Cost-Benefit Analysis on Chinese Higher Education Resources Based on Data Envelopment Analysis[*]

Hui Luan

Qufu Normal University, Qufu, China

With the continuous expansion of the universities in China, the gradually growing of limited higher education resources cannot meet the increased demand of contemporary teachers and students in China. Therefore, in this paper, the author analyzed the utilization and allocation of existing education resources in universities based on educational cost and benefit. Moreover, the author selected 11 schools of Qufu Normal University as an individual case. The data envelopment analysis (DEA) model was built according to the data on input (cost) and output (benefit) of educational resources of these 11 schools during 2016. After that, cost-benefit analysis of calculation result was conducted to provide reference for optimal allocation of established educational resources.

Keywords: higher education, educational resources, data envelopment model, cost-benefit analysis

Introduction

With the continuous and rapid expansion of universities in China, the limited educational resources of higher education gradually fail to meet ever-increasing demands of teachers and students in contemporary China. Therefore, government and universities increase investment in higher education. Through increment of all-round fund collection and educational investment, the shortage of educational resources in universities has been relieved to a certain extent. However, the shortage of funds and educational resources is still an unsolved problem which seriously affecting school quality of higher education in China. In fact, the supply and demand of resources of higher education in China today rely on the utilization of existing educational resources as well as educational investment of government and universities. Researches show that the shortage of educational resources co-exist with idle and waste, aggravating the contradiction between supply and demand of higher education resources. Therefore, we analyzed the utilization and allocation of existing education resources in universities based on educational cost and benefit. The utilization of higher education resources was objectively evaluated to develop more effective allocation plan of educational resources, facilitating healthy development of higher education in China.

Taking 11 schools of Qufu Normal University as examples, we analyzed cost-benefit ratio of educational resources in each school due to data envelopment analysis (DEA) model. After that, the global allocation and utilization of educational resources were discussed to provide the managers with reference, increasing utilization efficiency of education resources.

DEA Model

Theoretical Development of DEA Model

The DEA is used to evaluate the efficiencies of different decision-making unit (DMU) of multi-cost (input) and multi-benefit (output). The basic idea of DEA was proposed by professor Farrell in 1957. In 1978, Charnes, Cooper, and Rhodes developed DEA into multi-input and multi-output efficiency evaluation model (Model C2R) based on constant returns to scale (CRS). In 1984, DEA model was further modified by Banker, Charnes and Cooper to build technical and scale efficiency evaluation model (Model C2B) based on variable returns to scale (VRS). Sensibility analysis of DEA model, proposed by Charnes et al. in 1985, is used to re-evaluate the efficiency value by reducing input-output variables or the number of DMUs .

In 2004, professor Wei Quanlin firstly introduced DEA into China. After that, DEA was widely used in finance, economics, management, geology, and medicine. Up to now, few researches have focused on allocation, utilization, cost, and benefit of educational resources by DEA in Chinese educational circles. In the work, DEA was used to conduct cost-benefit analysis of educational resources of certain college in China. It is hoped that higher education managers objectively master the utilization of existing education resources to formulate more optimal plan, improving the cost-benefit ratio of education.

DEA Model Overview

Let the input (cost) vector of some DMU $x = (x_1, x_2, …, x_m)$ T and the output (benefit) vector $y = (y_1, y_2, …, y_s)$. Input and output vectors of n DMUj xj= $(x_1j, x_2j, …, x_mj)^T > 0$ and yj = $(y^1j, y^2j, …, y^sj)^T > 0$ ($j = 1, 2, …, n$). Thus, x$ij > 0$ ($i = 1, 2, …, m$) and y$rj > 0$ ($r = 1, 2, …, s$). Each DMU has m types of inputs (costs) and s types of outputs (benefits). Let the evaluated DMU be $DMUj_0$ (j_0 {1, 2, …, n}). The basic C2R Model of DEA is expressed as follows,

$$\max_{u_r; v_i} h_{j_0} = \frac{\sum_{r=1}^{s} u_r\, y_{r j_0}}{\sum_{i=1}^{m} v_i\, x_{i j_0}}$$

$$st. = \begin{cases} h_j \leq 1, j = 1, 2, …, n \\ v \geq 0, u \geq 0 \end{cases}$$

where h_{j_0} is the efficiency of Unit j0 of evaluation object, xi is the input quantity of the i-th resource in unit j_0, yr is the output quantity of the r-th resource in unit j_0, vi is the measure of the i-th input resource (weight coefficient), ur is the measure of the r-th output resource (weight coefficient), hj is the efficiency of the whole DCMs, and v and u are weight vectors of input and output resources.

The following dual model is obtained according to duality theory of linear programming,

$$\min\theta,$$

$$s.t. = \begin{cases} \sum_{j=1}^{n} \lambda_j\, x_j + s^- = \theta x_{0,} \\ \sum_{j=1}^{n} \lambda_j\, x_j - s^+ = y_{0,} \\ \sum_{j=1}^{n} \lambda_j \geq 1, \\ \lambda_j \geq 0, s^-, s^+ \geq 0, j = 1, 2, …, n, \end{cases}$$

Where s^- is the slack variable of input (cost) and output (benefit), and s^+ the surplus variable of input and output. Therefore, the obtained value by calculating the model is the relative efficiency of the j0-th evaluation unit. The conclusions are as follows:

1. If $\theta = 1$, $s^- = s^+ = 0$, then DEA is available to this DMU. In this system, the benefit obtained from the input (cost) achieves the optimal level;

2. If $\theta = 1$, $s^- = 0$, or $s^+ = 0$, then DEA is weakly available to this DMU. The cost can be reduced to ensure constant benefit, thus, improving cost-benefit ratio;

3. If $\theta < 1$, then DEA is not available to this DMU.

If $\frac{\sum_{j=1}^{n} \lambda j}{\theta} = 1$, the scale benefit of DMU remains and if $\frac{\sum_{j=1}^{n} \lambda j}{\theta} < 1$, the scale benefit increases. The input

can be suitably enlarged. If $\frac{\sum_{j=1}^{n} \lambda j}{\theta} > 1$, then the scale benefit decreases. It is not necessary to enlarge the

investment.

To determine whether a DMU is available is actually to determine whether it is on the efficiency frontier. If DEA is not available to DMU, then the original cost and benefit vectors can be adjusted by calculation to make DEA available.

Cost-Benefit Case Analysis of Qufu Normal University's Higher Education Resources Based on DEA Model

The educational resources that can be used and allocated each year are limited in each college. One of the objectives in the work is to obtain maximum utilization and benefit from existing investment by optimal allocation of limited educational resources. Only by mastering the actual situation of educational resource allocation, utilization, and benefit in each school can college-level management department target adjust resource allocation plan. Resource allocation should be reduced in the school with surplus resource input and insufficient output. In the school with insufficient resource input and surplus output, the resource allocation is suitably enlarged. Therefore, limited educational resources can be used to achieve optimal allocation and high returns on fixed cost.

Index and Original data Determination

In the work, we selected 11 schools of Qufu Normal University as DMUs. The input (cost) and output (benefit) indexes were obtained from relevant data of college bulletin in 2016. Table 1 shows the detailed input and output data.

The indexes of input (cost) and output (benefit) are as follows:

X1: Input (cost) index 1, namely, the total number of in-service staffs in school during 2016;

X2: Input (cost) index 2, namely, the total monetary equivalent of all instruments and equipments in use for the school during 2016 (10,000 yuan);

Y1: Output (benefit) index 1, namely, the total number of actual students at school during 2016;

Y2: Output (benefit) index 2, namely, the total number of projected researches by the teachers of the school during 2016;

Y3: Output (benefit) index 3, namely, the total amount of receiving research funds in the school during 2016 (10,000 yuan);

Y4: Output (benefit) index 4, namely, the total number of published academic works by teachers and students of the school during 2016.

Table 1

Eleven Schools' DMUs Input (Cost) and Output (Benefit) Indexes

DMU	Input (cost) data		Output (benefit) data			
	X1	X2	Y1	Y2	Y3	Y4
School of Mathematical Sciences	111	1,950.19	2,464	68	1,321.78	205
School of Computing	100	1,800.00	2,244	32	314.27	146
School of Management	79	788.00	1,259	16	184.00	83
School of Environmental Science and Engineering	83	1,693.00	2,182	18	159.12	90
School of Educational Science	143	415.60	6,687	18	323.10	151
School of Physical Education	105	855.12	2,672	26	254.00	107
School of Literature And History	79	386.00	1,897	25	188.00	85
School of Art	46	350.88	1,009	26	286.78	55
School of Chemical Engineering	55	179.70	705	5	43.00	30
School of Physics and Engineering	44	204.99	999	27	88.66	35
School of Politics and Law	59	185.00	203	6	2.70	31

Result Analysis

In the work, relevant data of Model C2R is analyzed by DEA-solver software to derive result statistics. After further processing, we obtain cost-benefit ratio and two variables from Model C2R (see Table 2).

Cost-benefit analysis focuses on finding efficiency frontier of DMU by discussing DEA efficiency value. Model calculation result shows that the yield rate frontier of DEA is formed by DMUs of School of Mathematical Sciences, School of Educational Sciences, School of Arts, and School of Physical Engineering. Model solution indicates that above four DMUs have $\theta = 1$, $s^- = 0$, and $s^+ = 0$. Therefore, the above four DMUs are relatively efficient. DMUs of seven other schools, such as School of Computing, have $\theta < 1$. Thus, DEA is invalid. There is surplus input (cost) or insufficient output (benefit) in these schools (see Figure 1).

In other seven schools with invalid DEA, there are slack or surplus variables in one or several input (cost) and output (benefit) indexes. These indexes of non-zero variables are the factors leading to low efficiency or invalid. The slack variable of input (cost) index refers to the redundancy of an input index relative to the input on effective frontier under fixed output (benefit) level.

The slack variable of output (benefit) index stands for the insufficiency of an output index relative to the input on effective frontier. According to the calculation result of slack variables of indexes, we further analyze the adjustment direction of DMU with invalid DEA to effective frontier.

Table 2 shows that the second teaching instruments of School of Computing have surplus input of 2,472,160 yuan under fixed output condition during 2016. In fixed input condition, School of Computing has 13.208 projected researches and insufficient receiving funds of 5,617,850 yuan. Therefore, relevant departments of college can adjust the input for School of Computing to achieve minimum input and maximum output. Also, other schools can adjust utilization and allocation of educational resources based on relevant data.

Table 2

Cost-Benefit Ratio and Two Variables by Model C2R

| DMU	DEA-value	Benefit ranking	Slack variable		Surplus variable			
			s_1^-	s_2^-	s_1^+	s_2^+	s_3^+	s_4^+
School of Mathematical Sciences	1.000	1	0.00000	0.000	0.000	0.000	0.000	0
School of Computing	0.852	3	0.00000	247.216	0.000	13.208	561.785	0
School of Management	0.731	6	0.00000	0.000	757.722	4.820	215.092	0
School of Environmental Science and Engineering	0.754	5	0.00000	650.459	0.000	4.607	274.272	0
School of Educational Science	1.000	1	0.00000	0.000	0.000	0.000	0.000	0
School of Physical Education	0.767	4	0.00000	0.000	274.600	0.000	211.124	0
School of Literature and History	0.977	2	0.00000	0.000	860.128	0.000	109.398	0
School of Art	1.000	1	0.00000	0.000	0.000	0.000	0.000	0
School of Chemical Engineering	0.519	8	0.00000	0.000	554.489	0.000	27.753	0
School of Physics and Engineering	1.000	1	0.00000	0.000	0.000	0.000	0.000	0
School of Politics and Law	0.520	7	0.25583	0.000	1114.204	0.000	65.022	0
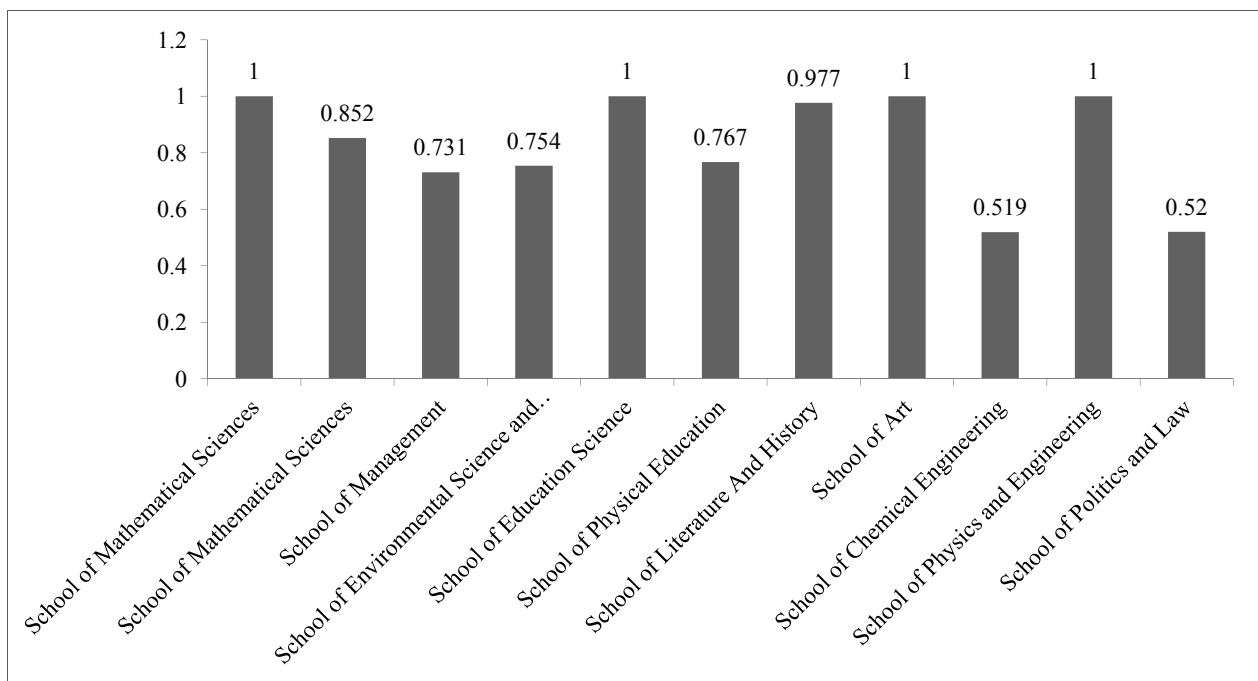
Figure 1. Cost-benefit ratios of educational resources of 11 schools in college during 2016.

Conclusion

Taking 11 schools of Qufu Normal University in China as examples, the paper analyzes input (cost) and output (benefit) by DEA to explore yield rate of educational resources during 2016. The allocation and benefit of educational resources are better grasped to optimize educational resources, improving cost-benefit ratio of education. Therefore, the problem of funds and educational resources' shortage could gradually solve.

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