Operational efficiency in Taiwan banks with consideration of nonperforming loans: A dynamic network DEA

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Abstract: This paper applies a slacks-based measure dynamic data envelopment analysis (SBM-DNDEA) model to simultaneously evaluate overall, deposit, lending, period, deposit-period and lending-period efficiencies for 22 Taiwanese banks over the period from 1999 to 2011. We treat deposit as the intermediate output, and use non-performing loan as undesirable output capturing the effect of carry-over activity. The results indicate that the improvement in individual process has positive effect on banks' performance, while efficiency in the deposit process may not guarantee efficiency in the lending process, and vice versa. The period efficiency for all banks has the stable variance. Besides, the efficiencies based on operational characteristics are further compared.

Keyword: Dynamic network data envelopment analysis, slacks-based measure, efficiency, bank, non-performing loan

1. INTRODUCTION

The performance of the banking sector has been a matter of concern. The most widely used method of evaluation on the banking industry is data envelopment analysis or DEA (Feith and Pariouras [7]). It is a nonparametric technique used in operation research for estimation of production efficiency in decision making units (DMUs). The efficiency frontier defines the maximum combination of outputs that can be produced for a given set of inputs. Any DMU off the frontier is considered inefficient. The first idea of multiple inputs and single output proposed by Farrell [6] was expanded by Charnes et al. [2], with the concept of multiple inputs and multiple outputs for efficiency measurement. The advantage of DEA is that a specific functional form for the production process does not need to be imposed on the model so that a possible misspecification is avoided through this approach. However, in order to obtain the objective performance assessment results, it needs to prudently determine in advance the inputs and outputs of all DMUs.In the previous literature of bank performance evaluation, the fixed assets and the number of employees represent input variables, while different kinds of earning assets (such as loans and investments) serve as output variables. But banks' major liabilities, i.e. deposits, are quite indisputable. In the perspective of intermediate approach, banks are regarded as financial intermediaries, which essential function aim to obtain surplus funds from savers and lend them to borrowers in need of funds. Consequently, deposits are treated as input variables. On the other hand, the production approach view banks as financial service providers. Deposits are considered as output variables since they are part of the services. If a bank has relatively more deposits and less loans, such bank will be identified as being inefficient under the intermediary approach however efficient under the production approach. Therefore, the adoption of different identification approaches will lead to different results of bank performance assessment.

Holod and Lewis [8] applied network DEA to deal with the dilemma of whether to treat deposits as an input or an output in banking operations. According to this method, which was initiated by Färe and Grosskopf [4], a bank's production unit is divided into two divisions. Bank deposits are regarded as part of the outputs from one division and utilized as inputs to the other devision. As a result, the effect of deposits on bank efficiency is determined by the combined efficiency scores at both divisions in the overall production process. Hence, the problem that different identification approaches lead to distinct bank performance assessment results could be solved. Besides, such division classification is closer to a bank's real operations. A bank's daily routine is mainly about accepting deposits and channels and turning those deposits into lending activities so that all funds are transferred between all divisions. In bank performance evaluation, the costs and benefits created in funds transfer process are considered as the basis of assessment. However, traditional DEA treated a DMU as a single division and failed to take into consideration the intermediate products serving as coordinating links between divisions. Network DEA can allow DMUs production process to be divided into various divisions and can process linking activities (or intermediate products) formally. Therefore, we can not only evaluate divisional efficiencies but also the overall efficiency of DMUs.

DMU outputs are composed of desirable outputs and undesirable outputs. If an undesirable output would result in potential output loss when evaluating DMUs' performance, it is necessary to credit DMUs for the production of undesirable outputs and penalize them for the production of undesirable outputs. For example, Yu [16] treated aircraft noise as an undesirable output when measuring physical efficiency of airports in Taiwan. The findings suggested that ignoring undesirable output would have a significant impact on airport performance. In addition, Boyd et al. [1] showed that when an undesirable production results such as nitrogen oxides (NOx) is obtained, inefficiency of glass industry increases accordingly. In the study by Färe et al. [5], the desirable outputs and the undesirable outputs were all included concurrently in thermal power plant performance measurement. As to the banking industry in Taiwan, the government has allowed the establishment of new banks since 1991. The number of banks was ever increasing and it was increased from 25 to 53 in just 10 years, that is, more than twice. However, at this moment, because that there was often a decline in the global financial market interest rates and that the spread between interest rates on deposits and loans was reduced due to an excessive competition in the banking sector, bank return on equity was quite low, which was reduced from 20.79% in 1990 to 3.61% in 2001. For banks, supply was increased but demand was decreased. For the purpose of finding a niche, cash card business as personal microfinance had been developed since 1999. In order to enhance sprint performance, banks issued card indiscriminately and neglected credit quality and risk management, which resulted in the outbreak of dual card crisis by the end of 2005. By May 2006 non-performing loans (NPL) of credit cards was 3.33% while non-performing loans of cash cards was 7.84%. The bad debts had cut away bank profitability instead. To sum up the above, in such a competitive financial environment, banks should not only seek to pursue higher loan growth but also pay attention to the future repayment ability of a debtor and reduce the amount of overdue loans in order to ensure the improvement of bank operating performance. Therefore, in the present study on the evaluation of bank efficiency, the undesirable output of non-performing loans should be included in the model.

Tone and Tsutsui [12] suggested that network DEA model could deal with intermediate products or linking activities in order to connect the activities in various divisions of production unit. When we apply this model to the assessment of bank performance and regard deposit variables as intermediate products, we can solve the problem of this contradictory role affecting the measurement of bank efficiency. Besides, in order to take into consideration the desirable and undesirable outputs and the dynamic effects on bank performance, we apply dynamic network DEA model in the slacks-based measure framework (SBM-DNDEA) proposed by Tone and Tsutsui [14]. The SBM-DNDEA is a composite of slacks-based measure network DEA and dynamic DEA model proposed by Tone and Tsutsui [12][13]. Unlike the previous studies that made use of the Malmquist index for measuring efficiency change over time (Chen and Ali, [3]; Wei, [15]; Lo and Lu, [10]; Liu and Wang, [9]), this model accounts for the effect of carry-over activities between two consecutive terms. The carry-overs play an important role in measuring the efficiency of DMUs in each term as well as over the whole terms based on the long-term viewpoint. In addition, the SBM-DNDEA model uses slacks-based measure (Tone, [11]) approach so that we do not stand on the assumption that inputs and outputs change proportionally for evaluating efficiencies. The undesirable output of bank, i.e. non-performing loans, can be considered as a carry-over link variable. The non-performing loans of a bank in current period may produce an effect on the lending business in next period. If the amount of non-performing loans is too high in current period, the bank will become more conservative in its lending business and reduce the loan amount in next period. In this way, it may help the bank to prevent that the amount of non-performing loans continues to expand. We suggest therefore that in a continuous period of banking operations, a more precise bank performance measurement can be made through the inter-connecting carry-over activities.

The remainder of this paper is organized as follows. Section 2 presents the model. Section 3 describes the data sources and relative variables, and discusses the empirical results. The conclusions are addressed in the last section.

2. METHODOLOGY

Traditional DEA models failed to into consideration the linking activities between divisions and carry-over activities between two consecutive terms, and treated the operational process as a "black box". In practice, a bank's operational process can be mainly divided into the deposit process and lending process which are connected in series. Bank deposits as the intermediate outputs obtained from the deposit process are used as inputs to the lending process. The non-performing loans as the undesirable outputs produced in current period may cause an effect on the lending process in next period. It is suitable to utilize the model that combines the network DEA, which accounts for the effects of inter-relationships among divisions, and dynamic DEA, which accounts for the impacts of carry-over activities between two consecutive terms, to estimate related performance indicator. In addition, the radial DEA models assume that inputs and outputs change proportionally and ignore non-radial slacks. The non-oriented SBM models allow banks to account for their input excess and output shortfall, simultaneously and non- proportionally. Thus, this paper adopts the SBM-DNDEA proposed by Tone and Tsutsui [14] to investigate divisional efficiencies, period efficiencies and overall efficiency within a unified mode. The conceptual structure of SBM-DNDEA model is depicted in Figure 1.

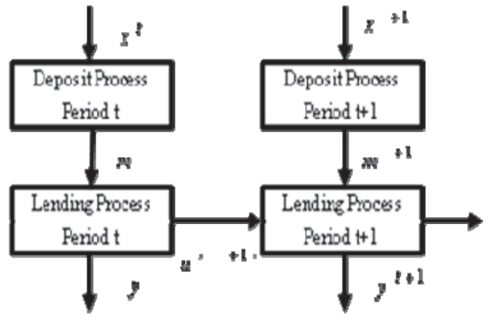

Figure 1: DNDEA structure for a bank

We denote that each bank runs two processes, in which the outputs at the deposit process are the inputs at the lending process. For the deposit process, each bank for period t uses original inputs $x^t \in R_+^N$ to produce intermediate products $m^t \in R_+^H$. For the lending process, each bank for period t uses intermediate products

<4>

as inputs to jointly produce final desirable outputs $y^t \in R_+^F$ and undesirable outputs $u^{(t,t+1)} \in R_+^L$ that are produced in period *t* and cause an impact in period *t*+1. The operational possibility set is defined as follows:

$$T\{(x^t, m^t, y^t, u^{(t,t+1)}): \tag{1}$$

$$\sum_{j=1}^{J} z_{j,D}^t x_{ij}^t \le x_i^t,\ i=1,\ldots,N,\ t=1,\ldots,T \tag{1.1}$$

$$\sum_{j=1}^{J} z_{j,L}^t y_{rj}^t \ge y_r^t,\ r=1,\ldots,M,\ t=1,\ldots,T \tag{1.2}$$

$$\sum_{j=1}^{J} z_{j,D}^t m_{hj}^t = m_h^t,\ h=1,\ldots,H,\ t=1,\ldots,T \tag{1.3}$$

$$\sum_{j=1}^{J} z_{j,L}^t m_{hj}^t = m_h^t,\ h=1,\ldots,H,\ t=1,\ldots,T \tag{1.4}$$

$$\sum_{j=1}^{J} z_{j,L}^t u_{pj}^{(t,t+1)} = u_p^{(t,t+1)},$$

$$p=1,\ldots,P,\ t=1,\ldots,T-1 \tag{1.5}$$

$$z_{j,D}, z_{j,L} \ge 0,\quad j=1,\ldots,J\} \tag{1.6}$$

where the *J*, *N*, *H*, *M*, *P* and *T* represent the total number of banks, inputs, intermediate outputs, desirable outputs, undesirable outputs and periods, respectively; z_D and z_L are intensity variables associated with the deposit process and lending process, respectively.

The overall operational efficiency (OE) score for bank *k* can be estimated by solving the following SBM-DNDEA model:

$$\underset{\rho, S_{i,D}^{t-}, S_{r,L}^{t+}, S_{p,b}^{t-}, z_D, z_L}{Min} \rho_k(x_k^t, m_k^t, y_k^t, u_k^{(t,t+1)})$$

$$= \frac{\sum_{t=1}^{T} W^t \left[1 - \left(\frac{w^D}{N}\sum_{i=1}^{N}\frac{S_{ik,D}^{t-}}{x_{ik}^t} + \frac{w^L}{P}\sum_{p=1}^{P}\frac{S_{pk,b}^{t-}}{u_{pk}^{(t,t+1)}}\right)\right]}{\sum_{t=1}^{T} W^t \left[1 + \frac{w^L}{M}\left(\sum_{r=1}^{M}\frac{S_{rk,L}^{t+}}{y_{rk}^t}\right)\right]} \tag{2}$$

$$\sum_{j=1}^{J} z_{j,D}^t x_{ij}^t = x_{ik}^t - S_{ik,D}^{t-},\ i=1,\ldots,N,\ t=1,\ldots,T \tag{2.1}$$

$$\sum_{j=1}^{J} z_{j,L}^t y_{rj}^t = y_{rk}^t, + S_{rk,L}^{t+},\ r=1,\ldots,M,\ t=1,\ldots,T \tag{2.2}$$

$$\sum_{j=1}^{J} z_{j,D}^t m_{hj}^t = m_{hk}^t,\ h=1,\ldots,H,\ t=1,\ldots,T \tag{2.3}$$

$$\sum_{j=1}^{J} z_{j,L}^t m_{hj}^t = m_{hk}^t,\ h=1,\ldots,H,\ t=1,\ldots,T \tag{2.4}$$

$$\sum_{j=1}^{J} z_{j,L}^t u_{pj}^{(t,t+1)} = \sum_{j=1}^{J} z_{j,L}^{t+1} u_{pj}^{(t,t+1)},$$
$$p=1,\ldots,P,\ t=1,\ldots,T-1 \tag{2.5}$$

$$\sum_{j=1}^{J} z_{j,L}^t u_{pj}^{(t,t+1)} = u_{pk}^{(t,t+1)} - S_{pk,b}^{t-},$$
$$p=1,\ldots,P,\ t=1,\ldots,T-1 \tag{2.6}$$

$$\sum_{t=1}^{T} W^t = 1, \tag{2.7}$$

$$w^D + w^L = 1, \tag{2.8}$$

$$z_{j,D}, z_{j,L}, S_{i,D}^{t-}, S_{r,L}^{t+}, S_{p,b}^{t-}, W^t, w^D, w^L \ge 0,$$
$$j=1,\ldots,J,\quad i=1,\ldots,N,\quad r=1,\ldots,M,$$
$$p=1,\ldots,P,\quad t=1,\ldots,T \tag{2.9}$$

where W^t, w^D and w^L are the weight to period *t*, the deposit process and the lending process, respectively. [1] We assume that the linking activities are fixed (as constraints (2.3)-(2.4)) and the carry-over activities act as the undesirable link (as constraints (2.5)-(2.6)),[2] because bank deposit is beyond the control of banks and non-performing loans is the bad product. This object function represents the non-oriented model that accounts for excesses in both the input resource and undesirable link as well as the shortfall in output product.

Besides the overall operational efficiency, we can identify its decompositions as follows:

Period-deposit efficiency (PDE):

$$\theta_{k,D}^t = 1 - \frac{1}{N}\left(\sum_{i=1}^{N}\frac{S_{ik,D}^{t-}}{x_{ik}^t}\right) \tag{3}$$

[1] W^t, w^D and w^L represent the relative importance of the efficiencies of individual period, deposit process and lending process, respectively. These weights are exogenously pre-assigned scalars. In this paper, we simply set $W^t = 0.0769$, $j=1,\ldots,13$, and $w^D = w^L = 0.5$.

[2] In order to represent that the undesirable output is treated as the input and can be decreased, the equality constraint (1.5) is changed to the inequality constraint (2.6). In addition, the constraint (2.5) is added in order to impose the continuity condition between two consecutive periods.

Period-lending efficiency (PLE):

$$\theta_{k,L}^{t} = \frac{1-\frac{1}{P}\left(\sum_{p=1}^{P}\frac{S_{pk,b}^{t-}}{u_{pk}^{(t,t+1)}}\right)}{1+\frac{1}{M}\left(\sum_{r=1}^{M}\frac{S_{rk,L}^{t+}}{y_{rk}^{t}}\right)} \tag{4}$$

Deposit efficiency (DE):

$$\delta_{k,D} = \sum_{t=1}^{T} W^{t}\left[1-\frac{1}{N}\left(\sum_{i=1}^{N}\frac{S_{ik,D}^{t-}}{x_{ik}^{t}}\right)\right] \tag{5}$$

Lending efficiency (LE):

$$\delta_{k,L} = \frac{\sum_{t=1}^{T} W^{t}\left[1-\frac{1}{P}\left(\sum_{p=1}^{P}\frac{S_{pk,b}^{t-}}{u_{pk}^{(t,t+1)}}\right)\right]}{\sum_{t=1}^{T} W^{t}\left[1+\frac{1}{M}\left(\sum_{r=1}^{M}\frac{S_{rk,L}^{t+}}{y_{rk}^{t}}\right)\right]} \tag{6}$$

Period efficiency (PE):

$$\varphi_{k}^{t} = \frac{1-\left(\frac{w^{D}}{N}\sum_{i=1}^{N}\frac{S_{ik,D}^{t-}}{x_{ik}^{t}}+\frac{w^{L}}{P}\sum_{p=1}^{P}\frac{S_{pk,b}^{t-}}{u_{pk}^{(t,t+1)}}\right)}{1+\frac{w^{L}}{M}\left(\sum_{r=1}^{M}\frac{S_{rk,L}^{t+}}{y_{rk}^{t}}\right)} \tag{7}$$

Although the overall efficiency ρ_k is unique by the above objective function (2), its components ($\theta_{k,D}^{t}$, $\theta_{k,L}^{t}$, $\delta_{k,D}$, $\delta_{k,L}$ and φ_{k}^{t}) may be multiple optima. In order to overcome the plurality problem, when we solve the objective functions (3)-(7), respectively, ρ_k is kept at the optimum value.

3. EMPIRICAL RESULTS

3.1. Data Description

This study uses the panel data set for 22 Taiwanese banks over the period from 1999 to 2011. Our dataset comes from the Taiwan Economic Journal (TEJ) database and the annual reports of banks. As for input variables, labor, fixed asset and operating expense are chosen as three inputs. Deposit is treated as the intermediate output flowing from the deposit process to the lending process. As for the output variables, loan and securities investment are selected as two final outputs. In addition, non-performing loan is used to capture the effect of carry-over activity. The descriptive statistics of input and output variables are summarized in Table 1.

Table 1: Summary statistics of inputs and outputs, 1999-2011

	Mean	Std. Dev.	Max	Min
Inputs				
Labor (the number of employee)	3,447.60	2,210.57	9,881.00	572.00
Fixed asset (NT$ 1,000)	10,613,746.06	9,203,071.97	34,969,332.00	1,320192.50
Operating expense (NT$ 1,000)	3,303264.21	2,923894.77	18,419,718.00	431,622.66
Intermediate input/output				
Deposit (NT$ 1,000)	515,143,563.62	419,504,889.37	1,531,478,016.00	52,803,596.00
Outputs				
Loan (NT$ 1,000)	408,683,866.78	333,319,716.15	1,349,334,144.00	43,440,680.00
Securities investment (NT$ 1,000)	110,751,180.28	130,504,137.17	501,325,920.00	2,538,644.50
Carry-over activity				
Non-performing loan (NT$ 1,000)	9,798669.33	13,949,212.67	81,439,904.00	19,178.08

3.2. Efficiency Results

By applying the SBM-DNDEA model, banks' performance can be calculated and classified into overall efficiency, deposit efficiency, lending efficiency, period efficiency, period-deposit efficiency and period-lending efficiency.

Table 2 presents the average result of overall efficiency measures for all banks and their components. The mean of overall efficiency is 0.6122, with a standard deviation of 0.1841, indicating that banks still have room to improve their efficiency by 38.72%, on average. By examining the efficiencies for the two processes, the mean of deposit efficiency is slightly higher than the mean of lending efficiency (0.7197 vs. 0.6321), implying that overall inefficiency of banks is much influenced by the inefficiency in terms of the lending process than that in terms of deposit process.

Additionally, we also compute the efficiency scores for each period. In Figure 2, the results indicate that the mean value of period efficiency for all banks has the stable variance over the period 1999-2011. This means that the whole bank industry maintains a stable management performance. When comparing the efficiency between the deposit process and the lending process, there exists an opposite trend between the period-deposit efficiency and the period-lending efficiency. This implies that Taiwanese banks focus on the improvement in efficiency for single process, but neglect to maintain the efficiency for another process.

Table 2: Overall efficiency and its components

	Overall efficiency		Deposit efficiency		Lending efficiency	
	Mean	Standard	Mean	Standard	Mean	Standard
Old vs. New						
Old banks	0.6600	0.2051	0.8191	0.1391	0.6514	0.2381
New bank	0.5724	0.1626	0.6368	0.1792	0.6160	0.2091
State-owned vs. Private						
State-owned banks	0.7433	0.1369	0.9152	0.0457	0.7037	0.1595
Private banks	0.5630	0.1675	0.6463	0.1779	0.6052	0.2005
FHC vs. Independent						
FHC banks	0.7225	0.1701	0.7243	0.2095	0.7674	0.2239
Independent banks	0.5202	0.1440	0.7158	0.1687	0.5193	0.1385
Total	0.6122	0.1841	0.7197	0.1837	0.6321	0.2180

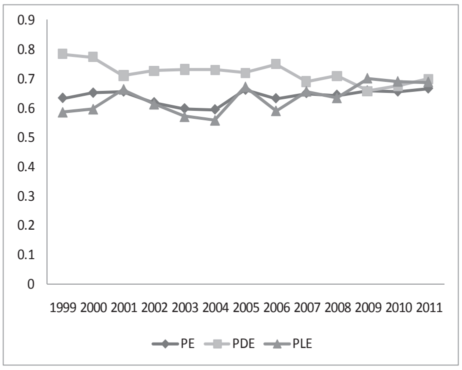

Figure 2: Period and period-divisional efficiencies

The pairwise comparisons of overall efficiency, deposit efficiency and lending efficiency measures are shown in Table 3. The correlations between overall efficiency and deposit efficiency as well as overall efficiency and lending efficiency are significantly positive, respectively. This implies that no matter the improvement in terms of the deposit process or the lending process can bring the benefit to banks. In addition, we find the insignificantly positive correlation between deposit efficiency and lending efficiency. This indicates that a bank with well operation in terms of the deposit process may not guarantee to increase its performance in terms of the lending process.

Table 3: Correlation coefficients between performance measures

	OE	DE	LE
OE	1	0.4612*	0.8842*
DE		1	0.0664
LE			1

*Notes: * is significant at the 5% level.*

3.3. Comparisons of Performances Based on Operational Characteristics

We now further explore whether the operational characteristics affect the efficiency of banks. First, since Taiwan's government in 1991 enacted the Commercial Bank Establishment Promotion Decree to remove the barriers to entry into banking markets and facilitate the establishment of many private banks, we divide observations into two groups: old banks, which were established before 1991, and new banks, which were established thereafter. Next, banks are classified into state-owned banks and private banks with respect to the ownership of banks. If the government is the largest shareholder in the bank, the bank is state-owned bank. Finally, since the government implemented the Financial Holding Company Act in 2001 to promote bank to integrate the cross-business operation and increase their competitive power, we separate observations into two groups: financial holding subsidiary banks (FHC banks), which established or joined in FHCs, and independent banks, which did not belong to FHCs.

The comparisons of old banks and new banks are displayed in Table 2. The result indicates that, on average, the overall efficiency of old banks was superior to new banks' (0.6600 vs. 0.5724). As for investigating the sources of inefficiency, the inefficiency of old banks is mainly attributed to the inefficiency for the lending process, while that of new banks results from the inefficiencies for two processes, simultaneously. This means that the better performance for old banks mainly comes from the better management in the deposit process. A possible explanation is that since old banks have operated over a long time, they can have some advantages via the accumulations of reputation and customer trust.

As for the period efficiency for old banks and new banks, the results are exhibited in Figure 3. New banks outperformed old banks before 2001, while old banks outperformed new banks after 2001, and the gap between them became larger over time. In terms of individual process, as seen in Figures 4-5, old banks had better performance than new bank in the deposit process over 1999-2011 and in the lending process after 2003. The results imply that the better performance of old banks after 2001 was attributed to the improvement of efficiency for the lending process and the maintenance of efficiency for the deposit process.

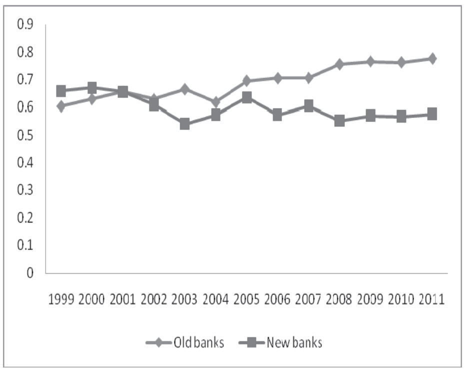

Figure 3: Period efficiencies between old

and new banks

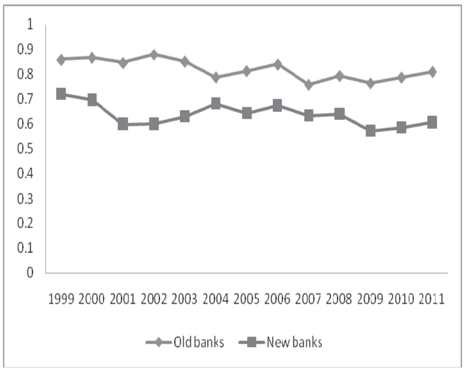

Figure 4: Period-deposit efficiencies between old and new banks

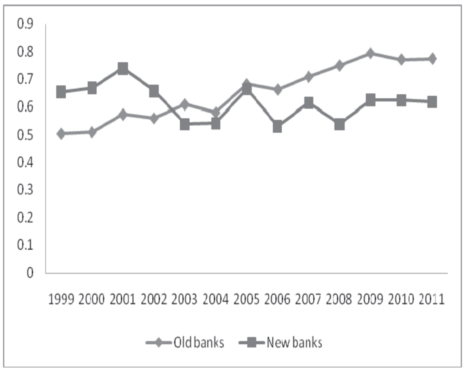

Figure 5: Period-lending efficiencies between old and new banks

With regard to the comparisons of state-owned and private banks, Table 2 exhibits that state-owned banks dominate private banks in all three efficiency dimensions (0.7433 vs. 0.5630, 0.9152 vs. 0.6463 and 0.7037 vs. 0.6052), especially for the deposit process. A possible explanation is that state-owned banks can get more trust from customers based on the support of the government, and thus obtain more deposits.

The period and period-divisional efficiencies with respect to ownership are shown in Figures 6-8. In Figure 6, the period efficiency of state-owned banks outperformed private banks. Since state-owned banks improved their efficiency, the gap between state-owned banks and private banks became larger after 2005. In Figure 7, state-owned banks had better performance than private banks in the deposit process. In Figure 8, private banks performed better in the periods 1999-2002 and 2004, while state-owned banks outperformed private banks in other periods. These results imply that state-owned banks expended the period efficiency score gaps by improving the efficiency for the lending process.

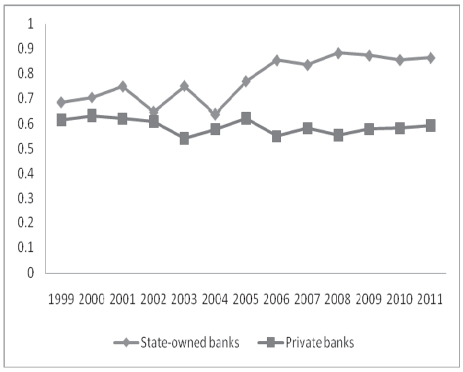

Figure 6: Period efficiencies between state-owned and private banks

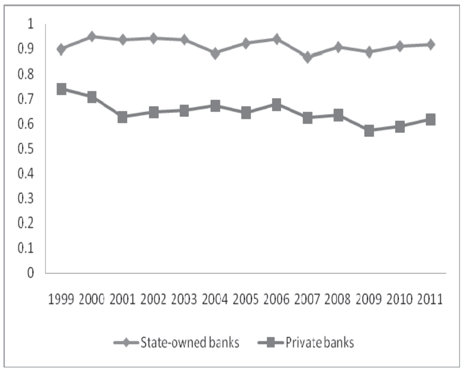

Figure 7: Period-deposit efficiencies between state-owned and private banks

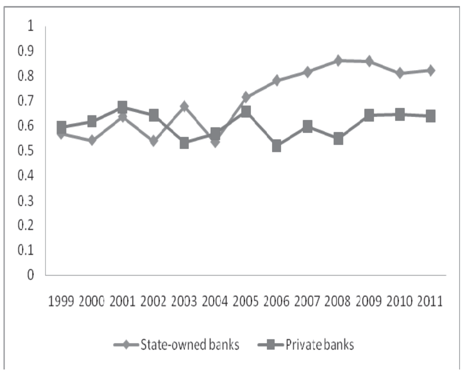

Figure 8: Period-lending efficiencies between

state-owned and private banks

Regarding the comparisons of FHC banks and independent banks, Table 2 shows that FHC banks tend to be more efficient than independent banks (0.7225 vs. 0.5202). The difference in terms of overall efficiency between FHC banks and independent banks is due to the worse performance of independent bank in terms of the lending process. The result implies that independent banks pay more attention to improving the efficiency in terms of the deposit process, but less in terms of the lending process.

These period efficiencies between FHC banks and independent banks are shown in Figure 9. As for period efficiency, FHC banks performed better than independent banks. However, the period efficiency score gap between FHC banks and independent banks did not have significant variances after 2002, when banks initiated to establish or join in FHCs, implying that establishing or joining in FHCs could not capture some benefits via the integration cross-business operation. With regard to the period-divisional efficiency in Figures 10-11, it can be found that the major difference between FHC banks and independent banks resulted from the efficiency in terms of the lending process. The result suggests that independent banks should effort to improve the efficiency in terms of the lending process.

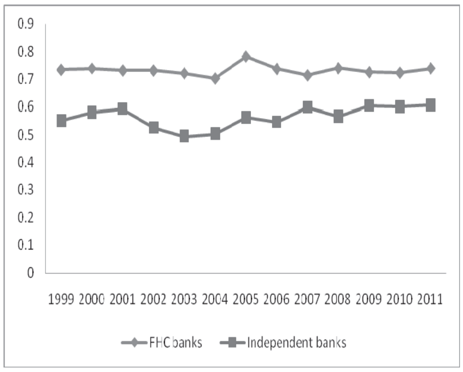

Figure 9: Period efficiencies between FHC and independent banks

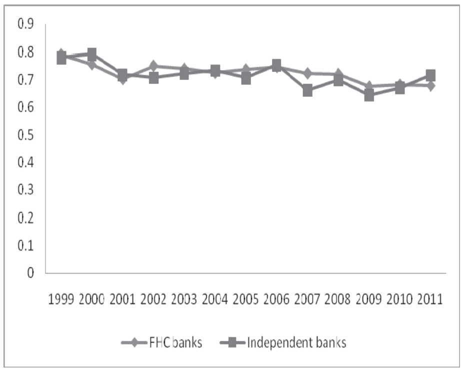

Figure 10: Period-deposit efficiencies between FHC and independent banks

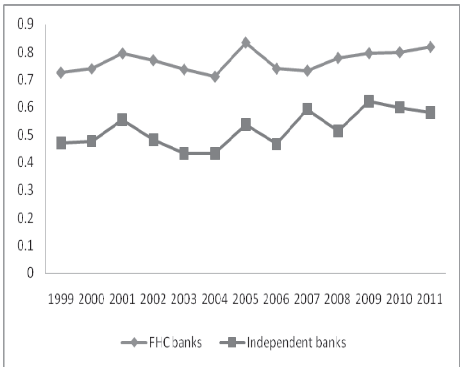

Figure 11: Period-lending efficiencies between FHC and independent banks

In order to further compare whether significant variability exists between old banks and new banks, stated-owned banks and private banks, as well as FHC banks and independent banks, respectively, the Mann-Whitney test is applied. The results are exhibited in Table 4. As for the comparison of old banks and new banks, the p-values are 0.2623, 0.0210 and 0.3225 for the overall efficiency, deposit efficiency and lending efficiency, respectively, implying that the statistically significant difference is in deposit efficiency of old banks from that of new banks, while overall efficiency and lending efficiency measures between old banks and new banks are not significantly different. The ownership of banks is found to significantly affect the overall efficiency and deposit efficiency, but does not significantly influence the performance in terms of the lending process. The results imply that the reputation of old banks and state-owned banks can increase deposit, but does not raise loans and investment. With regard to the comparison of FHC banks and independent banks, the test shows the significant differences in the overall efficiency and lending efficiency, with *P*-values of 0.0101, but the insignificant difference in the deposit efficiency, with *P*-value of 0.7416. The result indicates that the overall efficiency gap between FHC banks and independent banks is caused by the difference of efficiency in terms of the lending process.

Table 4: The Mann-Whitney test for categorical influence (*P*-value)

	OE	DE	LE
Old vs. new	0.2623	0.0210*	0.3225
State-owned vs. private	0.0390*	0.0015*	0.1725
FHC vs. independent	0.0101*	0.7416	0.0101*

*Notes: * is significant at the 5% level.*

4. CONCLUSION

In this paper, we apply the SBM-DNDEA model, which considers the linking activities between processes and the carry-over activities between two consecutive terms, to evaluate the performance of banks in Taiwan over the period from 1999 to 2011. Based on this model, we can calculate and classify overall efficiency into deposit efficiency, lending efficiency, period efficiency, period-deposit efficiency and period-lending efficiency.

Our empirical results indicate that overall inefficiency of banks mainly originates from the inefficiency in terms of the lending process and thus the improvement in the lending efficiency is more important than that of deposit efficiency. We also compute the efficiency scores for each period. The results indicate that although the whole bank industry maintains a stable management performance, there is an opposite trend between the period-deposit efficiency and the period-lending efficiency. Furthermore, the operational characteristics are also evaluated. Old banks and state-owned banks outperformed new banks and private banks in terms of the deposit process over 1999-2011 and thus the reputation can help banks to increase deposit, while FHC banks tend to be more efficient than independent banks in terms of the lending process. Hence, through this model, the managers and policy-makers can obtain the more quantity of information to monitor the operation status.

However, there are also some limitations in this paper. For simplicity, we assume that $W^t = 0.0769$, $j = 1,\ldots,13$, and $w^D = w^L = 0.5$. The adjustment of the weights may have a significant impact on the results. Future research could investigate the weights. In addition, we exclude the existence of shared inputs between deposit and lending processes. The inclusion of shared inputs into this model is worth considered in future research.

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