A study on the efficiency of public culture service based on DEA cross evaluation

Liping Fu[1], Juan Li[1, 2*], Zuting Zheng[2]

[1]*Public Resource Management Research Center, College of Management and Economics, Tianjin University, Tianjin, China*

[2] *Hebei United University, Tangshan, Hebei, China*

Received 14 June 2014, www.tsi.lv

Abstract

This paper analysed the inputs and outputs of public cultural services in 31 provinces of China in 2012, including municipalities and autonomous regions, based on the CCR model of DEA and the DEA cross-evaluation model. The DEAP2.1 software was also used for this empirical analysis to probe the performance and problems of the inputs and outputs of public cultural services. From analysis, this paper reached some conclusions, including the development of cultural services should be based on the increase of industrial inputs, as well as the optimization of resource allocation, so as to achieve the optimum state of inputs and outputs. The research results can provide a reference for the further improvement of the quality and inputs and outputs efficiency of public cultural services in all regions.

Keywords: Public Culture Services, DEA Model, Inputs and Outputs, Performance Evaluation

1 Introduction

DEA is a new field of cross study of operations research, management science, and mathematical economics, and it is used to study the relative effectiveness of decision-making units through mathematical programming calculation [1-5]. Compared with traditional methods, it has many advantages. By standardizing different variables of different units, DEA is very objective, and it can avoid many problems caused by various indicators and dimensions [6]. Initially, DEA is used by non-profit organizations to evaluate the efficiency of inputs and outputs, and it permits placing emphasis on choosing inputs and outputs [7]. Public cultural services cover a wide range, and involve more indicators' inputs and outputs, so it is hard to conduct effective evaluations of all the inputs and outputs [8]. Therefore, this paper adopted DEA cross-evaluation model and selected indicators to analyse the efficiency of inputs and outputs of public cultural services in 31 provinces of China in 2012.

2 The establishment of DEA model

2.1 THE EFFECTIVENESS JUDGMENT AND ECNOMIC IMLICATION OF DEA MODEL

The relative efficiency of many input and output sectors and units, is evaluated by DEA through the mathematical programming model [9].The effectiveness of a decision-making unit (DMU), is defined by the ratio between the weighed multi-index output and multi-index input of the unit [10].

$$DMU_L = \begin{bmatrix} x_i \\ y_i \end{bmatrix} (1 \le i \le n),$$

where $x_i = [x_{1i}, x_{2i}, \cdots, x_{mi}]^T 1$, $y_i = [y_{1i}, y_{2i}, \cdots, y_{si}]^T$ are the vectors of input index m of DMU_i $x_{1i}, x_{2i}, ..., x_{mi}$ and the vectors of output index s of $y_{1i}, y_{2i}, ..., y_{si}$ $(x_{ji}, y_{ji} > 0)$ respectively, denoted: $X = [x_1, x_2, ..., x_n]$, $Y = [y_1, y_2, ..., y_n]$, X is called the multi-index input matrix and Y is the multi-index output matrix.

Definition 1: $T = \{(x, y) \text{output } y \text{ can be produced by } x\}$ is called the input and output combination of DMU_I and set v_i as a weighting measurement of category i input, u_k is the measurement of category k output, then the weighting coefficient vector is:

$v = \{v_i, i = 1, 2, \cdots, m\}$; $u = \{u_k, k = 1, 2, \cdots, s\}$;

Definition 2: $h_j = \dfrac{u^T y_{kj}}{v^T x_j} = \dfrac{\sum_{k=1}^{s} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}}$, $j = 1, 2, \cdots, n$ is the effectiveness index of evaluation unit j DMU_j. Select appropriate u and v, make $h_j \le 1$; the increase of h_{j0} indicates that the evaluation unit DMU_{j0} can obtain more output with less input. Therefore, investigating the evaluation unit DMU_{j0} in multi-evaluation units is not the

* ***Corresponding author*** e-mail: lijuanzw@126.com

best way, change u and v as far as possible to obtain the maximum h_{j0}. Construct the following *CCR* model:

$$(\overline{p})\begin{cases} \max \dfrac{\sum_{k=1}^{S} u_k y_{kj0}}{\sum_{i=1}^{m} v_i x_{ij}} = V_{\overline{p}} \\ s.t. \dfrac{\sum_{k=1}^{S} u_k y_{kj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ j = 1,2,...,n \\ u_k \ge 0, k = 1,2,...,s \\ v_i \ge 0, i = 1,2,...,m \end{cases}, \quad (1)$$

Set $t = \dfrac{1}{v^T x_0}$, $\varpi = tv$ and $\mu = tu$, and then Equation (1) can be transformed to the linear programming model:

$$(p)\begin{cases} \max \mu^T y_0 = V_p \\ s.t. \varpi^T x_0 - \mu^T y_j \ge 0,\ j = 1,2,...,n \\ \varpi^T x_0 = 1 \\ \varpi \ge 0, \mu \ge 0 \end{cases}. \quad (2)$$

According to the duality theory of linear programming, the dual programming model of (*P*) is:

$$\begin{cases} \min \theta \\ s.t. \sum \lambda_j x_j + s^- = \theta x \\ \sum \lambda_j y_j - s^+ = y_0 \\ \lambda_j \ge 0, s^- \ge 0, s^+ \ge 0,\ j = 1,2,...,n \end{cases}. \quad (3)$$

The concept of Archimedes infinitesimal is introduced for getting solution conveniently in simplex method of linear programming and simplifying the inspection work:

$$(D_e) = \begin{cases} \min\left[\ \theta - \varepsilon\left(\hat{e}^T s^- + \hat{e}^T s^+\right)\ \right] \\ s.t. \sum \lambda_j x_j + s^- = \theta x_0 \\ \sum \lambda_j y_j - s^+ = y_0 \\ \lambda_j \ge 0, s^- \ge 0, s^+ \ge 0,\ j = 1,2,\cdots,n \end{cases}, \quad (4)$$

where: $\hat{e} = (1,...,1)^T \in R^m$, $e = (1,...,1) \in R^s$. The optimal solution of programming problem (D_ε) is λ^*, s^{*-}, s^{*+}, θ^*; if $\theta^* = 1$, then DMU_{j0} is weak *DEA* is efficient; if $\theta^* = 1$, $s^{*-} = 0$ and $s^{*+} = 0$, DMU_{j0} is *DEA*-efficient, and the models above are the CCR models of evaluation unit.

In CCR model θ is the effective value of the decision-making unit DMU_0 (refers to the effective application degree of input relative to output); X_i is the input factor combined with DMU_i and can be expressed by $(X_{i1}, X_{i2},..., X_{im})$; Y_i is the output factor combined with DMU_i and can be expressed by $(y_{i1}, y_{i2},..., y_{ip})$; λ is the combination ratio that is the decision-making unit *i* of a reconstructed effective *DMU* combination relative to DMU_0 and s^- and s^+ are slack variables.

Its economic implication is:

a. If $\theta = 1$ and $s^- = s^+ = 0$, DMU_0 is called *DEA*-efficient, in the economic system which is composed by *n* decision-making units, on the basis of original input X_0, the output Y_0 has reached to the optimum condition;

b. If $\theta = 1$ and $s^- \ne 0$ or $s^+ \ne 0$, DMU_0 is called the weak DEA efficiency and in the economic system which is composed by *n* decision-making units, reduce the s^- of the input X_0 and do not change the output Y_0 or don't change input X_0 and increase the s^+ of the output;

c. If $\theta < 1$, DMU_0 is called *DEA*-inefficient, in the economic system which is composed by *n* decision-making units, through combination reduce the proportion of original input X_0 and don't change the original output Y_0.

2.2 THE VALUE OF RETURNS TO SCALE IN DEA METHOD

Set $k = \sum \lambda_j$ and then *k* is called the value of returns to scale of DMU_0, where:

a. If $k = 1$, the returns to scale of DMU_0 do not change and now DMU_0 reaches the maximum output scale point;

b. If $k < 1$, the returns to scale are increasing and if the *k* decreases faster, the scale will increase faster; it indicates that the proper increase of input can bring the higher output on the basis of DMU_0 input X_0;

c. If $k > 1$, the returns to scale are decreasing and if the *k* increases faster, the scale will decrease faster; it indicates that the increase of input cannot bring the higher output on the basis of DMU_0 input X_0 and now it is unnecessary to increase the decision-making unit.

2.3 THE DEFINITION OF INPUT REDUNDANCY RATIO AND OUTPUT INEFFICIENCY RATIO

Set the input redundancy ratio as α_{ij} and $\alpha_{ij} = S_{ij}^- / X_{ij}$ indicates the proportion of the weighted indicators, which can be saved. In the same way, set $\beta_{IJ} = S_{ij}^+ / y_{ij}$ and β_{ij} is called as output inefficiency ratio indicating the proportion of weighted indicators, which shall be added.

The comparison of the input redundancy ratio or the output inefficiency ratio in different years in the economic system can show which aspects have been improved and should be strengthened in management. Moreover, the horizontal comparison can also be conducted to analyse the input redundancy ratio and output inefficiency ratio among different related economic systems in the same period of time.

3 The empirical research on the performance evaluation of public culture service based on DEA

3.1 THE SELECTION OF DECISION-MAKING UNITS

The DEA method is principally applied to the evaluation of Relative Merits among same kinds of samples, so the selected samples for evaluation must be of the same kind as DMU. In recent years, the Party Central Committee and the State Council have paid high attention to the construction of public culture service. The outline of the 12th Five-Year Plan has pointed out "to enhance public cultural products and services and establish and improve the public cultural services system" [11]. In recent years, the investment of public finance in the cultural construction has increased continuously, and the national cultural undertakings expense has increased in the latest five years with 20% annual growth rate and reached RMB 29.14 per capita in 2011 [12]. In this paper, the inputs and outputs data of 31 provinces, including municipalities and autonomous regions, in china, were selected as the decision-making units for the DEA evaluation, and the horizontal comparison on the public culture service performances were conducted to evaluate their advantages and disadvantages of various provinces, municipalities and autonomous regions in China. The inputs and outputs data in this study were taken form China Cultural Relics Statistics Yearbook 2013.

3.2 THE SELECTION OF EVALUATION INDICATORS

Different evaluation indicators of DEA system will result in different effectiveness evaluation results [13]. Therefore, the following aspects, including the realization of evaluation purpose, the complete reflection the evaluation purpose and the input vectors are connected with the output vectors, should be principally considered for the selection of evaluation indicators. The evaluation of the efficiency of public culture service is a complex system, involving multiple inputs and outputs. The inputs contain physical factors, such as people, money, and commodity, can be applied to quantitative calculation, and intangible factors, like national policy support and technical support and so on. The multiple outputs contain both various cultural activities aiming at the improvement of people's livelihood and the contributions to social and economic development.

According to the data size of unity, the principle of comparability, at the same time, the data availability, the representative of indicators and the principle of mutual independence of indicators, this paper chose three input indicators, and they were per capita cultural operating expense (RMB), cultural workers number, and public cultural institutions.

The number of the public cultural institutions is the sum of the number of art performance venues, libraries, museums and mass cultural centres; the number of cultural-practitioners is the total number of staff in the art performance venues, libraries, museums and mass cultural centres; the cultural undertakings expense per capita embodies the capital investment in the cultural undertakings by the government, which is the core indicator reflecting the cultural undertakings development. The output indicators selected in this paper were based on the forms of cultural activities and the output quantities, including the number of cultural activities, and the number of participating people, in which the number of cultural activities was the sum of the number of art groups' performances held in art stadium, and art exhibitions, cultural activities and training classes held by cultural centres; and the number of participating people was the sum of the number of audience of the art group performances, audience going to the art stadium or museums and attending art exhibitions, people participating in art exhibitions, cultural activities and training classes held by cultural centres.

3.3 DATA REDUCTION

The data reduction and analysis were made according to China Cultural Relics Statistics Yearbook 2013. The data of various indicators is unified and comparable. Table 1 presents the details of specific data:

TABLE 1 *DMU* input and output data of public culture service investment performance

Region	Cultural undertakings expense per capita (Yuan)	Numbers of cultural workers	Number of public cultural institutions	Number of cultural activity participators (10,000)	Number of cultural Activities (10,000)
Beijing	110.55	13361	486	3010.8656	10.5727
Tianjin	56.11	4893	135	1393.2055	3.2731
Hebei	15.74	21113	846	5356.566	10.2954
Shanxi	36.34	20545	660	5069.8109	13.5354
Inner Mongolia	65.12	10463	349	2681.9817	3.547
Liaoning	33.53	12878	481	3578.638	6.7711
Jilin	34.53	6615	226	1715.9153	3.5798
Heilongjiang	24.4	9342	355	3001.0366	3.6978

Shanghai	120.65	17981	380	4205.669	15.2522
Jiangsu	37.59	26692	1043	12275.8601	45.9412
Zhejiang	65.2	30551	1155	10006.7174	15.0313
Anhui	15.08	22564	1344	3802.5818	13.4117
Fujian	33.9	16491	585	4182.5967	7.148
Jiangxi	17.71	11267	496	4118.7341	5.4668
Shandong	21.36	18405	752	9402.1821	10.2993
Hainan	15.99	27708	864	11977.6866	12.0508
Henan	24	16711	577	5653.0646	8.0448
Hubei	19.12	12445	486	6107.1678	8.4259
Hunan	36.3	26251	757	11118.4997	11.5049
Guangdong	25	6439	294	2905.308	6.5208
Guangxi	64.5	3810	116	893.49	0.9768
Chongqing	41	7899	358	3051.2564	3.156
Sichuan	34.04	21870	961	6978.9988	11.6886
Guizhou	27.81	5058	258	1761.1226	2.2668
Yunnan	28.07	11841	534	3170.7065	6.0521
Tibet	88.09	3175	201	299.0573	0.8063
Shanxi	40.87	16647	531	5501.2832	4.8185
Gansu	35.38	9641	397	3508.3203	3.5298
Qinghai	89.8	2316	143	304.3684	1.259
Ningxia	68.84	1833	65	669.3121	1.0033
Sinkiang	56.01	8108	346	2399.3285	9.5304

4 Model calculation and analysis

4.1 SOLUTION TO CCR MODEL

The software DEAP 2.1 was applied in this paper to solve CCR model and sort the results of 31 provinces (including municipalities and autonomous regions) according to scale efficiency. See Table 2 for the results.

TABLE 2 Results of solution to CCR model

Region	Overall efficiency	Pure technical efficiency	Scale efficiency	Evaluation conclusion
Jiangsu	1	1	1.000 -	DEA-efficient
Shandong	1	1	1.000 -	DEA-efficient
Henan	1	1	1.000 -	DEA-efficient
Guangdong	1	1	1.000 -	DEA-efficient
Zhejiang	0.679	0.679	1.000 -	Weak DEA efficiency
Hunan	0.995	1	0.995 irs	DEA-inefficient, progressive increase of returns to scale
Sichuan	0.64	0.651	0.983 irs	DEA-inefficient, progressive increase of returns to scale
Shanghai	0.932	0.987	0.945 irs	DEA-inefficient, progressive increase of returns to scale
Shanxi	0.741	0.799	0.928 irs	DEA-inefficient, progressive increase of returns to scale
Guangxi	0.926	1	0.926 irs	DEA-inefficient, progressive increase of returns to scale
Beijing	0.517	0.562	0.92 irs	DEA-inefficient, progressive increase of returns to scale
Chongqing	0.756	0.836	0.905 irs	DEA-inefficient, progressive increase of returns to scale
Hubei	0.736	0.814	0.904 irs	DEA-inefficient, progressive increase of returns to scale
Gansu	0.712	0.804	0.886 irs	DEA-inefficient, progressive increase of returns to scale
Shanxi	0.601	0.706	0.852 irs	DEA-inefficient, progressive increase of returns to scale
Inner Mongolia	0.566	0.676	0.838 irs	DEA-inefficient, progressive increase of returns to scale
Fujian	0.548	0.654	0.838 irs	DEA-inefficient, progressive increase of returns to scale
Liaoning	0.587	0.704	0.834 irs	DEA-inefficient, progressive increase of returns to scale
Tianjin	0.787	1	0.787 irs	DEA-inefficient, progressive increase of returns to scale
Ningxia	0.785	1	0.785 irs	DEA-inefficient, progressive increase of returns to scale
Sinkiang	0.683	0.875	0.781 irs	DEA-inefficient, progressive increase of returns to scale
Jiangxi	0.738	1	0.738 irs	DEA-inefficient, progressive increase of returns to scale
Yunnan	0.723	1	0.723 irs	DEA-inefficient, progressive increase of returns to scale
Heilongjiang	0.542	0.757	0.716 irs	DEA-inefficient, progressive increase of returns to scale
Guizhou	0.659	0.957	0.688 irs	DEA-inefficient, progressive increase of returns to scale
Hebei	0.687	1	0.687 irs	DEA-inefficient, progressive increase of returns to scale
Hainan	0.651	1	0.651 irs	DEA-inefficient, progressive increase of returns to scale
Hainan	0.54	0.927	0.582 irs	DEA-inefficient, progressive increase of returns to scale
Jilin	0.579	1	0.579 irs	DEA-inefficient, progressive increase of returns to scale
Qinghai	0.316	0.853	0.370 irs	DEA-inefficient, progressive increase of returns to scale
Tibet	0.197	0.717	0.274 irs	DEA-inefficient, progressive increase of returns to scale

Note: the overall efficiency in the table refers to the technical efficiency with no consideration of the returns to scale; the pure technical efficiency refers to technical efficiency with the consideration of the returns to scale; and the scale efficiency refers to the scale efficiency with consideration of returns to scale.

According to the result of solution to CCR model in Table 2, we can see that the scale efficiency in Jiangsu, Shandong, Henan and Guangdong is 1, reflecting the relative optimality of input and output of public culture service. These four regions put more in the public culture service area, which is also started relatively earlier and has already stepped into a mature phase. Although the scale

efficiency of Zhejiang is also 1, the overall efficiency and pure technical efficiency are not 1, indicating that a higher investment in public culture service is made after awareness of its importance, which has not achieved a good effect and needs further adjustment.

There are 26 DEA-inefficient regions, with efficient pure technical efficiency (the pure technical efficiency is 1) and inefficient scale efficiency (the scale efficiency is less than 1) in 9 regions of Hunan, Guangxi, Tianjin, Ningxia, Anhui, Jiangxi, Guizhou, Hebei and Jilin, indicating the weak mean technical level in these regions and demand for further projection analysis of its reasons.

In order to know the reasons for weak scale efficiency of public culture service in the inefficient DEA regions, the projection analysis was carried out and the results were listed in Table 3.

TABLE 3 Rankings of various provinces and projection analysis of decision-making unit of inefficient DEA

Region	**Rank**	**DEA efficiency value (θ)**	**Input redundancy**			**Insufficient output**	
			Cultural undertakings expense per capita (Yuan)	*The number of cultural workers*	*The number of public cultural institutions*	*The number of the cultural activity participators (10,000)*	*The number of cultural activities (10,000)*
Jiangsu	1	1.000 -	0	0	0	0	0
Shandong	1	1.000 -	0	0	0	0	0
Henan	1	1.000 -	0	0	0	0	0
Guangdong	1	1.000 -	0	0	0	0	0
Zhejiang	1	1.000 -	39.127	9804.798	370.677	0	0
Hunan	6	0.995 irs	0	0	0	0	0
Sichuan	7	0.983 irs	11.875	7629.674	389.193	0	0
Shanghai	8	0.945 irs	61.718	8265.713	4.896	143.845	0
Shanxi	9	0.928 irs	8.216	4873.498	106.751	0	2.303
Guangxi	10	0.926 irs	0	0	0	0	0
Beijing	11	0.92 irs	48.383	6231.31	212.703	130.26	0
Chongqing	12	0.905 irs	6.738	1298.195	69.37	0	2.524
Hubei	13	0.904 irs	4.461	4881.733	107.259	28.089	0
Gansu	14	0.886 irs	6.934	1889.581	77.81	0	2.962
Shanxi	15	0.852 irs	10.699	9262.899	194.315	180.556	0
Inner Mongolia	16	0.838 irs	21.124	3596.463	113.212	0	1.301
Fujian	17	0.838 irs	11.713	7396.247	202.134	25.283	0
Liaoning	18	0.834 irs	9.93	5093.557	142.45	0	0.093
Tianjin	19	0.787 irs	0	0	0	0	0
Ningxia	20	0.785 irs	0	0	0	0	0
Sinkiang	21	0.781 irs	7.026	1017.025	57.504	754.663	0
Anhui	22	0.738 irs	0	0	0	0	0
Jiangxi	23	0.723 irs	0	0	0	0	0
Yunnan	24	0.716 irs	6.808	2871.867	134.329	378.67	0
Heilongjiang	25	0.688 irs	1.05	1810.192	15.278	178.928	2.584
Guizhou	26	0.687 irs	0	0	0	0	0
Hebei	27	0.651 irs	0	0	0	0	0
Hainan	28	0.582 irs	4.72	714.312	8.488	52.178	0.707
Jilin	29	0.579 irs	0	0	0	0	0
Qinghai	30	0.370 irs	21.138	341.55	72.435	430.986	0
Tibet	31	0.274 irs	24.904	897.602	109.405	520.704	0.371

The projection analysis in Table 3 shows that the actual values of various input and output indexes are the same as the project values in the four regions of Jiangsu, Shandong, Henan and Guangdong with the relatively optimum input and output of public culture service, so the corresponding adjustment amount is 0, indicating that the input and output level in these regions has reached the optimum utilization state. As a weak DEA efficient region, Zhejiang Province is faced with serious input redundancy, so the investment in the public culture service should be reduced appropriately, which will not result in the decrease of output.

According to Table 3, it is not hard to discover that with the pure technical efficiency 1, the input redundancy and insufficient output in 9 regions is 0, indicating that the input and output of the public culture service in these regions are relatively balanced. However, the input can be increased appropriately due to the smaller scale of the public culture service, which can result in the incensement of the output and the scale efficiency and gradually achieve a mature public culture service. Other regions like Sichuan and Shanghai belong to the inefficient regions in pure technical efficiency and scale efficiency. Analysed from an input point, these regions are all faced with the redundant input in cultural undertakings expense per capita, cultural-practitioner quantity and public cultural institution quantity. Under a low technical level, with the other factors unchanged, increasing the input of cultural undertakings expense per capita, cultural-practitioner quantity and public cultural institution quantity excessively will result in inefficient production. Therefore, analysed from a public culture service performance point, the optimization of resource allocation and incensement of industrial input should be carried out together, with the expectation of achieving the optimum state of input and output. Analysed from an output point, there exists the

insufficient person-time and quantity of the cultural activities in most regions, which needs to be improved in the future.

4.2 DEA CROSS EVALUATION MODEL

The DEA cross evaluation model is proposed to solve the problem of failure to distinguish the advantages and disadvantages of decision-making units by the traditional DEA evaluation method [14]. In the new DEA cross evaluation, the DEA is used as a kind of ranking tool for multi-criteria decision making, with the main function of distinguishing the efficiency of efficient decision-making units so that these units can be ranked.

Basic idea of cross evaluation: calculate the efficiency value of other DMU_K by the optimum weight $w_i^* = \begin{bmatrix} v_i^* \\ u_i^* \end{bmatrix}$ of each DMU_i to obtain the cross evaluation value:

$$E_{ik} = \frac{y_k^T u_i^*}{x_k^T v_i^*} . \tag{5}$$

The higher value of E_{ik} is, more beneficial for DMU_k but the more adverse for DMU_i.

Since the optimal solutions u_i^* and v_i^* are not unique, the cross evaluation value E_{ik} is uncertain. According to E_{ik} and $i \in \{1,2,...,n\}$, $k \in \{1,2,...,n\}$, the linear programming below may be solved by the aggressive cross evaluation:

$$\begin{cases} \min y_k^T u \\ s.t.\ \ y_j^T u \le x_j^T v \ \ (1 \le j \le n), \\ y_i^T u = E_{ii} x_i^T v, \\ x_k^T v = 1, \\ u \ge 0, v \ge 0 \end{cases} . \tag{6}$$

The cross evaluation value can be worked out by the optimal solution u_{ik}^* and v_{ik}^* in Equation (6):

$$E_{ik} = \frac{y_k^T u_{ik}^*}{x_k^T v_{ik}^*} = y_k^T u_{ik}^* . \tag{7}$$

The cross evaluation matrix is constituted by the cross evaluation value:

$$E = \begin{bmatrix} E_{11} & E_{12} & ... & E_{1n} \\ E_{21} & E_{22} & ... & E_{2n} \\ ... & ... & ... & ... \\ E_{n1} & E_{n2} & ... & E_{nn} \end{bmatrix} .$$

In the above matrix, the elements E_{ii} on the principal diagonal are the self-evaluation value and the non-principal diagonal $E_{ik}\left(k \ne i\right)$ is the cross evaluation value. E is the evaluation value of DMU_i by decision-making units i, indicating that the higher values account for the superior of DMU_i; row i of E (except the elements on the principal diagonal) is the evaluation value of DMU_i for other decision-making units, indicating that the lower the values are, the more beneficial for DMU_i:

$$e = \frac{1}{n} \sum_{k-1}^{n} E_{ki} . \tag{8}$$

Take the average value of column i of E as an index for measurement of advantage or disadvantage of DMU_i and regard e_i as the overall evaluation of decision-making units for DMU_i, and the higher e_i accounts for the superior of DMU_i. The calculation results by DMU_i MATLAB software are shown in Table 4.

TABLE 4 Results of e value in cross evaluation model

e_i	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
Value	0.422	0.553	0.488	0.505	0.441	0.493	0.467	0.541
e_i	e_9	e_{10}	e_{11}	e_{12}	e_{13}	e_{14}	e_{15}	e_{16}
Value	0.556	0.962	0.570	0.319	0.461	0.604	0.873	0.866
e_i	e_{17}	e_{18}	e_{19}	e_{20}	e_{21}	e_{22}	e_{23}	e_{24}
Value	0.625	0.856	0.819	0.738	0.401	0.576	0.543	0.502
e_i	e_{25}	e_{26}	e_{27}	e_{28}	e_{29}	e_{30}	e_{31}	
Value	0.444	0.130	0.584	0.572	0.198	0.591	0.536	

According to the table above: $e_{10} > e_{15} > e_{16} > e_{18} > e_{19} > e_{20} > e_{17} > e_{14} > e_{30} > e_{27} > e_{22} > e_{28} > e_{11} > e_9 > e_2 > e_{23} > e_8 > e_{31} > e_4 > e_{24} > e_6 > e_3 > e_7 > e_{13} > e_{25} > e_5 > e_1 > e_{21} > e_{12} > e_{29} > e_{26}$.

The new ranking for 31 regions obtained according to the above ranking of values of e is shown in Table 5.

According to Table 5, various input and output performances of public culture service in Jiangsu rank the first place but the e value has not reached 1 yet, indicating that insufficient input possibly exists at some aspects except cultural undertakings expense per capita. Therefore, cultural-practitioner quantity and public cultural institution quantity etc. and the further improvement shall be carried out.

TABLE 5 Analysis of the results of cross evaluation

Region	**Jiansu**	**Shandong**	**Henan**	**Hunan**	**Guangdong**	**Guangxi**	**Hubei**	**Jiangxi**
Ranking	1	2	3	4	5	6	7	8
Region	Ningxia	Shaanxi	Chongqing	Gansu	Zhejiang	Shanghai	Tianjin	Sichuan
Ranking	9	10	11	12	13	14	15	16
Region	Heilongjiang	Sinkiang	Shanxi	Guizhou	Liaoning	Hebei	Jilin	Fujian
Ranking	17	18	19	20	21	22	23	24
Region	Yunnan	Inner Mongolia	Beijing	Hainan	Anhui	Qinghai	Tibet	
Ranking	25	26	27	28	29	30	31	

5 Research conclusion

This paper made a comprehensive assessment and analysis on the performance and efficiency of public cultural service of 31 provinces (including municipalities and autonomous regions) in China. In order to avoid subjective judgment, the evaluation of the inputs and outputs of different regions' public cultural service was made in a quantitative way, which made the results more objective. On the basis of DEA analysis results, the deep analysis was made for the 31 regions with adequate application of projecting analysis and the overall efficiency ranking was carried out in the 31 decision-making units through DEA cross evaluation models. The conclusions were drawn as follows:

Conclusion 1: all of the 31 provinces (including municipalities and autonomous regions) have increased the investment in public cultural service to some degree, in accordance with the requirement of the outline of the 12th Five-Year Plan, which advocates enhancing the supply of public cultural product and service, and establishing and perfecting the system of public cultural services. The industrial scale in Jiangsu, Shandong, Henan and Guangdong province has been greatly improved, occupying the top list of 31 provinces (including municipalities and autonomous regions) in China. Their system of public cultural service becomes more and more mature, while the other regions still need to make more advancement in increasing the input and output efficiency of public cultural service, perfecting the allocation of resources and using efficiency.

Conclusion 2: statistics show that the scale efficiency in Zhejiang province is 1, but both its overall efficiency and pure technical efficiency are not 1, which indicate that although a higher investment in public culture service has been made after realizing its importance, the higher investment has not achieved better results and Zhejiang needs further adjustment to the quantity of output value.

Conclusion 3: despite the inputs and outputs of public cultural service in 9 regions, including Hunan and Guangxi, are relatively balanced, their scale efficiency is not high. Therefore, more investment should be properly made to increase the scale efficiency, gradually making the public cultural service industry become mature.

Conclusion 4: the pure technical efficiency and scale efficiency in Shanghai and Sichuan and other regions do not make any sense, which means restricted by the technical factors, if they do not change other conditions, excessive input of people, money and materials in public cultural service will lead to inefficient results. So considering the efficiency and performance of public cultural service, these regions should increase the input of public cultural service as well as allocating resources optimally, to achieve a best state of input and output. Analysed from the perspective of output, most regions perform insufficiently in output, so the improvement and promotion should be carried out in the future.

Conclusion 5: although Jiangsu province tops the comprehensive list of every input and output performance index of public culture service, its e value has not reached 1 through DEA cross efficiency evaluation. It indicates that insufficient input exists in some other aspects, besides cultural undertakings expense per capita, cultural-practitioner quantity and public cultural institution quantity and so on, and needs to be improved in the future.

References

[1] Deraman N A 1982 Data envelopment analysis (DEA) evaluation framework of hotel services *Recent Researches in Economics* **56**(1) 154-9

[2] Jun T 2000 Research of multiple criteria random DEA model and application on evaluation investment Chinese Quarterly *Journal of Mathematics* **15**(2) 70-5 *(in Chinese)*

[3] Caves W D 1982 The economic theory of index numbers and the measurement of input output and productivity *Econometrics* **50**(6) 1393-1414

[4] Charnes A, Cooper W 1982 Measuring the efficiency of decision making units *European Journal of Operational Research* **73**(2) 429-44

[5] Mohammadi A, Ranaei H 2011 The Application of DEA based malmquist productivity index in organizational performance analysis *International Research Journal of Finance and Economics* **62**(6) 68-76

[6] Renshou Z et al. 2011 Research on performance of cultural industry in 13 provinces of China based on DEA model-based on input-output data of 2007 from 13 cities of Guangdong *China Soft Science* **26**(2), 183-92 *(in Chinese)*

[7] Xiuge T, Fenghu W 2011 Research on the efficiency of public investment in culture based on DEA *Development Studies* **28**(2) 90-3 *(in Chinese)*

[8] Yanxin Z 2013 Performance evaluation of public culture service: empirical research based on DEA *Journal of Shandong Administration Institute* **25**(2) 33-8 *(in Chinese)*

[9] Wenyan W, Yulan Z 2013 Empirical research on the tendency of culture industry input and output efficiency based on DEA-Based on the culture industry input and output data from 2004-2010 of Jiangsu *Nanjing University of Finance and Economics* **30**(9) 51-55 *(in Chinese)*

[10] Jiating W, Rong Z 2009 Research on efficiency of cultural industry in 31 provinces of China based on three-stage DEA model *China Soft Science* **24**(9) 75-82 *(in Chinese)*
[11] Jianmei J 2008 A Study on the performance evaluation of government common culture service system *The Journal of Shanghai Administration Institute* **9**(4) 60-5 *(in Chinese)*
[12] Han X, Ma X 2012 A Study on the cultural industry development efficiency of China based on DEA model *Journal of Yunnan University of Finance and Economics* **28**(3) 146-153 *(in Chinese)*
[13] Xu J, Xu X, Chen X, Cui L, Lu C, Xue B 2013 Evaluation on urban efficiencies of Gansu province based on DEA-cross model *Journal of Natural Resources* **28**(4) 618-624 *(in Chinese)*
[14] L. Biao 2011 Research on the scientific and technological resources allocation efficiency based on DEA cross model *Modern Management Science* **28**(12) 35-8 *(in Chinese)*

Authors

Liping Fu, born in February, 1963, Tianjin City, P.R. China

Current position, grades: Professor at the College of Management and Economics, Tianjin University, China.
University studies: B.Sc. in Political Economics at Beijing Normal University in China. M.Sc. and Ph.D. in World Economy at Nankai University in China.
Scientific interest: public management, technological innovation.
Publications: more than 50 papers.
Experience: teaching experience of 29 years, more than 10 scientific research projects.

Juan Li, born in March, 1979, Tangshan City, Hebei Province, P.R. China

Current position, grades: Associate professor at the College of Yisheng, Hebei United University, China.
University studies: B.Sc. in Industrial Analysis at Jilin Institute of Chemical Technology in China. M.Sc. at Yanshan University in China.
Scientific interest: public management, technological innovation.
Publications: more than 20 papers.
Experience: teaching experience of 8 years, 3 scientific research projects.

Zuting Zheng, born in May, 1978, Tangshan City, Hebei Province, P.R. China

Current position, grades: Associate professor at the College of Economics, Hebei United University, China.
University studies: B.Sc. in Industrial Foreign Trade at Harbin Engineering University, China. M.Sc. in industrial economics at Hebei Polytechnic University in China and PhD in Technological Economics and Management at Tianjin University in China.
Scientific interest: technological innovation and industrial economics.
Publications: more than 20 papers.
Experience: teaching experience of more than 10 years, more than 20 scientific research projects.