cost efficiency which can be further decomposed into technical and allocative efficiencies. However, the most important objective of a bank, obviously, is to create profit. The number of DEA papers on profit efficiency is rather limited because of the insufficient output/input price information. Based on the same difficulty, most of the DEA literature measures productivity change in terms of quantity rather than profit. Since this study is related to banks' risk-adjusted profit performance, including productivity change, only the most relevant DEA literature is reviewed here.

The number of DEA papers aimed at productivity change in terms of profit is quite limited. Grifell-Tatjé and Lovell (1999) decomposed profit change into six different components so as to address its linkage with productivity change. There are several papers following the work of Grifell-Tatjé and Lovell (1999), such as Asaftei (2008), Sahoo and Tone (2009), Juo et al. (2012) and Juo (2014). However, profit decompositions in the above papers are also unit-dependent.

The constraints of leverage ratio and risk-based equity capital were used in Färe et al. (2004) to measure the profit inefficiency of U.S. banks. Based on their work, Koutsomanoli-Filippaki et al. (2009) and Koutsomanoli-Filippaki et al. (2012) used equity capital, considering the risk-return trade-off, to investigate profit efficiency of the banks in European countries. Fu et al. (2015) also decomposed profit inefficiency to compare profit performance of Taiwan's and China's banks. So far very few papers based on the Nerlovian profit measure profit performance in terms of productivity change. Juo et al. (2015) combine Luenberger productivity (LPI) and the Nerlovian profit measure to develop a profit productivity indicator which can be further decomposed into useful components in terms of profit. However, the indicator in Juo et al. (2015) did not take risk into account.

There have been papers on Taiwan's FHCs to explore their operating performance. Chiou (2009) investigated the influences of Financial Holding Company Act implemented in 2001 on commercial bank performance and the determinants of performance of banks in Taiwan during 1999–2004. Because FHCs in Taiwan have each begun to function as a management umbrella by investing in different types of financial services such as banking, insurance, and securities, Lo and Lu (2009) focused on this local financing issue from an integrated methodological perspective by model innovations proposed in several earlier studies, such as the combined efficiency of profitability and marketability, slacks based measure (SBM) of super efficiency and the SBM Malamquist index. Lu and Lo (2009) used an interactive benchmark model which resolves the problems associated with ranking fairly for both efficient and inefficient decision making units (DMUs) to 14 FHCs in Taiwan. Hu et al. (2009) adopted a multiple data envelopment analysis (DEA) approach, CCR (as proposed by Chambers et al., 1978), BCC (as proposed by Banker et al., 1984), Bilateral, SBM and the free disposal hull model, to rate the relative efficiency of Taiwan's FHCs in an emerging economy. Liu (2011) took the series relationship of two individual stages into account to measure of profitability and marketability efficiencies of Taiwan's FHCs. So far all the papers on Taiwan's FHCs have never considered productivity change resulting from the change in the improper output/input compositions and the change in relative output/input prices.

Considering risk and profit, this study divides Taiwan's banks into two groups-that is, banks that joined FHCs (named as FHC banks) and banks that have not joined FHCs (named as non-FHC banks), which are compared in terms of productivity change.

The remainder of this study is organized as follows. Section 2 proposes the methodology to decompose profit inefficiency and the profit productivity change for the model with risk adjustment and the model without risk adjustment. Section 3 lists the definitions of variables and data descriptions. Section 4 deals with the empirical results. The conclusions follow in Section 5.

2. Methodology

Assume that there are k=1, 2, ..., K banks which use the variable input vector xt ( ) to produce the output vector yt ( ) in time period t (t = 1, 2,..., T). The directional distance function (DDF) of Chambers et al. (1996) is used to establish the production set. Under the variable returns to scale (VRS), the production set of DMU k without risk adjustment can be denoted by:

$$S^t = \left\{ \begin{array}{c} (y_k^t, x_k^t): \sum_{o=1}^K \lambda_{om}^t y_{om}^t \geq y_{km}^t, \sum_{o=1}^K \lambda_{on}^t x_{on}^t \leq x_{kn}^t, \sum_{o=1}^K \lambda_o^t = 1; \\ m = 1, \ldots, M; n = 1, \ldots, N; k = 1, \ldots, K \end{array} \right\} \quad (1)$$

The risk-adjusted production set of DMU k is defined as:

$$\hat{S}^t = \left\{ \begin{array}{c} (y_k^t, x_k^t, e_k^t): \sum_{o=1}^K \lambda_{om}^t y_{om}^t \geq y_{km}^t, \sum_{o=1}^K \lambda_{on}^t x_{on}^t \leq x_{kn}^t, \sum_{o=1}^K \lambda_o^t e_o^t \leq e_k^t, \\ \sum_{o=1}^K \lambda_o^t = 1; m = 1, \ldots, M; n = 1, \ldots, N; k = 1, \ldots, K \end{array} \right\} \quad (2)$$

The inequality, $\sum_{o=1}^K \lambda_o^t e_o^t \leq e_k^t$, in $\hat{S}t$ denotes the quasi-fixed input constraint. That is, equity capital cannot be adjusted in the short run.

Based on Chambers et al. (1996), technical inefficiencies without and with risk adjustment are defined as Equations (3) and (4) respectively.

$$TI^t \equiv \vec{D}^t(y^t, x^t; g_y^t, -g_x^t) = sup\{\beta^t : (y^t + \beta^t g_y^t,\ x^t - \beta^t g_x^t) \in S^t\} \quad (3)$$

$$\widehat{TI}^t \equiv \widehat{D}^t(y^t, x^t, e^t; g_y^t, -g_x^t, 0) = sup\{\hat{\beta}^t : (y^t + \hat{\beta}^t g_y^t,\ x^t - \hat{\beta}^t g_x^t) \in \hat{S}^t\} \quad (4)$$

The risk-adjusted profit function is defined as:

$$\hat{\pi}^t(p^t, w^t) = sup_{x^*, y^*}\{p^t y^* - w^t x^* : (y^*, x^*) \in \hat{S}^t\} \quad (5)$$

where (y*, x*) is the profit maximizing quantity vectors of output and variable input in $\hat{S}t$ and pt$\in R_+^M$ and wt $\in R_+^N$ are the price vectors of outputs and variable inputs in period t, respectively.

In the spirit of the conventional LPI, the study modifies the work of Juo et al. (2015) to define the risk-adjusted profit productivity indicator ($\widehat{PPI}^{t,t+1}$ over two time periods, t and t+1, as: $\widehat{PPI}^{t,t+1}$

$$= \frac{1}{2}\left\{\left[\frac{\hat{\pi}^t(p^t,\ w^t)-(p^t\ y^t-w^t\ x^t)}{p^t\ g_y^t+w^t\ g_x^t} + \frac{\hat{\pi}^t(p^t,\ w^t)-(p^t\ y^{t+1}-w^t\ x^{t+1})}{p^t\ g_y^{t+1}+w^t\ g_x^{t+1}}\right] + \left[\frac{\hat{\pi}^{t+1}(p^{t+1},\ w^{t+1})-(p^{t+1}\ y^t-w^{t+1}\ x^t)}{p^{t+1}\ g_y^t+w^{t+1}\ g_x^t} - \frac{\hat{\pi}^{t+1}(p^{t+1},\ w^{t+1})-(p^{t+1}\ y^{t+1}-w^{t+1}\ x^{t+1})}{p^{t+1}\ g_y^{t+1}+w^{t+1}\ g_x^{t+1}}\right]\right\} \qquad (6)$$

Equation (6) is defined as the average value of two terms (brackets) which respectively represent the change in productivity based on two benchmarks, the risk-adjusted profit boundaries in periods t and t+1. All the components in Equation (8) are normalized by the directional vector values corresponding to their respective quantity and price vectors.Thus $\widehat{PPI}$ and its further decompositions are unit independent. A value of $\widehat{PPI}$ greater than 0 indicates profit productivity improvement, a value less than 0 denotes profit productivity deterioration, and a value equal to 0 implies unchanged profit productivity.

$\widehat{PPI}^{t,t+1}$ in Equation (6) can be further decomposed into the changes in risk-adjusted profit efficiency ($\Delta\widehat{\pi E}^{t,t+1}$) and profit technology ($\Delta\widehat{\pi T}^{t,t+1}$) as:

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

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

$$(\Delta\widehat{\pi T}^{t,t+1}) \qquad (7)$$

where $\Delta\widehat{\pi E}^{t,t+1}$ indicates the degree of catch-up with the risk-adjusted profit boundary over time and $\Delta\widehat{\pi E}^{t,t+1}$ calculates the shift of the risk-adjusted profit boundary. Values of $\Delta\widehat{\pi E}^{t,t+1}$ and $\Delta\widehat{\pi T}^{t,t+1}$ greater than 0 mean improvement, while values of less than 0 suggest deterioration.

The study now further decomposes $\Delta\widehat{\pi E}^{t,t+1}$ into the changes in technical efficiency ($\Delta\widehat{TE}^{t,t+1}$) and allocative efficiency ($\Delta\widehat{AE}^{t,t+1}$) as:

$$\Delta\widehat{\pi E}^{t,t+1}$$

$$= \left[\hat{D}^t(y^t, x^t, e^t; g_y^t, -g_x^t, 0) - \hat{D}^{t+1}(y^{t+1}, x^t, e^{t+1}; g_y^{t+1}, -g_x^{t+1}, 0)\ \right] \qquad (\Delta\widehat{TE}^{t,t+1})$$

$$+\left[\left(\frac{\hat{\pi}^t(p^t,\ w^t)-(p^t y^t-w^t x^t)}{p^t\ g_y^t+w^t\ g_x^t} - \hat{D}^t(y^t, x^t, e^t; g_y^t, -g_x^t, 0)\right) - \left(\frac{\hat{\pi}^{t+1}(p^{t+1},\ w^{t+1})-(p^{t+1} y^{t+1}-w^{t+1} x^{t+1})}{p^{t+1}\ g_y^{t+1}+w^{t+1}\ g_x^{t+1}} - \hat{D}^{t+1}(y^{t+1}, x^{t+1}, e^{t+1}; g_y^{t+1}, -g_x^{t+1}, 0)\right)\right]$$

$$(\Delta\widehat{AE}^{t,t+1}) \qquad (8)$$

Here, $\Delta\widehat{TE}^{t,t+1}$ measures the degree of catch-up with the risk-adjusted production frontier, whereas $\Delta\widehat{AE}^{t,t+1}$ indicates the extent of catch-up with the maximum-profit composition of output-input over time. The critical value of judging improvement and deterioration in the above components is 0. The values of $\Delta\widehat{TE}^{t,t+1}$ and $\Delta\widehat{AE}^{t,t+1}$ greater than 0 denote improvement, whereas the values of less than 0 represent deterioration.

On the other hand, the shift of profit boundary ($\Delta\widehat{\pi T}^{t,t+1}$) in Equation (7) can be decomposed into the change in risk-adjusted technical change ($\Delta\hat{T}^{t,t+1}$) and the risk-adjusted price effect ($\Delta\widehat{PE}^{t,t+1}$) as:

$$\Delta\widehat{\pi T}^{t,t+1} = \frac{1}{2}\left\{\begin{array}{c}\left[\hat{D}^{t+1}\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)-\hat{D}^t\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)\right]\\ +\left[\hat{D}^{t+1}\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)-\hat{D}^t\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)\right]\end{array}\right\}\ (\Delta\hat{T}^{t,t+1})$$

$$+\frac{1}{2}\left\{\begin{array}{c}\left[\begin{array}{c}\left(\frac{\hat{\pi}^{t+1}(p^{t+1},\ w^{t+1})-(p^{t+1}y^t-w^{t+1}x^t)}{p^{t+1}g_y^t+w^{t+1}g_x^t}-\frac{\hat{\pi}^t(p^t,\ w^t)-(p^t y^t-w^t x^t)}{p^t g_y^t+w^t g_x^t}\right)\\ -\left(\hat{D}^{t+1}\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)-\hat{D}^t\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)\right)\end{array}\right]\\ +\left[\begin{array}{c}\left(\frac{\hat{\pi}^{t+1}(p^{t+1},\ w^{t+1})-(p^{t+1}y^{t+1}-w^{t+1}x^{t+1})}{p^{t+1}g_y^{t+1}+w^{t+1}g_x^{t+1}}-\frac{\hat{\pi}^t(p^t,\ w^t)-(p^t y^{t+1}-w^t x^{t+1})}{p^t g_y^{t+1}+w^t g_x^{t+1}}\right)\\ -\left(\hat{D}^{t+1}\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)-\hat{D}^t\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)\right)\end{array}\right]\end{array}\right\}\ (\Delta\widehat{PE}^{t,t+1})\quad (9)$$

The first component, $\Delta\hat{T}^{t,t+1}$, reflects the shift of risk-adjusted production frontier over time. A value of greater than 0 means the improvement in technology, while a value of less than 0 denotes technical deterioration. However, the shift of the risk-adjusted profit boundary ($\Delta\widehat{\pi T}^{t,t+1}$) is not only induced by the shift of production frontier but also induced by the impact of the change in relative output-input prices on the risk-adjusted profit boundary, which is denoted by $\Delta\widehat{PE}^{t,t+1}$. In sum, $\widehat{PPI}^{t,t+1}$ can be expressed as the sum of the following components

$$\widehat{PPI}^{t,t+1}=\Delta\widehat{\pi E}^{t,t+1}+\Delta\widehat{\pi T}^{t,t+1} =(\Delta\widehat{TE}^{t,t+1}+\Delta\widehat{AE}^{t,t+1})+(\Delta\hat{T}^{t,t+1}+\Delta\widehat{PE}^{t,t+1}) \quad (10)$$

Under the technology without risk adjustment, S^t, the profit productivity indicator ($\widehat{PPI}^{t,t+1}$) can be decomposed into the components which correspond to those in Equation (10) as:

$$PPI^{t,t+1} = \Delta\pi E^{t,t+1} + \Delta\pi T^{t,t+1} = (\Delta TE^{t,t+1} + \Delta AE^{t,t+1}) + (\Delta T^{t,t+1} + \Delta PE^{t,t+1}) \quad (11)$$

All the terms in Equation (11) are defined by the same structures as those in Equations (6) to (9) where $\hat{\pi}^a$ (p^a,w^a) and $\hat{D}^a(y^b,x^b,e^b;g_y^b,-g_x^b,0)$ are replaced by π^a (p^a,w^a) and $\vec{D}^a(y^b,x^b;g_y^b,-g_x^b)$ for a=t, t+1 and b=t, t+1.

For each bank, the risk-adjusted directional distance functions, $\hat{D}^t\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)$, $\hat{D}^t\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)$, $\hat{D}^{t+1}\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)$, and $\hat{D}^{t+1}\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)$ are measured by the linear programming models in Equations (12) to (15).

$$\hat{D}^t\left(y^t,x^t,e^t;g_y^t,-g_x^t,0\right)=\max\beta$$
$$\begin{aligned} s.t.\ &\textstyle\sum_{o=1}^{K}\lambda_o y_{om}^t \ge y_m^t+\beta g_y^t \quad m=1,\dots,M\\ &\textstyle\sum_{o=1}^{K}\lambda_o x_{on}^t \le x_n^t-\beta g_x^t \quad n=1,\dots,N\\ &\textstyle\sum_{o=1}^{K}\lambda_o e_o^t \le e_n^t\\ &\textstyle\sum_{o=1}^{K}\lambda_o=1,\quad \lambda_o^t\ge 0\end{aligned}\quad (12)$$

$$\hat{D}^t\left(y^{t+1},x^{t+1},e^{t+1};g_y^{t+1},-g_x^{t+1},0\right)=\max\beta$$
$$\begin{aligned} s.t.\ &\textstyle\sum_{o=1}^{K}\lambda_o y_{om}^t \ge y_m^{t+1}+\beta g_y^{t+1} \quad m=1,\dots,M\\ &\textstyle\sum_{o=1}^{K}\lambda_o x_{on}^t \le x_n^{t+1}-\beta g_x^{t+1} \quad n=1,\dots,N\\ &\textstyle\sum_{o=1}^{K}\lambda_o e_o^t \le e_n^{t+1}\\ &\textstyle\sum_{o=1}^{K}\lambda_o=1,\quad \lambda_o^t\ge 0\end{aligned}\quad (13)$$

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$$\hat{D}^{t+1}\left(y^{t+1}, x^{t+1}, e^{t+1}; g_y^{t+1}, -g_x^{t+1}, 0\right) = \max \beta$$

$$\begin{aligned} & s.t. \sum_{o=1}^{K} \lambda_o y_{om}^{t+1} \geq y_m^{t+1} + \beta g_y^{t+1} \quad m = 1, \dots, M \\ & \sum_{o=1}^{K} \lambda_o x_{on}^{t+1} \leq x_n^{t+1} - \beta g_x^{t+1} \quad n = 1, \dots, N \\ & \sum_{o=1}^{K} \lambda_o e_o^{t+1} \leq e_n^{t+1} \\ & \sum_{o=1}^{K} \lambda_o = 1, \quad \lambda_o^{t+1} \geq 0 \end{aligned} \quad (14)$$

$$\hat{D}^{t+1}\left(y^{t}, x^{t}, e^{t}; g_y^{t}, -g_x^{t}, 0\right) = \max \beta$$

$$\begin{aligned} & s.t. \sum_{o=1}^{K} \lambda_o y_{om}^{t+1} \geq y_m^{t} + \beta g_y^{t} \quad m = 1, \dots, M \\ & \sum_{o=1}^{K} \lambda_o x_{on}^{t+1} \leq x_n^{t} - \beta g_x^{t} \quad n = 1, \dots, N \\ & \sum_{o=1}^{K} \lambda_o e_o^{t+1} \leq e_n^{t} \\ & \sum_{o=1}^{K} \lambda_o = 1, \quad \lambda_o^{t} \geq 0 \end{aligned} \quad (15)$$

The maximum profits, $\pi^t(p^t, w^t)$ and $\pi^{t+1}(p^{t+1}, w^{t+1})$, are measured by the following linear programming models.

$$\begin{aligned} & \hat{\pi}^t(p^t, w^t) = \max \sum_{m=1}^{M} p_m^t y_m^* - \sum_{n=1}^{N} w_n^t x_n^* \\ & s.t. \sum_{o=1}^{K} \lambda_o y_{om}^t \geq y_m^* \quad m = 1, \dots, M \\ & \sum_{o=1}^{K} \lambda_o x_{on}^t \leq x_n^* \quad n = 1, \dots, N \\ & \sum_{o=1}^{K} \lambda_o e_o^t \leq e_n^t \\ & \sum_{o=1}^{K} \lambda_o = 1, \lambda_o \geq 0 \end{aligned} \quad (16)$$

$$\begin{aligned} & \hat{\pi}^{t+1}(p^{t+1}, w^{t+1}) = \max \sum_{m=1}^{M} p_m^{t+1} y_m^* - \sum_{n=1}^{N} w_n^{t+1} x_n^* \\ & s.t. \sum_{o=1}^{K} \lambda_o y_{om}^{t+1} \geq y_m^* \quad m = 1, \dots, M \\ & \sum_{o=1}^{K} \lambda_o x_{on}^{t+1} \leq x_n^* \quad n = 1, \dots, N \\ & \sum_{o=1}^{K} \lambda_o e_o^{t+1} \leq e_n^{t+1} \\ & \sum_{o=1}^{K} \lambda_o = 1, \lambda_o \geq 0 \end{aligned} \quad (17)$$

The variable returns to scale (VRS) constraint, $\sum_{o=1}^{K} \lambda_o = 1$, effectively ensures feasible solutions, otherwise we will find either unbounded profit or zero maximal profit under the constant returns to scale (CRS) assumption.

Without risk adjustment, the directional distance functions and the profit functions under the production technology St in Equation (1) can be obtained by excluding the quasi-fixed input constraint from Equations (12) to (17).

3. Variables and data

There are two outputs, financial investments (y1) and loans (y2) and three variable inputs, funds (x1), labor (x2, the number of employees) and physical capital (x3, the net value of property and equipment). Equity capital (e) is the only fixed input in order to control for risk-return trade-off. The unit prices of outputs are defined as: the ratio of interests obtained from loans over the amount of loans (p1) and the average interest earned per New Taiwan Dollar (TWD) of investments (p2). The variable input prices include: the average interest paid per TWD of borrowed funds (w1), the ratio of labor cost over the number of staff (w2), and the non-labor operational cost (operational expenses other than personnel expenses) per TWD of physical capital (w3).

Table 2 summarizes statistics of all variables. This study chooses the balanced panel data of Taiwan's banks covering 2010-2016. The dataset consists of Taiwan's banks which are further divided to two groups-that is, the banks that established or joined FHCs (i.e. FHC banks) and the banks that have not established or joined FHCs (i.e. non-FHC banks).

Table 1 first shows the banks' operations in terms of output and input quantities. We observe the difference in prices of outputs and inputs between FHC and non-FHC banks. Although the operation size of FHC banks was larger than non-FHC banks in terms of output and input quantities, both the former's output prices were lower than the later during most of the sample years. As for input prices, both the prices of funds and physical capital (w1 and w3) in FHC banks were lower than those in non-FHC banks in most of the sample years. On the other hand, FHC banks' labor price (w2) was higher than that of non-FHC banks during the whole sample period.

Next, we explore the structure of revenue which is first reflected by the gap between investments (y1) and loans (y2). Within each group, loans (y2) dominated investments (y1) and the former output share to loans was over 70% during the whole sample period. Moreover, the gap between investments and loans was larger within non-FHC banks than that within FHC banks. However, there is a different scenario in which the price of investment (p1) dominated the price of loan (p2) in the first four sample years, 2008-2011. Their difference was huger within the non-FHC group. The price of investment was slightly lower than that of loan for both groups after 2011. The above results seem to indicate that there were improper compositions of outputs in Taiwnan's banks, especially for non-FHC banks.

Table 1: *Descriptive statistics of variables (mean), 2008-2014*

		2010	2011	2012	2013	2014	2015	2016
	y1	315,901	304,589	320,760	350,599	382,989	420,599	432,989
	y2	864,572	933,216	981,222	1,036,428	1,095,993	1,136,429	1,295,991
	p1	0.0222	0.0240	0.0209	0.0158	0.0157	0.0128	0.0137
	p2	0.0186	0.0206	0.0217	0.0213	0.0218	0.0223	0.0219
	x1	1,191,436	1,249,110	1,310,362	1,422,052	1,501,515	1,522,052	1,631,515
FHC banks	x2	5,529	5,736	5,790	6,015	6,126	6,213	6,228
	x3	20,144	22,271	22,559	22,627	23,372	24,628	25,371
	w1	0.0053	0.0067	0.0073	0.0069	0.0075	0.0079	0.0072
	w2	1.2452	1.2816	1.3349	1.4173	1.5276	1.6183	1.7266
	w3	0.3803	0.3800	0.4368	0.4045	0.4107	0.4145	0.4117
	e	88,113	93,483	103,631	112,330	127,436	132,336	137,431
	y1	65,687	73,265	95,560	93,454	103,203	116,931	119,568
	y2	327,803	337,307	361,198	382,605	389,115	403,975	428,278
	p1	0.0685	0.0423	0.0414	0.0348	0.0220	0.0173	0.0146
	p2	0.0375	0.0229	0.0220	0.0247	0.0260	0.0256	0.0251
	x1	402,465	440,589	468,782	495,723	510,291	528,725	556,643
non-FHC banks	x2	2,567	2,590	2,687	2,674	2,654	2,609	2,643
	x3	7,266	7,249	7,131	7,116	6,878	7,012	7,124
	w1	0.0185	0.0091	0.0059	0.0073	0.0081	0.0076	0.0076
	w2	1.0085	1.0290	1.0849	1.1294	1.1409	1.2304	1.2709
	w3	0.3575	0.3704	0.4339	0.4865	0.5329	0.5010	0.5476
	e	28,958	31,381	33,614	36,509	39,077	41,390	44,792

4. Empirical results

4.1. Profit productivity analysis at the industry level

The results of decomposing the profit productivity indicator at the industry level are summarized in Table 2. The indicator is first decomposed into the profit efficiency change and the profit technology change. For comparison, the results are divided into those with risk adjustment and those without risk adjustment. As discussed above, the profit productivity indicator is defined by the normalized average differential of profit inefficiencies between two periods. After adjusting risk, the normalized average ratio of the banking industry's profit loss due to a change in productivity and a change in relative prices decreased by 0.0412 over the period 2010-2016. Both profit efficiency change and profit technology change made positive contribution to the risk-adjusted profit productivity indicator, up to the average degree of $\Delta\widehat{\pi E}$ = 0.0227 and $\Delta\widehat{\pi T}$ =0.0185 respectively. The panel results of this industry show that the risk-adjusted profit efficiency deteriorated ($\Delta\widehat{\pi E}<0$) in two out of six sample periods (2011-2012 and 2014-2015), and the risk-adjusted profit technology deteriorated ($\Delta\widehat{\pi T}<0$) in three sample periods (2010-2011, 2012-2013 and 2013-2014). Their combined effect induced improvement in the risk-adjusted profit productivity over all the sample periods. Moreover, the risk-adjusted profit productivity improved up to the highest degree of $\widehat{PPI}$ =0.0691 during the period 2011-2012.

average degrees of improvement in profit productivity and its two components outperformed those in the risk-adjusted results. Second, compared to the risk-adjusted results, profit productivity without risk adjustment did not always improved over all the sample periods. The later deteriorated during the period 2010-2011, in which the deterioration in profit efficiency ($\Delta\pi$E=-0.2344) dominated the improvement in profit technology ($\Delta\pi$T=0.2177).

The further decompositions of the changes in profit efficiency and profit technology are presented in Table 3 which divides the results into those with and without risk adjustment. The risk-adjusted results first show that all the four components of profit productivity improved on average. The change in allocative efficiency was the dominant source of profit efficiency change and the price effect was the main source of profit technology change.

The panel results in Table 3 further show that all the components of the risk-adjusted profit productivity improved in four out of six sample periods. As shown in Table 2, the risk-adjusted profit productivity of the overall Taiwan banking industry improved

Table 2: *Decomposition of profit productivity indicator at the industry level*

		2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	**2010-2016**
With risk adjustment	$\widehat{PPI}$	0.0165	0.0691	0.0342	0.0521	0.0381	0.0373	**0.0412**
	$\Delta\widehat{\pi E}$	0.0434	-0.2171	0.2457	0.0541	-0.0040	0.0141	**0.0227**
	$\Delta\widehat{\pi T}$	-0.0268	0.2862	-0.2115	-0.0020	0.0421	0.0232	**0.0185**
Without risk adjustment	PPI	-0.0167	0.1596	0.1434	0.1805	0.1247	0.1573	**0.1248**
	$\Delta\pi$E	-0.2344	-0.8765	0.5677	0.6685	0.0501	0.2814	**0.0761**
	$\Delta\pi$T	0.2177	1.0361	-0.4243	-0.4881	0.0746	-0.1241	**0.0486**

The other half of Table 2 shows the results of decomposing profit productivity indicator without risk adjustment. Compared to the risk-adjusted results, there are two major differences. First, the

with the highest degree (up to $\widehat{PPI}$ =0.0691) during the period 2011-2012, and the price effect was the dominant component with a value of $\Delta\widehat{PE}$ = 0.2581 (see Table 3). Under the risk-adjusted technology, allocative efficiency change and the price effect dominated the other two components in most of the sample periods.

Table 3: *Decomposition of the changes in profit efficiency and profit technology at the industry level*

			2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	**2010-2016**
With risk adjustment	$\Delta\widehat{\pi E}$	$\Delta\widehat{TE}$	-0.0087	-0.0102	0.0211	0.0073	0.0027	0.0015	**0.0023**
		$\Delta\widehat{AE}$	0.0520	-0.2069	0.2246	0.0468	-0.0067	0.0126	**0.0204**
	$\Delta\widehat{\pi T}$	$\Delta\hat{T}$	0.0008	0.0281	-0.0210	-0.0033	0.0007	0.0042	**0.0016**
		$\Delta\widehat{PE}$	-0.0276	0.2581	-0.1905	0.0013	0.0414	0.0190	**0.0169**
Without risk adjustment	$\Delta\pi E$	ΔTE	-0.0075	-0.0083	0.0204	0.0057	0.0050	0.0003	**0.0026**
		ΔAE	-0.2270	-0.8683	0.5473	0.6628	0.0451	0.2811	**0.0735**
	$\Delta\pi T$	ΔT	-0.0005	0.0283	-0.0200	-0.0001	0.0005	0.0036	**0.0019**
		ΔPE	0.2182	1.0078	-0.4043	-0.4879	0.0741	-0.1277	**0.0467**

The results without risk adjustment are presented in the bottom half of Table 3. As shown in Table 2, profit productivity deteriorated with a degree of PPI =-0.0167 during the first period, 2010-2011, and the deterioration of allocative efficiency was the main source, up to a degree of ΔAE =-0.2270 (see Table 3). Profit productivity grew afterwards. It improved up to the highest degree of PPI =-0.1805 during the 2013-2014, and allocative efficiency change was the main source, up to a degree of ΔAE =0.6628.

4.2. Profit productivity analysis with respect to the type of banks

Table 4 shows the estimates of the profit productivity indicator and its sources of growth, the change in profit efficiency and profit technology, with respect to the type of banks. Both the FHC and non-FHC banks improved in profit productivity in most of the sample periods, up to the average degrees of $\widehat{PPI}$ =0.0360 versus 0.0450. However, two groups' profit productivity growth came from different sources. The former came from their profit boundaries shifted up, up to the average degree of $\Delta\widehat{\pi T}$ =0.0308. On the other hand, the growth of non-FHC banks' profit productivity was mainly attributed to the improvement in technical efficiency, with an average degree of $\Delta\widehat{\pi E}$ =0.0354. With respect to the panel results, Table 4 further shows that non-FHC banks' profit productivity not only improved during the whole sample period but also outperformed that of FHC banks in most of the sample periods. (table 4)

The results without risk adjustment appear in the bottom half of Table 4. There are several similar points to those in the risk-adjusted results. Fist, non-FHC banks still outperformed FHC banks in the average growth of profit productivity and the improvement in profit efficiency was the dominant source. Second, for FHC banks, profit productivity deteriorated in only one period, 2010-2011, during which profit efficiency deterioration was the main source. Third, FHC banks improved profit productivity up to the highest degree in the period 2011-2012. Fourth, non-FHC banks had the highest profit

Table 4: *Decomposition of profit productivity indicator with respect to the type of banks*

			2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	**2010-2016**
With risk adjustment	FHC banks (13)	$\widehat{PPI}$	-0.0214	0.1165	0.0310	0.0353	0.0264	0.0279	**0.0360**
		$\Delta\widehat{\pi E}$	-0.1054	-0.0224	0.1305	0.0284	-0.0073	0.0072	**0.0052**
		$\Delta\widehat{\pi T}$	0.0841	0.1389	-0.0996	0.0069	0.0338	0.0207	**0.0308**
	Non-FHC banks (18)	$\widehat{PPI}$	0.0439	0.0349	0.0366	0.0642	0.0465	0.0440	**0.0450**
		$\Delta\widehat{\pi E}$	0.1509	-0.3577	0.3289	0.0727	-0.0016	0.0190	**0.0354**
		$\Delta\widehat{\pi T}$	-0.1070	0.3926	-0.2923	-0.0085	0.0481	0.0250	**0.0096**
Without risk adjustment	FHC banks (13)	PPI	-0.0633	0.1801	0.0563	0.0463	0.0362	0.0408	**0.0494**
		$\Delta\pi E$	-0.3427	0.1531	0.2609	0.0606	-0.0028	0.0508	**0.0300**
		$\Delta\pi T$	0.2794	0.0270	-0.2046	-0.0143	0.0391	-0.0100	**0.0194**
	Non-FHC banks (18)	PPI	0.0169	0.1447	0.2062	0.2774	0.1885	0.2414	**0.1792**
		$\Delta\pi E$	-0.1562	-1.6202	0.7893	1.1076	0.0883	0.4480	**0.1094**
		$\Delta\pi T$	0.1731	1.7649	-0.5830	-0.8302	0.1002	-0.2066	**0.0698**

productivity growth in 2013-2014 during which the improvement in profit efficiency offset the deterioration in profit technology. In Table 4 the major difference between two measures is the source of FHC banks' average profit productivity growth. On average, the improvement in profit technology was main source under the risk-adjusted technology. Without risk adjustment, the improvement in profit efficiency was the main source, up to an average degree of $\Delta\pi E$ =0.0300

The further decompositions of the changes in profit efficiency and profit technology with respect to the type of banks are presented in Table 5. The risk-adjusted results are presented first and then the results without risk adjustment will follow. For the FHC banks, the average improvement in profit efficiency ($\Delta\widehat{\pi E}$ =0.0052 in Table 5) came from improvements in both technical efficiency at an average of $\Delta\widehat{TE}$ =0.0034 and allocative efficiency at an average degree of $\Delta\widehat{AE}$ =0.0018. As for the source of profit technology growth, $\Delta\widehat{\pi T}$, the favorable price effect made positive contribution, with an average degree of $\Delta\widehat{PE}$ =0.0326, which offset the tiny deterioration in technology, with an average degree of $\Delta\hat{T}$ =-0.0018. As for the non-FHC banks, the improvement in profit efficiency was mainly due to the allocative efficiency growth, up to the average degree of and $\Delta\widehat{AE}$ =0.0338. On the other hand, for non-FHC banks, both $\Delta\hat{T}$ and $\Delta\widehat{PE}$ made positive contributions to the profit technology growth, up to 0.0040 and 0.0056 on average, respectively. In sum, for FHC and non-FHC banks, their profit productivity growth was mainly attributed to different sources. The former came from the favorable price effect and the later was due to the improvement in allocative efficiency.

As shown in Table 5, the risk-adjusted profit productivity of FHC banks deteriorated in only one period, 2010-2011, during which the deterioration in allocative efficiency was the main source, with a degree of $\Delta\widehat{AE}$=-0.0962. Then FHC banks improved the risk-adjusted profit productivity in the period 2011-2012, up to the highest degree of $\widehat{PPI}$ =0.1165 (see Table 4). Table 5 shows that this improvement $\Delta\widehat{PE}$s attributed to the favorable price =0.1265 during 2011-2012. For non-FHC banks, Table 5 shows the highest degree of the risk-adjusted profit productivity growth in the period 2013-2014, up to a degree of $\widehat{PPI}$=0.0642. It can found in Table 8 that the improvement in allocative efficiency was the main source.

The results without risk adjustment are further presented in the bottom half of Table 5. There are several similar points to those in the risk-adjusted results. Fist, for FHC banks three out of four sources (except for technology change) made positive contributions to profit productivity on average. Second, for non-FHC banks all four components made positive contributions to profit productivity growth on average. However, there is one major difference between the two measures. The favorable price effect within FHC banks dominated the other three sources of the average profit productivity growth under the risk-adjusted technology. Without risk adjustment, their profit productivity growth was mainly attributed to the improvement in allocative efficiency.

5. Conclusions

The aim of commercial banks establishing or joining FHCs is to seek a greater business scope and resource share so as to obtain the optimal capital and cost reduction. These actions are supposed to bring higher profit efficiency and productivity growth. On the other hand, risk is an important issue which should be taken into account in analyzing banks' profit performance. In order to investigate whether banks in FHCs could operate with higher profit productivity, this study divides the data of Taiwan's banks over the period 2010-2016 into two groups, the FHC banks and the non-FHC banks. Moreover, the risk-adjusted results are compared with those without risk adjustment.

The empirical results are summarized as follows. Regardless of the measures with and without risk adjustment, the non-FHC banks' profit productivity not only improved during the whole sample period but also outperformed that of FHC banks in most of the sample periods. The improvement in allocative efficiency played the key role within the non FHC banks. However, there is one major difference between the two measures regarding the FHC banks' average profit productivity. The favorable price effect within FHC banks dominated the other three sources of profit productivity growth under the risk-adjusted technology. Without risk adjustment, their profit productivity growth was mainly attributed to the improvement in allocative efficiency.◆

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Table 5: *Decomposition of the changes in profit efficiency and profit technology with respect to the type of banks*

				2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	**2010-2016**
With risk adjustment	FHC banks (13)	$\Delta\widehat{\pi E}$	$\Delta\widehat{TE}$	-0.0092	0.0098	0.0205	-0.0006	0.0013	-0.0017	**0.0034**
			$\Delta\widehat{AE}$	-0.0962	-0.0322	0.1100	0.0290	-0.0086	0.0089	**0.0018**
		$\Delta\widehat{\pi T}$	$\Delta\hat{T}$	-0.0022	0.0124	-0.0138	-0.0036	-0.0064	0.0030	**-0.0018**
			$\Delta\widehat{PE}$	0.0862	0.1265	-0.0858	0.0105	0.0402	0.0177	**0.0326**
	Non-FHC banks (18)	$\Delta\widehat{\pi E}$	$\Delta\widehat{TE}$	-0.0082	-0.0246	0.0215	0.0131	0.0038	0.0038	**0.0015**
			$\Delta\widehat{AE}$	0.1591	-0.3332	0.3074	0.0596	-0.0053	0.0152	**0.0338**
		$\Delta\widehat{\pi T}$	$\Delta\hat{T}$	0.0029	0.0395	-0.0261	-0.0031	0.0059	0.0052	**0.0040**
			$\Delta\widehat{PE}$	-0.1099	0.3532	-0.2661	-0.0054	0.0422	0.0198	**0.0056**
Without risk adjustment	FHC banks (13)	$\Delta\pi E$	ΔTE	-0.0105	0.0149	0.0202	-0.0021	0.0035	-0.0039	**0.0037**
			ΔAE	-0.3322	0.1382	0.2407	0.0627	-0.0063	0.0547	**0.0263**
		$\Delta\pi T$	ΔT	0.0017	0.0092	-0.0140	0.0009	-0.0069	0.0076	**-0.0003**
			ΔPE	0.2778	0.0178	-0.1906	-0.0153	0.0460	-0.0176	**0.0197**
	Non-FHC banks (18)	$\Delta\pi E$	ΔTE	-0.0053	-0.0250	0.0205	0.0113	0.0061	0.0032	**0.0018**
			ΔAE	-0.1509	-1.5952	0.7687	1.0963	0.0822	0.4447	**0.1076**
		$\Delta\pi T$	ΔT	-0.0021	0.0421	-0.0244	-0.0009	0.0059	0.0006	**0.0036**
			ΔPE	0.1753	1.7228	-0.5587	-0.8293	0.0944	-0.2072	**0.0662**

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Summary

Sau khi luật công ty cổ phần tài chính được thực hiện vào năm 2011, các ngân hàng đài loan đã trải qua nhiều thay đổi về cơ cấu. Nghiên cứu này sử dụng chỉ số lợi nhuận điều chỉnh rủi ro để xem xét liệu các ngân hàng trong các công ty cổ phần tài chính có thể hoạt động với tăng trưởng hiệu suất cao hơn so với các ngân hàng không thành lập hoặc ra nhập công ty cổ phần tài chính hay không. Vốn chủ sở hữu được coi là một nhân tố rủi ro trong nghiên cứu này. Dữ liệu về các ngân hàng đài loan giai đoạn 2010 – 2016 được sử dụng để so sánh.