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The Study of Chinese Listed Bank's Efficiency Growth Mode in Internet Finance Era

—Based on Full-Combination DEA-PCA Model

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Abstract

In the era of internet finance, the scholars and practitioners around the world are paying attention to how to enhance the competitiveness of commercial banks by choosing the appropriate growth pattern of business performance. This paper uses empirical research to discuss the growth model of business performance within 16 listed commercial banks in China by full-combination DEA-PCA model. We find that there are significant differences on the performance evaluation of each listed bank due to whether they consider internet factor or not. Furthermore, we apply PCA model which is based on the result of full-combination DEA model to classify the growth pattern of business performance into "Internet Business Oriented" which enhances performance by internet finance innovation and "Traditional Business Oriented" which maintains performance by traditional banking business. According to the performance of each listed bank in the PCA analysis chart, we classify these banks further into four groups: "Emphasis on internet business", "Emphasis on traditional business", "Emphasis on internet business with overburdened traditional business" and "Balance between internet business and traditional business". Each group of banks has its own strength and weakness. At last, according to the characteristics of different bank groups, we put forward the corresponding efficiency strategy recommendations.

Keywords

Internet Finance, Full-Combination DEA-PCA Model, Efficiency Growth Model

1. Introduction

With the rapid development of electronic information technology and computer tech-

nology, the world entered the age of the Internet. In recent years, China's internet industry grows fast. As of the end of 2014, Chinese netizens reached 649 million people, the Internet penetration rate reached 47.9%; whereas a decade ago, in 2004 Chinese netizens only had 0.94 million people, and the Internet penetration rate was only 7.3%[1]. At the third session of the 12th National People's Congress, Premier Li proposed the concept of "Internet +" in order to optimize the allocation of resources and improve the efficiency of resources integration by prompting Internet technology graft into the traditional industries. When the advantages of the Internet is rooted in the financial sector, it can stimulate strong creativity in financial sector, and then format the new internet financial model to inject new vitality into economic.

According to the statistics of research firm iResearch, the deal size of China Internet banking in China has reached 1304.4 billion RMB, an increase of 40.23% compared to last year[2]. In the same year, the total assets of commercial banks in China amounted to 134.8 trillion RMB, an increase of 13.5% compared to last year[3]. The total asset of China's 16 listed banks is about 78.5% of total commercial bank assets. The rapid development of Internet banking that affects Chinese listed banks has caused widespread concern in financial practitioners, experts and scholars at domestic and abroad. Internet banking as an important part of Internet finance, as well as a new trend and channel of China's banking industry development not only changes the Chinese commercial bank business model, but also changes the development direction of China's banking industry.

On the one hand, internet banking due to the low cost, high efficiency, low error rate, convenience and other advantages has become a new way to improve the operating performance of Chinese commercial banks and has been incorporated into many banks' development planning; On the other hand, internet banking has expanded the commercial bank's function, scope of services and development path as a financial intermediary by combining the Internet banking business mode and traditional banking business mode, and also enriched the commercial banks' ways of efficiency growth at the same time. However, due to the different inherent advantages of Chinese commercial banks, their choices of enhancing efficiency patterns are different. Therefore, the starting point of this paper is using empirical means to evaluate the operating efficiency of China's listed banks, trying to find out its current efficiency growth pattern and analyze the reasonableness of its efficiency growth pattern, and according to the actual operation situation, we put forward some policies and recommendations to improve the operating efficiency of sample listed banks.

With respect to foreign countries, the studies of commercial banks' efficiency are less, especially those combined with Internet banking factors, the existing research cannot give full play to the role of theory into practice. Therefore, this article attempts to provide some useful supplement for existing studies. In general, contribution of this paper is mainly reflected in three aspects: Firstly, we study multiple input and output

[1]Source: Wind economic database (EDB) economic data industry - China Internet development statistics.
[2]Source: IResearch Report "The industry chain of Chinese banking e-commerce development trend in 2015".
[3]Source: China Banking Regulatory Commission "China Banking operation Report (2014)".

indicators which are impacting commercial bank's efficiency by incorporating the financial information and non-financial information; Secondly, we take new ideas and methods to evaluate the efficiency of commercial banks, namely: the use of a combination of full-DEA-PCA model to evaluate the efficiency of the listed banks; Finally, we found that the current efficiency growth pattern of China's commercial banks can be divided into "network service oriented" and "traditional business oriented". According to the performance of listed banks in the principal component analysis graph, China's listed banks will be further divided into four groups to analyze the efficiency growth path, so we propose policy recommendations to enhance the operation efficiency of each group based on its characteristic. The rest of the paper is organized as follows: The second part is literature review, which sorts out and analyzes the efficiency of commercial bank's research methods, the index system and conclusions; The third part is model design, which explains the features and principles of the model chosen and the reason for the model; The fourth part is data and variable declaration, which explains the selected sample, data sources and empirical model index system; The fifth part is empirical analysis, which puts the sample data into the model to calculate and analyze the result; The sixth part is the conclusion, which summarizes the finding, then proposes measures, recommendations and outlook.

2. Literature Review

2.1. The Research of Bank Efficiency Evaluation Method

Currently, the comment regarding the efficiency of commercial banks is mainly used in cutting-edge analysis and its derivative analysis (parametric method and non-parametric method). Farrell (1957) found that Linear programming effectively solve the long-standing index problem and construct an effective production frontier that composed by the optimal production efficiency point, and thus provides a scientific mathematical methods to measure efficiency from the quantitative aspect. Frontal analysis became the main research method of studying financial industry efficiency [1]. Berger and Humphrey (1997) reviewed the literature of operating efficiency about 130 financial institutions of 21 countries, they further classified the frontal analysis as non-parametric method and parameter method according to the different requirements of efficiency frontier production function to the model parameters, the different assumptions of the random error term and invalidity and the strength of the efficient frontier limited condition [2].

On the basis of frontal analysis, Charnes, Cooper and Rhodes (1978) presented data envelopment analysis (DEA) under the assumption of constant returns to scale. DEA which involves the theory of operations research, econometrics and management science selecting multiple input indicators and output indicators, then using mathematical programming (such as multi-objective programming and linear programming) to detect the efficient frontier of decision unit under the Pareto optimal state. It can assess relative efficiency score between subjects and mainly used for testing sample's technical efficiency, scale efficiency and comprehensive efficiency [3]. DEA have

choiceness applicability that do not need to make the prior assumption about the best practice frontier and allows dynamic change of the sample efficiency. It also does not need to use dimensionless process to the sample data and assume input variable weights. In addition, DEA do not have to determine the function expression between the input and output. Through the study of DEA, Tim (1998) proposed the "two-stage" approach DEA model that is combining the efficiency values of DEA with other mathematical programming (such as Tobit model, PCA analysis, etc.). The principle is to calculate the validity of decision units by DEA; then regress the efficiency value to each factor and analyze the deep-seated reasons about influencing efficiency [4].

2.2. The Research of Commercial Bank's DEA Efficiency Evaluation

DEA become the mainstream method for domestic and foreign to analysis financial institution efficiency, especially bank efficiency, due to its highly flexibility, fine practicability, less constraints and good compatibility with other mathematical tools.

Foreign scholars use DEA to study the efficiency of commercial banks relatively earlier than domestic. Rangan *et al.* (1988) use DEA to analysis 215 US banks technical efficiency. The results show that the overall sample of pure technical efficiency value is 0.72, pure technical inefficiency lead to lower overall technical efficiency [5]. Similar, Isik and Hassan (2002) use DEA to analysis scale efficiency of the Turkey bank industry. The results show that the overall sample of scale efficiency value is 0.92, scale inefficiency lead to lower technical efficiency, and further lead to cost inefficiency [6]. Berger and Mester (1997) use non-parametric mathematical programming DEA model analysis US banking performance during 1991-1997. The researchers found that the US banking industry during that period have low overall efficiency [7].

In terms of using single model analysis commercial bank efficiency, Wei and Wang (2000) use DEA estimates the technical efficiency, pure technical efficiency, scale efficiency and returns to scale of domestic commercial bank, the research found that the average technical efficiency of state-owned banks is lower than the joint-stock commercial bank [8]. Zhang (2003) emphasizes the technical efficiency, scale efficiency and Malmquist Index of domestic bank, the result shows that the joint-stock commercial banks have highest efficiency [9]. And then, Zhang (2003) pays attention to the X-efficiency of Chinese commercial banks, the study finds that changes in the external economic environment and regulatory policy have a greater impact on the overall efficiency of the bank industry; the strengthening of the market competition will help to improve the efficiency of the bank industry [10]. Domestic state-owned commercial bank have low comprehensive efficiency due to excessive redundancy rate which caused by excessive factor input (Chi *et al.*, 2006) [11].

In terms of using composite model analysis commercial bank efficiency, Zhu Nan, Yin Zhuo and Dong Yi (2004) use the DEA-Tobit model to evaluate the efficiency and its influence factor of China's four state-owned commercial banks and top-ten joint-stock commercial banks. The conclusion shows that the low efficiency of sate-owned commercial bank is caused by excessive employees. The low profitability and single

property right are the main factor for the low efficiency [12]. Through using the Malmquist productivity index of DEA model to estimate the TFP of 11 listed commercial banks in china, Cai and Guo (2009) found that the overall technical changes showed a downward trend, while the scale efficiency and pure technical efficiency showed an upward trend, the shareholding reform is good for improving the operation efficiency of commercial bank [13]. Zhao and Wang (2008) suggested that the efficiency of domestic commercial banks are mainly from the contribution of profitability and resource allocation capabilities through constructing DEA efficiency linear regression model which introduced indicators of profitability, liquidity and so on [14]. Yuan *et al.* (2006) analyzed the domestic commercial banks efficiency of service, profitability, overall by introducing multi-stage super efficiency into DEA model, they found that the difference of the overall efficiency between state-owned commercial bank and joint-stock commercial banks come from the profitability efficiency, while the service efficiency is similar [15]. Zhou *et al.* (2010) used relational Two-stage DEA model to evaluate the technical efficiency, pure technical efficiency and scale efficiency of 15 commercial banks in China. The analysis found that the technical efficiency of state-owned commercial banks is lower than the joint-stock commercial banks, and scale inefficiency lead to technical inefficiency [16].

2.3. The Selection of Commercial Bank's DEA Efficiency Evaluation Indicator

The research on indicators related to the efficiency of the banking industry is primarily based on the application of Data Envelopment Analysis (DEA), and which indicators are included is determined by the Production theory, Capital Portfolio theory and the financial inter-mediation theory (Li and Liu, 2005) [17]. The production theory regards commercial banks as a producer of saving accounts and loan accounts, while banks are treated as intermediaries between borrowers and lenders under the capital portfolio theory and financial inter-mediation theory. Thus, different variables are selected based on different theories.

These theories normally measure the banks' inputs by three dimensions: labor, fixed assets and interest expenditures, mentioned by Yong Liu and Hongsheng Mu (2007) [18]. For example, Wei and Wang (2000) suggest that inputs could be defined by labor, capital and loanable funds [8]; while under the Capital Portfolio theory and the financial inter-mediation theory, some researchers choose equity, fixed assets and costs to represent the banks' inputs (Zhang, 2003) [9]. However, there is no consensus on the indicators of the banks' outputs. The capital portfolio theory and financial inter-mediation theory are employed by majority of Chinese researchers to find suitable indicators of outputs. Cai and Guo (2009) consider the following three variables as banks' outputs: interest income, non-interest income and total amount of loans, supported by the financial intermediation theory [13]. Factors such as new loans, the total amount of savings, return on capital employed and revenue are used to measure outputs in Capital Portfolio theory (Chi, 2006) [11]. Zhao and Wang (2008)'s research which is derived from the theory of production provides another measurement of inputs and outputs.

The number of employees and the total amount of capital are considered to be inputs, and earnings after tax per person and loan-to-deposit ratio are defined to be outputs [14]. On the other hand, some abroad researchers, for example, Bergber and Humphfrey (1997) believe that the factors associated with the efficiency of bank branches should be determined by the theory of production, while variables related to the efficiency of the total banking industry should be decided by the financial inter-mediation theory [2].

Besides, the investigation of Internet corporations conducted by Serrano-Cinca *et al.*, (2005) discover that the indicators of inputs and outputs should combine financial information with non-financial information in order to give a better explanation of the impact of the Internet on the efficiency [19].

Throughout the existing domestic and foreign literature, we find that although domestic scholars have made outstanding contribution on evaluation of the efficiency of commercial banks, but the factors that influence efficiency are still lacked of study; the DEA model is still need to refine; the information mining is not comprehensive. In addition, China is in the age of the Internet Financial, therefore, research on efficiency of commercial banks should also be fully integrated Internet financial factors in order to deepening the commercial bank efficiency growth mode of systematic research .

3. The Model Design

In this paper, we use full-combination DEA-PCA model to evaluate commercial bank's efficiency. Firstly, we analysis the performance of china listed bank under different input and output variables combination by using full-combination DEA model; Secondly, we use principal component analysis (PCA) to analysis the results of full-combination DEA.

3.1. Full-Combination DEA

DEA with strong applicability and explanatory nature can evaluate the relative effectiveness of multiple input-output decision units and variables that under each decision unit. And then, the best way to improve the efficiency is found through studying the low efficiency variable. In this way, we can get a lot of information that has deep economic meaning and background in economics (Wei Quanling, 2004) [20].

Let us assume there are N sample banks (decision unit), each bank have K inputs and M outputs. For i bank, inputs and outputs are represented by vectors X_i and Y_i, then we can construct the sample banks input matrix $X_{K\times N}$ and output matrix $Y_{M\times N}$.

Under the assumption of constant returns to scale, we can calculate the relative efficiency value for i bank as follows:

$$\max_{u,v} \frac{u^{\mathrm{T}} y_i}{v^{\mathrm{T}} x_i} \tag{1}$$

$$s.t.\ \ \frac{u^{\mathrm{T}} y_i}{v^{\mathrm{T}} x_i} \le 1,\ \ i = 1, 2, \cdots, N,$$

$$u, v \ge 0,$$

where u is order $M\times 1$ output weightvector, v is order $K\times 1$ input weight vector. To avoid multiple solutions, we add constraint $v^{\mathrm{T}}x_i = 1$:

$$\begin{aligned} &\max_{u,v}\left(u^{\mathrm{T}}y_i\right) \\ &s.t.\ v^{\mathrm{T}}x_i = 1, \\ &u^{\mathrm{T}}y_i - v^{\mathrm{T}}x_i \le 0,\ i = 1,2,\cdots,N, \\ &u, v \ge 0, \end{aligned} \tag{2}$$

In order to finding out the unique optimal solution, we use binary linear program transfer into dual form that base on formula (2):

$$\begin{aligned} &\min_{\theta,\lambda}\Theta \\ &s.t.\ Y\cdot\lambda - y_i \ge 0, \\ &-X\cdot\lambda + \theta\cdot x_i \ge 0, \\ &\lambda \ge 0, \end{aligned} \tag{3}$$

where θ is a scalar and λ is a vector of $N\times 1$ constants. The value of $\theta\left(0\le\theta\le 1\right)$ is the efficiency score for the bank *i*. If $\theta = 1$, the bank *i* is on the optimal production frontier that implies 100% efficiency; if $0\le\theta<1$, the bank *i* is inefficiency, $\left(1-\theta\right)$ is excessive input for the bank *i*. Repeat the above process can determine the final efficiency score of each bank.

Full-combination DEA model is base on the traditional DEA model that we mention above. Full-combination DEA model can analysis different variable combination by exchanging input and output variables, then make full use of the data information through the index variable to calculate samples efficiency. The main reason for the combination of different variables to establish the full-combination DEA model is that: first, all variable combinations are equivalent, and each model that consist of different variable is feasible; second, The efficiency score of each sample bank will be changed due to the result of efficiency evaluation depends on the choice of input and output variables; third, The evaluation of different combinations is meaningful, because the evaluation reveal the strengths and weaknesses of each sample bank by analyzing the different of each efficiency evaluation under different variable combination.

3.2. Principal Component Analysis (PCA)

Pearson's (1901) [21] study found that the Principal Component Analysis (PCA) can extract the features of multi-sample classification. Without reducing the inherent information contained in the original data, PCA can transform the original data into an "effective" feature component which has fewer dimensions, then achieve the optimal variance in the statistical mean square. In this paper, we use PCA to analyze all the efficiency score from each full combination DEA model. The extracted principal component variables can be maintain much of the original data information and denoise by eliminating the redundant dimension, so as to reveal the hidden characteristics of the sample bank and increase the effectiveness of the interpretation of the data, then ex-

plore the main correlation between the bank information and highlight the similarities and differences.

Assume that there are n sample banks in the data set, each sample bank select P variables, using the matrix X to represent all the observation indicators ($n \times p$):

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix} = \begin{bmatrix} x_1, & x_2, & \cdots & x_p \end{bmatrix}$$

we use original vector to calculate the mean vector which was standardized, then calculate the covariance matrix S and the correlation coefficients matrix R:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} x_i, \quad \tilde{X} = \frac{\left(\bar{X} - \mu\right)}{\sigma} \tag{4}$$

$$S = \frac{1}{n}\tilde{X} \cdot \tilde{X}^{\mathrm{T}} \tag{5}$$

$$R = \left(r_{ij}\right)_{m \times m}, \quad \left(r_{ij}\right) = \frac{S_{ij}}{\sqrt{\left(S_{ii} \cdot S_{jj}\right)}} \tag{6}$$

where μ is the expectation of the original variable X, σ is the variance of the original variable X, r_{ij} is correlation coefficient.

The correlation coefficient matrix R is brought into formula (7) to calculate characteristic root λ_i and characteristic vector I_i:

$$\left|R - \lambda \cdot I\right| = 0 \tag{7}$$

Therefore, we obtain the ordered 2 characteristic roots $\lambda_1 \geq \lambda_2$, $\sum \lambda_k = 2\left(k = 1, 2\right)$ and the related 2 characteristic vectors $\left(I_{m1}, I_{m2}\right)\left(m = 1, 2\right)$. These characteristic vectors compose the principal components Y_m. The components in vectors are, respectively, the coefficients in each corresponding Y_m:

$$Y_m = \sum_{m=1}^{2} I_m \lambda_n, \ m = 1, 2, \ n = 1, 2, \cdots, N, \tag{8}$$

we calculate the weights (w_k) of the principal components and PCA scores (z_n) for each model Y_m.

$$z_n = \sum_{k=1}^{2}\left(w_k \cdot Y_k\right), \ n = 1, 2, \cdots, N, \tag{9}$$

where $w_k = \lambda_i / \sum \lambda_i$.

4. The Description of Data and Variables

This paper agrees with Ho *et al.* (2008) [22] and Stoica *et al.* (2013) [23] point of view which select the indicator that relate with the commercial bank and internet banking as input-output variables, as shown in **Table 1**.

The particular note is the two non-financial indicators: The net value of software and E-banking transaction shunt rate.

Table 1. The input-output variable of full combination DEA efficiency analysis.

Variable	Variable properties	Variables code	Item	Variables unit
Input variables	Financial input variables	a	Deposit	million
		b	Total operating costs	million
		c	Number of employees	people
	Non-financial input variables	d	The net value of software	million
Output variables	Financial output variables	1	Total Revenues	million
	Non-financial output variables	2	E-banking transaction shunt rate	percentage

4.1. The Net Value of Software

Internet banking business must use professional computer software to deal with the transaction settlement and other online business program. Due to the performance of commercial banks and computer software investment is connection, so we take the net value of software as a non-financial index and put it into the DEA model.

4.2. E-Banking Transaction Shunt Rate

Another non-financial output variable in this paper is E-banking transaction shunt rate which can measure the achievement of the listed bank in internet financial development. E-banking transaction shunt rate refers to the total number of transactions by E-banking channels divided by the total number of transactions. The e-banking channels of listed banks including Internet banking, telephone banking, mobile banking, self-service banking, among them the Internet banking accounted for the largest. Generally speaking, the e-banking transaction shunt rate will increase with the improve of the innovation of the Internet finance, so we use the e-banking transaction shunt rate as an output indicators to reflect the internet financial innovation achievement of the Listed Bank.

Given that listed bank have large scale, strict supervision, standardized operation processes, sound control mechanisms , so we selects Chinese 16 listed banks represent Chinese bank industry as the research object. The data are collected from the annual report of each listed banks in 2014, the social responsibility report, the general meeting of shareholders and the Wind economic database, as shown in Table 2.

5. The Analysis of Empirical Result

5.1. The Analysis of DEA Empirical Result

The traditional DEA model take all input and output variables into the model, included the four input variables: a, b, c, d and the two output variables: 1, 2, the model is named "abcd12". The full-combination DEA model is permutated and combined all the

Table 2. The major input-output variables data descriptive statistical indicators in 2014.

The major descriptive statistical indicators	Deposit (a)	Total operating costs (b)	Number of employees (c)	The net value of software (d)	Total Revenues (1)	E-banking transaction shunt rate (2)
The minimum value	306,531	8292	6108	87	15,294	72.56
The maximum value	15,024,101	283,474	486,343	3746	614,918	96.49
The average value	4,577,730	98,409	129,672	933	197,442	86.98
The standard deviation	4,892,713	94,968	165,288	945	200,036	6.84

Note: Deposits, Total operating cost, The net value of software and Total revenue units are millions of RMB; The number of employees units is "people"; the e-banking transactions shunt rate unit is "%".

input-output variables to form different sets of variables. This paper involves six input and output variables which have 45 kinds of permutation and combination. We use DEA analysis the efficiency of each permutation and combination model, these models can be named "a1", "a2", "a12"... "d1", "d2", "d12". Table 3 is the DEA analysis result that included 45 kinds of variable set of 16 listed banks in China.

As shown in Table 3, Some banks DEA efficiency is poor due to its model only contain output variable 2 (E-banking transaction shunt rate), such as a2, ab2, abc2, abcd2, abd2, ac2, acd2, ad2, b2, bc2, bcd2, bd2, c2, cd2, d2 models, where the average score of efficiency evaluation is lower than 0.4, and the standard deviation is more than 0.3. However, these banks which in the DEA model with output variables 1 (total revenue) or the output variables 1 (total revenue) and 2 (E-banking transaction shunt rate) have higher efficiency score.

For example, there are 10 banks achieve 100% efficiency when considers all six variables in traditional DEA model abcd12, these banks are ICBC, Huaxia bank, Bank of Beijing, Minsheng Bank, Bank of Nanjing, Bank of Ningbo, Ping An Bank, Pudong Development Bank, Citic Bank and Merchants Bank. But through the full-combination DEA model analyzing, it is found that these banks score in the 45 combination model are significantly different. For example, ICBC achieve 100% efficiency in model abcd12 and other 7 model which contain output variable 1 (Total Revenue), but it achieve low score in efficiency when the model contain output variable 2 (E-banking transaction shunt rate), such as the score of a2 and ac2 model only reach 0.019 and the score of c2 model is 0.016. So we can conclude that ICBC is 100% DEA efficiency for model abcd12 and inefficiency for model a2, ac2, c2. It means ICBC have advantage in the traditional business when introduced internet factor (output variable 2) will decrease the efficiency score.

Thus, if the evaluation factor has changed, the results of the DEA efficiency of Chinese listed banks will appear significantly different. In order to analyzing the reasons for the differences in efficiency evaluation of the banks, the PCA method is introduced to further study.

Table 3. The DEA results of 45 kinds of variable set.

(a)

China listed bank	a1	a2	a12	ab1	ab2	ab12	abc1	abc2	abc12	abcd1	abcd2	abcd12	abd1	abd2	abd12
Bank of China	0.767	0.03	0.767	0.901	0.04	0.901	0.901	0.04	0.901	0.901	0.044	0.901	0.901	0.044	0.901
Agriculture Bank	0.757	0.02	0.757	0.834	0.023	0.834	0.834	0.023	0.834	0.866	0.043	0.866	0.866	0.043	0.866
ICBC	0.756	0.019	0.756	0.995	0.029	0.995	0.995	0.029	0.995	1	0.094	1	1	0.094	1
Construction Bank	0.791	0.023	0.791	0.954	0.032	0.954	0.954	0.032	0.954	0.991	0.081	0.991	0.991	0.081	0.991
Communication Bank	0.776	0.07	0.776	0.866	0.086	0.866	0.866	0.086	0.866	0.931	0.156	0.931	0.903	0.156	0.903
Everbright Bank	0.804	0.174	0.81	0.891	0.211	0.891	0.898	0.211	0.898	0.898	0.236	0.898	0.891	0.236	0.891
Huaxia Bank	0.768	0.211	0.778	0.836	0.244	0.84	0.846	0.244	0.851	1	1	1	1	1	1
Bank of Beijing	0.734	0.337	0.756	0.957	0.5	1	1	0.721	1	1	0.721	1	0.957	0.5	1
Minsheng Bank	1	0.135	1	1	0.135	1	1	0.139	1	1	0.366	1	1	0.366	1
Bank of Nanjing	0.796	0.696	0.849	0.859	0.785	0.924	0.921	1	1	0.928	1	1	0.859	1	1
Bank of Ningbo	0.921	1	1	0.95	1	1	0.95	1	1	0.95	1	1	0.95	1	1
Ping An Bank	0.884	0.201	0.892	1	0.259	1	1	0.259	1	1	0.303	1	1	0.303	1
Pudong Development Bank	0.829	0.105	0.829	0.918	0.127	0.918	0.989	0.161	0.989	1	0.161	1	0.92	0.158	0.92
Industrial Bank	0.98	0.127	0.98	1	0.127	1	1	0.142	1	1	0.255	1	1	0.255	1
Merchants Bank	0.921	0.102	0.921	0.935	0.102	0.935	0.935	0.105	0.935	0.935	0.138	0.935	0.935	0.138	0.935
Citic Bank	0.818	0.116	0.818	0.867	0.125	0.867	0.899	0.15	0.899	1	0.33	1	0.901	0.326	0.911
Minimum	0.734	0.019	0.756	0.834	0.023	0.834	0.834	0.023	0.834	0.866	0.043	0.866	0.859	0.043	0.866
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	0.831	0.210	0.843	0.923	0.239	0.933	0.937	0.271	0.945	0.963	0.371	0.970	0.942	0.356	0.957
Standard deviation	0.084	0.269	0.089	0.060	0.284	0.062	0.058	0.329	0.061	0.046	0.353	0.047	0.052	0.343	0.051

(b)

China listed bank	ac1	ac2	ac12	acd1	acd2	acd12	ad1	ad2	ad12	b1	b2	b12	bc1	bc2	bc12
Bank of China	0.767	0.03	0.767	0.767	0.039	0.767	0.767	0.039	0.767	0.901	0.04	0.901	0.901	0.04	0.901
Agriculture Bank	0.757	0.02	0.757	0.757	0.043	0.757	0.757	0.043	0.757	0.794	0.023	0.794	0.794	0.023	0.794
ICBC	0.756	0.019	0.756	0.962	0.086	0.962	0.962	0.086	0.962	0.995	0.029	0.995	0.995	0.029	0.995
Construction Bank	0.791	0.023	0.791	0.875	0.077	0.875	0.875	0.077	0.875	0.954	0.032	0.954	0.954	0.032	0.954
Communication Bank	0.785	0.075	0.785	0.785	0.153	0.785	0.776	0.153	0.776	0.843	0.086	0.843	0.846	0.086	0.846
Everbright Bank	0.82	0.194	0.828	0.82	0.22	0.828	0.804	0.22	0.81	0.855	0.211	0.855	0.864	0.211	0.864
Huaxia Bank	0.794	0.242	0.807	1	1	1	1	1	1	0.777	0.244	0.784	0.79	0.244	0.79
Bank of Beijing	1	0.721	1	1	0.721	1	0.734	0.337	0.756	0.957	0.5	1	1	0.721	1
Minsheng Bank	1	0.139	1	1	0.366	1	1	0.366	1	0.781	0.12	0.781	0.803	0.138	0.803
Bank of Nanjing	0.921	1	1	0.928	1	1	0.796	1	1	0.787	0.785	0.923	0.816	1	1
Bank of Ningbo	0.921	1	1	0.921	1	1	0.921	1	1	0.808	1	1	0.822	1	1
Ping An Bank	0.893	0.215	0.901	0.893	0.275	0.901	0.884	0.275	0.892	1	0.259	1	1	0.259	1
Pudong Development Bank	0.989	0.161	0.989	1	0.161	1	0.829	0.15	0.829	0.88	0.127	0.88	0.912	0.161	0.912
Industrial Bank	1	0.142	1	1	0.255	1	0.98	0.255	0.98	0.836	0.124	0.836	0.86	0.142	0.86
Merchants Bank	0.922	0.105	0.922	0.922	0.138	0.922	0.921	0.138	0.921	0.77	0.097	0.77	0.789	0.105	0.789
Citic Bank	0.899	0.15	0.899	1	0.33	1	0.834	0.326	0.834	0.769	0.125	0.769	0.794	0.15	0.794
Minimum	0.756	0.019	0.756	0.757	0.039	0.757	0.734	0.039	0.756	0.769	0.023	0.769	0.789	0.023	0.789
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	0.876	0.265	0.888	0.914	0.367	0.925	0.865	0.342	0.885	0.857	0.238	0.880	0.871	0.271	0.894
Standard deviation	0.094	0.331	0.101	0.090	0.355	0.094	0.091	0.342	0.096	0.082	0.285	0.089	0.079	0.329	0.087

(c)

China listed bank	bcd1	bcd2	bcd12	bd1	bd2	bd12	c1	c2	c12	cd1	cd2	cd12	d1	d2	d12
Bank of China	0.901	0.044	0.901	0.901	0.044	0.901	0.404	0.025	0.404	0.55	0.033	0.55	0.17	0.024	0.17
Agriculture Bank	0.796	0.043	0.796	0.796	0.043	0.796	0.3	0.012	0.3	0.494	0.037	0.494	0.348	0.033	0.348
ICBC	1	0.094	1	1	0.094	1	0.392	0.016	0.392	0.9	0.083	0.9	0.9	0.083	0.9
Construction Bank	0.975	0.081	0.975	0.958	0.081	0.958	0.414	0.019	0.414	0.718	0.07	0.718	0.606	0.065	0.606
Communication Bank	0.931	0.156	0.931	0.845	0.156	0.845	0.524	0.074	0.524	0.773	0.149	0.773	0.357	0.116	0.357
Everbright Bank	0.874	0.236	0.874	0.855	0.236	0.855	0.565	0.192	0.565	0.704	0.192	0.712	0.165	0.13	0.165
Huaxia Bank	1	1	1	1	1	1	0.556	0.241	0.556	1	1	1	1	1	1
Bank of Beijing	1	0.721	1	0.957	0.5	1	1	0.721	1	1	0.721	1	0.096	0.159	0.159
Minsheng Bank	1	0.352	1	0.784	0.344	0.832	0.644	0.137	0.644	1	0.352	1	0.593	0.291	0.593
Bank of Nanjing	0.917	1	1	0.788	1	1	0.727	1	1	0.917	1	1	0.222	0.707	0.707
Bank of Ningbo	0.822	1	1	0.808	1	1	0.579	0.989	0.989	0.685	0.989	0.989	0.12	0.473	0.473
Ping An Bank	1	0.303	1	1	0.303	1	0.594	0.212	0.594	0.784	0.251	0.793	0.219	0.181	0.219
Pudong Development Bank	1	0.161	1	0.881	0.158	0.881	0.809	0.161	0.809	1	0.161	1	0.229	0.105	0.229
Industrial Bank	1	0.25	1	0.839	0.248	0.853	0.692	0.141	0.692	0.996	0.25	0.996	0.403	0.19	0.403
Merchants Bank	0.857	0.126	0.857	0.771	0.126	0.771	0.597	0.104	0.597	0.791	0.124	0.791	0.223	0.089	0.223
Citic Bank	1	0.33	1	0.772	0.322	0.801	0.669	0.15	0.669	1	0.33	1	0.508	0.263	0.508
Minimum	0.796	0.043	0.796	0.771	0.043	0.771	0.3	0.012	0.3	0.494	0.033	0.494	0.096	0.024	0.159
Maximum	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Average	0.942	0.369	0.958	0.872	0.353	0.906	0.592	0.262	0.634	0.832	0.359	0.857	0.385	0.244	0.441
Standard deviation	0.072	0.354	0.066	0.086	0.343	0.087	0.173	0.331	0.220	0.170	0.357	0.172	0.272	0.268	0.263

5.2. Principal Component Analysis (PCA)

In this section, we use PCA to further analysis the efficiency model considered with DEA efficiency score which calculated by 45 models in previous section. Firstly, we further analysis DEA results by using principal component analysis. The results of the extracted principal components are shown in Table 4.

The number of principal components extraction principle is selecting the ordered m principal components with eigenvalue above 1. We select the ordered 2 principal components: The first principal component (PC1) contribution rate was 43.40%, the second principal components (PC2) contribution rate was 20.92%, and the cumulative contribution rate of the both PC1 and PC2 was 64.32%.

The initial factor load matrix reflects the dependent degree of the original index on the common factor, and each load matrix value represents the correlation coefficients between the principal components and the corresponding variables (Table 5), where

Table 4. The result of principle component extraction.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	19.529	43.397	43.397	19.529	43.397	43.397
2	9.415	20.922	64.319	9.415	20.922	64.319
3	6.124	13.610	77.929			
4	5.189	11.531	89.460			
5	2.894	6.432	95.892			
6	0.772	1.717	97.609			
7	0.379	0.842	98.450			
8	0.261	0.580	99.031			
9	0.205	0.455	99.485			
10	0.112	0.250	99.735			
11	0.055	0.122	99.857			
12	0.034	0.076	99.933			
13	0.020	0.045	99.978			
14	0.007	0.016	99.994			
15	0.003	0.006	100.000			
16	1.25E−015	2.78E−015	100.000			
…	…	…	…			
45	−2.21E−015	−4.91E−015	100.000			

Table 5. The matrix of initial factor load.

Model	PC1	PC2	Model	PC1	PC2	Model	PC1	PC2
abcd2	0.881	−0.380	cd12	0.826	0.290	a12	0.469	0.167
acd2	0.880	−0.383	a2	0.815	−0.444	b12	0.367	0.239
cd2	0.880	−0.382	abcd12	0.772	0.538	d12	0.334	0.091
bcd2	0.879	−0.382	abd12	0.770	0.467	ab1	0.234	0.811
abd2	0.862	−0.405	ac12	0.747	0.119	abc1	0.409	0.784
c12	0.862	−0.143	bcd12	0.741	0.505	abd1	0.277	0.781
bd2	0.860	−0.410	d2	0.683	−0.340	abcd1	0.475	0.775
c2	0.848	−0.415	acd1	0.671	0.500	bcd1	0.249	0.761
ac2	0.846	−0.418	ad12	0.647	0.199	ab12	0.495	0.633
abc2	0.844	−0.413	abc12	0.635	0.554	bc1	−0.013	0.616
bc2	0.844	−0.413	c1	0.632	0.151	b1	−0.113	0.590
ab2	0.838	−0.430	bd12	0.613	0.127	ad1	0.318	0.491
b2	0.835	−0.433	ac1	0.607	0.278	bd1	0.019	0.477
ad2	0.833	−0.422	cd1	0.566	0.475	d1	−0.050	0.355
acd12	0.827	0.342	bc12	0.473	0.200	a1	0.290	0.306

the majority value of the first principal component PC1 was positive and has a large weight, so it can be regarded as an approximate measure of the overall performance of the sample bank. The higher the value of PC1 is, the better the overall performance of the sample bank is, and vice versa.

The second principal component (PC2) is divided into two types: The first type is the negative value model; these models are abcd2, acd2, cd2, bcd2, abd2, c12, bd2, c2, ac2, abc2, bc2, ab2, b2, ad2, a2, d2. These models common feature is only containing output variable 2 (electronic banking transactions flow rate), which means the factors of internet banking play a decisive role in the efficiency evaluation of commercial banks, so we call "internet banking oriented" model. The second type is the positive value model, these models are acd12, cd12, abcd12, abc12, ac12, bcd12, acd1, ad12, abc12, c1, bd12, ac1, cd1, bc12, a12, b12, d12, ab1, abc1, abd1, abcd1, bcd1, ab12, bc1, b1, ad1, bd1, d1, a1. These models common feature is containing output variable 1 (Total Revenue), which means these models belong to the traditional business category, so we call it "traditional business oriented" model.

In order to expressing more clearly, the principal component correlation coefficient value of each model is represented in a coordinate diagram, as shown in Figure 1.

In Figure 1, the horizontal axis represents the principal component PC1. We use PC1 approximate represents the comprehensive performance, due to its contribution

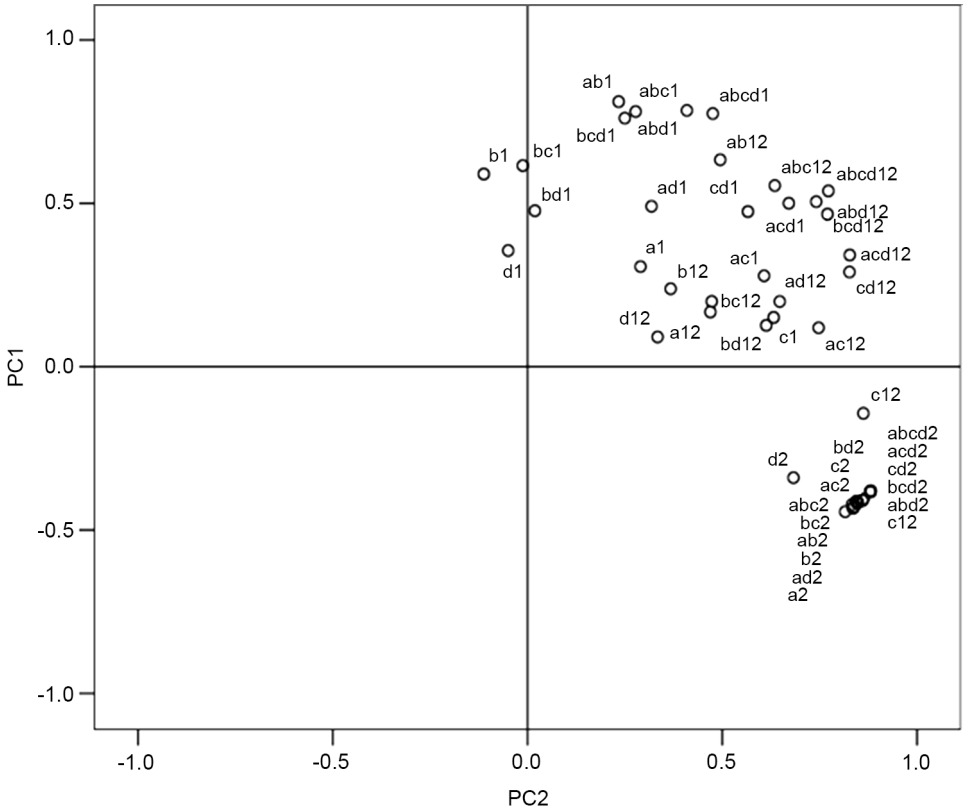

Figure 1. The principal component analysis chart of 45 DEA models.

rate was 43.40%, where the horizontal axis from left to right means comprehensive performance gradually increased. The vertical axis represents the principal component PC2, where the part above the origin of the vertical axis represents "traditional business oriented" and the part below the origin of the vertical axis represents "internet banking oriented". As shown in the figure, the point on the coordinate chart is mainly distributed in the first quadrant and the fourth quadrant, where the "traditional business oriented" model is distributed in the first quadrant, and the "internet banking oriented" model is distributed in the fourth quadrant.

5.3. The Analysis of Chinese Listed Bank Efficiency Growth Model

All the listed bank samples principal components score, comprehensive score and ranking, as shown in **Table 6**.

According to the score of the principal component of the listed banks, the coordinates were drawn, as shown in **Figure 2**.

In **Figure 2**, the horizontal axis PC1 represents the comprehensive performance, where the horizontal axis from left to right means comprehensive performance gradually increased. The vertical axis PC2 represents the degree of "traditional business oriented" or "internet banking oriented", where the part above the origin of the vertical axis represents "traditional business oriented" which the greater PC2 positive value is, the deeper degree of "traditional business oriented" and the part below the origin of the

Table 6. The Principal component analysis results of Listed Banks.

The listed bank	PC1	PC2	Comprehensive Score	Rank
Bank of Ningbo	1.832	−1.127	0.559	1
Bank of Beijing	1.067	0.316	0.529	2
Bank of Nanjing	1.663	−1.468	0.415	3
Industrial Bank	0.328	1.191	0.392	4
Minsheng Bank	0.418	0.995	0.389	5
Ping An Bank	0.194	1.083	0.311	6
ICBC	−0.275	1.602	0.216	7
Huaxia Bank	0.757	−0.538	0.216	8
Pudong Development Bank	0.010	0.725	0.156	9
Construction Bank	−0.581	0.937	−0.056	10
Citic Bank	−0.129	−0.133	−0.084	11
Merchants Bank	−0.554	−0.143	−0.270	12
Everbright Bank	−0.762	−0.837	−0.506	13
Communication Bank	−0.968	−0.622	−0.550	14
Bank of China	−1.281	−0.467	−0.654	15
Agriculture Bank	−1.719	−1.513	−1.063	16

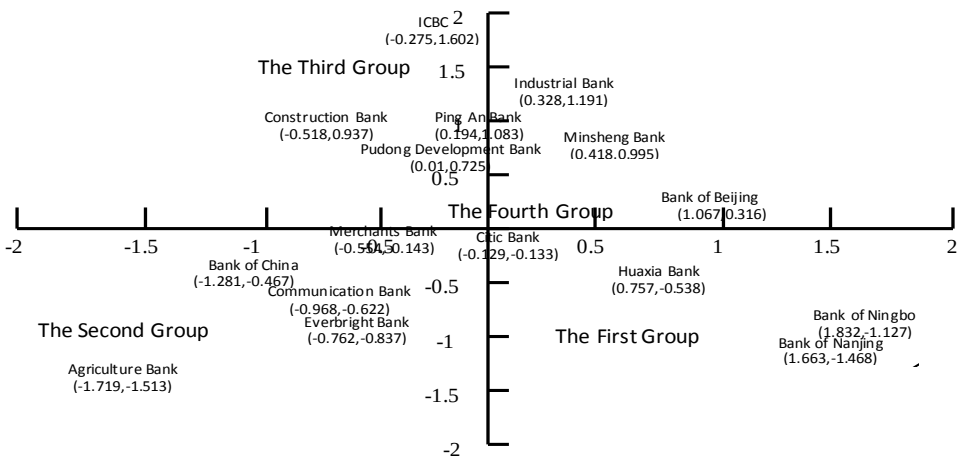

Figure 2. The chart of Principal component analysis results of Listed Banks.

vertical axis represents "internet banking oriented" which the greater PC2 negative value is, the deeper degree of "internet banking oriented".

Bank of Ningbo, For example, which lies in the forth quadrant, have the largest PC1 value and a relatively large PC2 negative value. It means the Bank of Ningbo emphasiz-

ing on the internet business and have good comprehensive performance: In the full-combination DEA analysis results, the score of Bank of Ningbo in the model with output variables 2 (e-banking transaction shunt rate) are generally higher, mostly close to or equal to 1 which means Ningbo bank is a typical "internet business oriented" bank. What's more, ICBC lies in the second quadrant, have the largest PC2 value. It means ICBC is emphasizing on traditional business bank (traditional business has larger proportion and the internet business have smaller proportion): the score of Bank of Ningbo in the model with output variable 2 (e-banking transaction shunt rate) are generally lower than 0.1, but have relatively high score in the model without output variable 2. It means the internet banking factor have negative effect on ICBC's DEA efficiency score, so ICBC is a typical "traditional business oriented" bank.

According to the distribution of the banks in Figure 2, we divides the 16 listed banks into four groups: The first group including Bank of Ningbo, Nanjing and Huaxia, these banks have high overall performance under the internet business, so we defined this group as "emphasis on internet business" bank; The second group includes the Agricultural Bank, Bank of China, Bank of communications, China Everbright Bank. These bank although attach importance to development of internet business, but due to the heavy burden of the traditional business, the overall performance is relatively low. In this paper, we defined the second group as "emphasis on internet business but overburden in traditional business" bank; The third group includes ICBC, industrial bank, Ping An bank, Minsheng bank, Pudong Development bank and the Construction Bank, these banks have great advantages in the traditional business, but the internet business is inefficiency, the overall operating efficiency belongs to the middle level, we define the third group as "emphasis on traditional business" bank; The fourth group includes merchant bank, Citic bank and bank of Beijing, these banks have not obvious advantages in the internet business and traditional business, and its performance is in medium level, we define the fourth group as "emphasis on internet business and traditional business" bank.

In summary, China's 16 listed banks efficiency growth model can be summarized as shown in Table 7.

Table 7. The classification of China 16 listed banks' efficiency growth model.

Group	Banks	Efficiency growth model
First Group	Bank of Ningbo, Nanjing, Huaxia	emphasis on internet business
Second Group	Bank of Agriculture, China, Communication, Everbright	emphasis on internet business but overburden in traditional business
Third Group	ICBC, Bank of Industrial, Ping An, Minsheng, Pudong Development, Construction	emphasis on traditional business
Fourth Group	Bank of Merchant, Citic, Beijing	emphasis on internet business and traditional business

6. Conclusions and Recommendations

6.1. Conclusions

In this paper, we used full-combination of DEA-PCA which considered financial variables and non-financial variables to analyze the efficiency growth model of China's listed banks under the internet finance age and the study showed that the listed bank performance evaluation of internet factor was obvious different.

The results demonstrate that the efficiency growth models of 16 Chinese listed banks can be classified into two types which are "Internet business oriented" and "traditional business oriented". According to the results of DEA analysis, the 16 listed banks are divided into four groups by using PCA: The first group is defined as "Emphasis on Internet business", the second group is defined as "Emphasis on internet business but overburden in traditional business". Each type of group has its own characteristics, so it is important for decision makers to realize these characteristics in order to make better development strategies.

6.2. Advice of Efficiency Growth Model of China's Listed Bank

The first group is "emphasis on internet business" banks, theses banks are Bank of Ningbo, Nanjing and Huaxia whose capital scale is relatively small but has obvious advantages in internet business. These banks should use internet finance advantages which are high efficiency, low expensive cost and multiple consumers, and overcome some of their problems, which are small scale, limited number of branches, few customer resources and little brand influence. Besides, it is also important to appropriately increase the physical bank branches and use internet business advantage to stimulate the traditional business and improve overall operation performance.

The second group is "Emphasis on internet business but overburden in traditional business" banks, theses banks are Bank of China, Bank of Agriculture, Bank of Communications and China Everbright Bank which have relatively large asset scale and good at Internet business rather than traditional business, but the overall operating performance is relatively not so good. This type of banks should increase internet business investment to improve the efficiency of them and increase the Internet innovation of traditional business at the same time. Meanwhile, this group of banks needs to appropriately reduce the physical bank branches, streamline the number of employees and strictly control operating costs in order to improve the operating performance of traditional business.

The third group is "Emphasis on traditional business" banks, these banks are ICBC, Construction Bank, Pudong Development Bank, Ping An Bank, Minsheng Bank and Industrial Bank which have strong competitiveness in the traditional business due to the advantage of scale, technology, product, employees and service. This group of banks should strengthen the traditional business advantages, increase investment in internet banking business innovation, exploit profit growth point and reduce operating costs, in order to improve the operating performance.

The fourth group is "Emphasis on internet business and traditional business", these banks are Merchant Bank, Citic Bank, Bank of Beijing which focus on the balance development of internet business and traditional business. This group of banks should increase the innovative integration of traditional business and internet business in order to play the develop coordination role of traditional business and internet business. Through promoting the "Internet +" financial innovation and paying attention to the collaboration development between traditional business and internet business, Chinese's' listed bank can improve its operating performance efficiently and make a contribution to China's economic development. At the same time, the financial regulatory authorities should strengthen the "Internet +" financial innovation supervision to guard against financial risks.

References

[1] Farrell, M.J. (1957) The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society*, **120**, 253-290. http://dx.doi.org/10.2307/2343100

[2] Berger, A.N. and Humphrey, D.B. (1997) Efficiency of Financial Institutions: International Survey and Directions for Future Research. *European Journal of Operational Research*, **982**, 175-212. http://dx.doi.org/10.1016/S0377-2217(96)00342-6

[3] Charnes, A., Cooper, W.W. and Rhodes, E. (1978) Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, **2**, 429-444. http://dx.doi.org/10.1016/0377-2217(78)90138-8

[4] Coelli, T. (1998) A Multitage Methodology for the Solution of Orientated DEA Models. *Operations Research Letters*, **23**, 143-149. http://dx.doi.org/10.1016/S0167-6377(98)00036-4

[5] Rangan, N., Grabowski, R., Hassan, Y.A. and Pasurka, C. (1988) The Technical Effiency of US Banks. *Economics Letters*, **28**, 169-175. http://dx.doi.org/10.1016/0165-1765(88)90109-7

[6] Isik, I. and Kabir, H.M. (2002) Technical, Scale and Allocative Effiencies of Turkish Banking Industry. *Journal of Banking & Finance*, **26**, 719-766. http://dx.doi.org/10.1016/S0378-4266(01)00167-4

[7] Berger, A.N. and Mester, L.J. (1997) Inside the Black Box: What Explains Differences in the Efficiencies of Financial Institutions. *Journal of Banking & Finance*, **21**, 895-947. http://dx.doi.org/10.1016/S0378-4266(97)00010-1

[8] Wei, Y. and Wang, L. (2000) The Non-Parametric Approach to The Measurement of Efficiency: The Case of China Commercial Banks. *Journal of Financial Research*, **3**, 88-96.

[9] Zhang, J.H. (2003) DEA Method on Efficiency Study of Chinese Commercial Banks and the Positivist Analysis from 1997 to 2001. *Journal of Financial Research*, **3**, 11-25.

[10] Zhang, J.H. (2003) The X Efficiency Analysis of Commercial Banks in China. *Journal of Financial Research*, **6**, 46-57.

[11] Chi, G.T., Yang, D. and Wu, S.S. (2006) The Research on Overall Efficiency of Chinese Commercial Banks Based on DEA Approach. *Chinese Journal of Management Science*, **5**, 52-61.

[12] Zhu, N., Zhuo, X. and Dong, Y. (2004) An Empirical Analysis on The Efficiency of State-Owned Commercial Banks in China and the Reform Strategies. *Management World*, **2**, 18-26.

[13] Cai, Y.Z. and Guo, M.J. (2009) Empirical Study on Total Factor Productivity of China's Listed Commercial Banks. *Economic Research Journal*, **9**, 52-65.

[14] Zhao, Y.L. and Wang, J.T. (2008) The Interpretation Result of Efficiency, Influence Factor, Capacity Model of Commercial Bank. *Journal of Financial Research*, **3**, 58-69.

[15] Yuan, Y.F., Guo, L. and Guo, X.G. (2006) Studies on Efficiency of Chinese Banking Based on the Multi-Stage Super-Efficiency DEA Model. *Journal of Central University of Finance & Economics*, **6**, 46-51.

[16] Zhou, F.M., Zhang, H.Y., Zhou, H. and Sun, B.Q. (2010) Efficiency Evaluation of China's Commercial Banks Based on Two Stage DEA Model. *Journal of Financial Research*, **11**, 169-179.

[17] Li, X.Q. and Liu, X.B. (2005) Measuring the Efficiency of Chinese Banks and Analyzing the Influencial Factors. *Journal of Shanghai University of Finance and Economics*, **4**, 16-22.

[18] Liu, Y. and Mu, H.S.H. (2007) A Review on the Efficiency of Banking in China. *Audit and Economy Research*, **1**, 84-89.

[19] Serrano-Cina, C., Fuertes-Callen, Y. and Mar-Molinero, C. (2005) Measuring DEA Efficiency in Internet Companies. *Decision Support Systems*, **38**, 57-73.

[20] Wei, Q.L. (2004) DEA. China Science Publishing & Media Ltd., Beijing.

[21] Pearson, K. (1901) On Lines and Planes of Closest Fit to Systems of Points in Space. *Philosophical Magazine*, **11**, 559-572. http://dx.doi.org/10.1080/14786440109462720

[22] Ho, C.-T.B. and Wu, D.D. (2009) Online Banking Performance Evaluation Using Data Envelopment Analysis and Pincipal Component Analysis. *Computers & Operations Research*, **36**, 1835-1842. http://dx.doi.org/10.1016/j.cor.2008.05.008

[23] Stoica, O., Mehian, S. and Sargu, A. (2015) The Impact of Internet Banking on the Performance of Romanian Banks: DEA and PCA Approach. *Procedia Economics and Finance*, **20**, 610-622. http://dx.doi.org/10.1016/S2212-5671(15)00115-X