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Efficiency Analysis of Universities in China Using DEA

Wan Lin Zhang*, Xiao Yan He,Shao Kang Yang, Dariush Khezrimotlagh
Department of Applied Statistics, Faculty of Economic and Administration, University Malaya, KL, Malaysia

*Corresponding Author
Wan Lin Zhang
Email: willa16317@gmail.com

Abstract: The government spending in higher education in China has annually been increased and the scientific research level of university determines its ability of receiving resources/budgets. This paper applies Data Envelopment analysis (DEA) for evaluating the relative efficiency of top 20 universities in China. Nine factors inclusive 4 inputs and 5 outputs are selected to find the rank of universities in 2013. Kourosh and Arash Model (KAM) is applied while a very small negligible thickness of the efficient frontier is introduced. KAM represents that only one university can be efficient with 10^{-6}degree of freedom (DF) and other DMUs are inefficient with 10^{-6}-DF while three universities were completely inefficient. The suggested KAM rankings are compared with the measured rankings by China Statistical Press (CSP). A significant difference can be seen between the two sets of ranking which suggests CSP to resurvey its methodology to rank universities of China.
Keywords: Data envelopment analysis, Kourosh and Arash model, Efficiency, University, China.

INTRODUCTION

The education system, which is referred to as a procedure of receiving and learning knowledge, plays an increasing important role in the development of societies, particularly in the aspect of knowledge economy. Educational expenditure accounts for 4% of GDP [1], comparing with countries in worldwide, the ratios of public education expenditure in developed countries are much higher than the ratios in developing countries. The average ratio of public education expenditure accounts for 5.2% of GDP world widely, 5.5% for developed countries, 4.6% for developing countries, China only makes a contribution of 2.41%.

As the expansion of higher education in various provinces in China, the quantity of educational resources that mainly depend on public expenditure grows more intense gradually; the situation that Chinese education is going through makes government to rethink about the solution of current efficiency problems. The level of university's scientific research determines its ability of receiving resources. Each university must put endeavor in improving the efficiency of resource distribution in order to get more resource from government or other third parties. Tian et al. [2] used Data Envelopment Analysis (DEA) to analyze the relative efficiency of 75 universities from three different parts, east part, middle part and west part, of China. Jill and Li [3] also measured the efficiency of 109 Chinese regular universities in 2003 and 2004 by applying DEA. Lu [4] studies the economies of scale in education industry by using DEA method, and findings showed that average scale of higher education in China is relatively small, which is because of low efficiency between inputs and outputs. Wang and Chen [5] used DEA Window Analysis (CCR model and BCC model) to analyze relative efficiency and catch-up effect.

DEA is a common tool for measuring the relative efficiency of a set of homogenous Decision Making Units (DMUs) with multiple inputs and outputs in many contexts and area. Since Charnes et al. [6] introduced DEA, a good number of researches has intensely been studied in theory and application of DEA. In this paper, the rank of 20 top universities of China according to China Statistic Press (CSP) is surveyed. Several factors are considered and divided into two sets of inputs and outputs in order to rank them by DEA. A recent robust model in DEA, called Kourosh and Arash Model (KAM) is applied to review CSP ranking [7].

The rest of this paper is organized in 5 section. In Section 2 a short history on DEA and the used models in this paper are illustrated. Data introduced in Section 3 and the results of DEA models are illustrated in Section 4. Sections 5 concludes the paper. Simulations are calculated by Microsoft Excel Solver 2013.

Background on DEA

DEA is a non-parametric method in operation research and economics for estimating production

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frontier. It provides selecting multiple inputs and multiple outputs to assess the relative efficiency score of homogenous DMUs. DEA defines a Production Possibility Set (PPS) according to a set of n number of available DMUs inclusive number of inputs and p number of outputs, and defines the frontier of the PPS as an estimation of the efficient frontier. Charnes et al. [6] identified DEA as a linear programming models based on Farrell idea [8].

Banker et al. [9] extended the first DEA model for Variable Returns to Scale (VRS) and introduced Banker, Charnes and Cooper (BCC) model. BCC in Input-Oriented (IO) approach (Output-Oriented (OO)) radially decreases (increases) the values of inputs (outputs) without worsening their outputs (inputs) values in order to reach to the frontier. DMUs which aren't lied on the frontier are called inefficient. If a DMU is lied on the frontier, it is called technically efficient.

Khezrimotlagh et al. [10] illustrated that a technically efficient DMU may neither be efficient nor be more efficient than all inefficient DMUs. Since the conventional DEA models are not able to discriminate between technically efficient DMUs, they proposed Kourosh and Arash Method (KAM) to improve the discrimination power of DEA significantly. KAM considers the efficient frontier as an efficient tape which is thicker than the efficient frontier by a very small negligible diameter. Table 1 introduces BCC and KAM VRS models.

In KAM, the weights are defined as $w_j^- = 1/x_{lj}$ and $w_k^+ = 1/y_{lk}$, where $x_{lj} > 0$ and $y_{lk} > 0$, and if $x_{lj} = 0$ or $y_{lk} = 0$, the weights are defined as 1.

The components of epsilon vector, ε_j^- and ε_k^+, are also defined as $\varepsilon \times \min\{x_{ij}: x_{ij} \neq 0, i = 1,2,\dots,n\}$ and $\varepsilon \times \min\{y_{ik}: y_{ik} \neq 0, i = 1,2,\dots,n\}$, respectively, when ε is a nonnegative real number. The value of ε is considered as a very small positive real number in order to have a negligible thickness in the frontier.

According to Khezrimotlagh et al. [7] a technically efficient DMU is called efficient with ε-DF if $1 - KA_\varepsilon^* < \delta$, otherwise, it is called inefficient with ε-DF. The value of δ depends to the aim of measuring the efficiency scores of DMUs and would be defined by $\varepsilon/(m+p)$ or $\varepsilon/10$ or greater value to have at least one efficient DMU with ε-DF in the sample.

If the value of epsilon is 0, KAM is the same as the weighted Additive DEA model (ADD) [11], and is almost completely the same as the non-linear Slack-Based Measure (SBM) [12].

Table 1: Some VRS DEA models.

Name	**Model**	**Targets and efficiency score**
BBC-IO	$\theta^* = \min \theta$, Subject to: $\sum_{i=1}^n \lambda_i x_{ij} + s_j^- = \theta x_{lj}$, for $j = 1,2,\dots,m$, $\sum_{i=1}^n \lambda_i y_{ik} - s_k^+ = y_{lk}$, for $j = 1,2,\dots,p$, $\sum_{i=1}^n \lambda_i = 1$, $\lambda_i \geq 0$, for $i = 1,2,\dots,n$.	$x_{lj}^* = \theta_l^* x_{lj} - s_{lj}^{-*}$, for $j = 1,2,\dots,m$, $y_{lk}^* = y_{lk} + s_{lk}^{+*}$, for $k = 1,2,\dots,p$.
BBC-OO	$\varphi^* = \max \varphi$, Subject to: $\sum_{i=1}^n \lambda_i x_{ij} + s_j^- = x_{lj}$, for $j = 1,2,\dots,m$, $\sum_{i=1}^n \lambda_i y_{ik} - s_k^+ = \varphi y_{lk}$, for $j = 1,2,\dots,p$, $\sum_{i=1}^n \lambda_i = 1$, $\lambda_i \geq 0$, for $i = 1,2,\dots,n$.	$x_{lj}^* = x_{lj} - s_{lj}^{-*}$, for $j = 1,2,\dots,m$, $y_{lk}^* = \varphi_l^* y_{lk} + s_{lk}^{+*}$, for $k = 1,2,\dots,p$.
ε-KAM-VRS	$\max \sum_{j=1}^m w_j^- s_j^- + \sum_{k=1}^p w_k^+ s_k^+$, Subject to: $\sum_{i=1}^n \lambda_i x_{ij} + s_j^- = x_{lj} + \varepsilon_j^-$, for $j = 1,2,\dots,m$, $\sum_{i=1}^n \lambda_i y_{ik} - s_k^+ = y_{lk} - \varepsilon_k^+$, for $j = 1,2,\dots,p$, $\sum_{i=1}^n \lambda_i = 1$, $\lambda_i \geq 0$, for $i = 1,2,\dots,n$, $s_j^- \geq 0$, for $j = 1,2,\dots,m$, $s_k^+ \geq 0$, for $k = 1,2,\dots,p$.	$x_{lj}^* = x_{lj} - s_{lj}^{-*} + \varepsilon_j^-$, for $j = 1,2,\dots,m$, $y_{lk}^* = y_{lk} + s_{lk}^{+*} - \varepsilon_k^-$, for $k = 1,2,\dots,p$, $KA_\varepsilon^{*l} = \dfrac{\sum_{k=1}^p w_k^+ y_{lk} / \sum_{j=1}^m w_j^- x_{lj}}{\sum_{k=1}^p w_k^+ y_{lk}^* / \sum_{j=1}^m w_j^- x_{lk}^*}$.

Data Selection

Table 2 illustrates 20 different universities of China and their introduced abbreviations in this study.

Table 2: Name of Universities in China.

Name of University	Code	Name of University	Code
Shandong University	SHU	Dalian University of Technology	DUT
Huazhong University of Science and Technology	HST	Tianjin University	TIU
Harbin Institute of Technology	HIT	Amoy University	AMU
Jilin University	JIU	Beijing Normal University	BNU
Nankai University	NAU	South China University of Technology	SCT
University of Science and Technology of China	STC	Tongji University	TOU
Xi`an Jiaotong University	XJU	Beihang University	BEU
Central South University	CSU	Lanzhou University	LAU
Southeast University	SOU	Chongqing University	CHU
Renmin University of China	RUC	China Agricultural University	CAU

Table 3 represents the data of each university inclusive 4 inputs and 5 outputs. These data are collected from official university websites and National Bureau Statistics of China [1]. The universities are also arranged from China Statistical Press (CSP) [13-14] ranking in 2013 from SHU to CAU (Tables 2-4). The considered factors are introduced as follows:

Input1:The total area of university,
Input2: The total number of lecturers at university,
Input3: The total number of departments at university,
Input4: The total number of students that enrolled and studied at university in 2013,
Output1: The score given by CSP to assess the undergraduate education training,
Output2: The score given by CSP to assess the postgraduate education training,
Output3: The score given by CSP to assess the scientific research,
Output4: The score given by CSP to assess the social research,
Output5: The employment rate for all graduated students in 2013.

Table 3: Data of 20 Universities of China.

University	**Input1**	**Input2**	**Input3**	**Input4**	**Output1**	**Output2**	**Output3**	**Output4**	**Output5**
SHU	8000.00	59523	3320	40	27.83	19.68	41.16	11.97	85
HST	7000.00	55751	3120	47	27.99	18.45	41.47	9.37	81
HIT	5212.35	51423	2970	24	28.26	15.16	49.12	2.65	79
JIU	15000.00	68957	6568	45	25.99	18.04	35.58	10.41	92
NAU	6841.50	24305	1988	38	23.54	15.24	26.83	18.08	78
STC	2025.00	15500	1572	30	23.75	10.16	39.64	2.77	86
XJU	3045.00	39136	2753	30	20.48	16.03	28.06	8.60	81
CSU	5886.00	54472	4114	31	20.33	15.44	30.43	4.85	93
SOU	5880.00	32000	2573	29	19.02	16.47	29.13	5.37	78
RUC	1050.00	25310	1852	18	18.50	15.91	2.64	31.09	84
DUT	6498.00	34764	3711	25	19.54	12.46	32.11	3.79	92
TIU	2730.00	28710	2446	20	18.18	14.66	29.22	4.65	82
AMU	8747.00	39979	2678	27	17.36	14.50	18.61	12.65	77
BNU	1107.00	23800	2100	26	16.44	14.46	13.62	16.00	79
SCT	4410.00	40447	2368	25	16.66	12.98	26.22	4.66	80
TOU	3855.00	36622	2786	22	16.72	14.94	25.21	3.52	82
BEU	3000.00	27811	2111	10	16.74	11.50	26.52	3.55	80
LAU	3807.00	31463	1966	35	15.28	9.83	24.25	3.99	88
CHU	5500.00	50000	2700	33	13.34	12.38	16.31	6.02	90
CAU	1945.50	26599	1613	15	13.12	8.81	22.86	2.83	83

Applying DEA Models

Since multiples of inputs values do not cause the same effects on outputs values, VRS is considered to rank selected universities. Columns 2-4 of Table 4 illustrate the technical efficiency scores of BCC-IO, BCC-OO and ADD model (0-KAM)[15].

Table 4: The results of applying VRS DEA models.

DMUs	**BCC-IO**	**BCC-OO**	**ADD**	**10^{-6}-KAM**	**Rank**	**Decision**	**Reference Sets**
SHU	1.0000	1.0000	1.0000	0.99999981	3	Inefficient with 10^{-6}-DF	SHU, HIT, RUC
HST	1.0000	1.0000	1.0000	0.99999707	10	Inefficient with 10^{-6}-DF	SHU, HST, HIT, NAU, RUC
HIT	1.0000	1.0000	1.0000	0.99999988	1	Efficient with 10^{-6}-DF	SHU, HIT
JIU	1.0000	1.0000	1.0000	0.99999443	13	Inefficient with 10^{-6}-DF	SHU, JIU, CSU, RUC
NAU	1.0000	1.0000	1.0000	0.99999977	5	Inefficient with 10^{-6}-DF	NAU,STC,RUC
STC	1.0000	1.0000	1.0000	0.99999986	2	Inefficient with 10^{-6}-DF	STC,RUC
XJU	1.0000	1.0000	1.0000	0.99999714	9	Inefficient with 10^{-6}-DF	HIT,STC,XJU,RUC
CSU	1.0000	1.0000	1.0000	0.99999335	14	Inefficient with 10^{-6}-DF	SHU,STC,CSU,RUC
SOU	1.0000	1.0000	1.0000	0.99999493	12	Inefficient with 10^{-6}-DF	SHU,NAU,SOU,RUC, TIU
RUC	1.0000	1.0000	1.0000	0.99999978	4	Inefficient with 10^{-6}-DF	STC,RUC
DUT	1.0000	1.0000	1.0000	0.99999300	15	Inefficient with 10^{-6}-DF	HIT,STC,RUC,DUT
TIU	1.0000	1.0000	1.0000	0.99999755	8	Inefficient with 10^{-6}-DF	HIT,STC,RUC,TIU,BEU
AMU	0.7547	1.1213	0.5194	0.51937391	19	Inefficient	HIT,STC,RUC
BNU	1.0000	1.0000	1.0000	0.99999912	7	Inefficient with 10^{-6}-DF	STC,RUC,BNU
SCT	0.8341	1.0672	0.5337	0.53366260	18	Inefficient	HIT,STC,RUC
TOU	0.8959	1.0210	0.4808	0.48083006	20	Inefficient	HIT,STC,RUC
BEU	1.0000	1.0000	1.0000	0.99999946	6	Inefficient with 10^{-6}-DF	HIT,RUC,BEU
LAU	1.0000	1.0000	1.0000	0.99996425	16	Inefficient with 10^{-6}-DF	STC,RUC,DUT, LAU
CHU	1.0000	1.0000	1.0000	0.99995973	17	Inefficient with 10^{-6}-DF	STC, CSU, RUC, LAU, CHU
CAU	1.0000	1.0000	1.0000	0.99999670	11	Inefficient with 10^{-6}-DF	STC, RUC, BEU, CAU

Since the minimum values of each factor in Table 3 are as follows:

Factors	Input1	Input2	Input3	Input4	Output1	Output2	Output3	Output4	Output5
Min Values	1050.00	15500	1572	10	13.12	8.81	2.64	2.65	77

by introducing the value of epsilon as 10^{-6}, the components of epsilon vector, ε_j^- and ε_k^+, by calculating $\varepsilon \times \min\{x_{ij}: x_{ij} \neq 0, i = 1,2,\dots,n\}$ and $\varepsilon \times \min\{y_{ik}: y_{ik} \neq 0, i = 1,2,\dots,n\}$, are measured, respectively, which are $\varepsilon_1^- = 0.00105000$, $\varepsilon_2^- = 0.01550000$, $\varepsilon_3^- = 0.00157200$, $\varepsilon_4^- = 0.00001000$, $\varepsilon_1^+ = 0.00001312$, $\varepsilon_2^+ = 0.00000881$ and $\varepsilon_3^+ = 0.00000264$, $\varepsilon_4^+ = 0.00000265$, $\varepsilon_5^+ = 0.00007700$. As can be seen, the epsilons are completely negligible according to the minimum values of each factor. The value of δ is also selected as $\varepsilon/5$ in order to have at least one efficient DMU with 10^{-6}-DF [16].

Columns 5-8 show the results of KAM with 10^{-6}-DF. According to the table, KAM with a very small negligible thickness of the frontier, simultaneously arranges and benchmarks all technically efficient and inefficient DMUs appropriately. None of universities can be efficient if δ is selected as $\varepsilon/(m+p)$, that is, $10^{-5}/9$. Only HIT can be efficient with 10^{-6}-DF while δ is selected as $10^{-5}/9$.The value of δ is also selected as $10^{-5}/5$. In this case, the first three ranked universities by 10^{-6}-KAM could be called efficient with 10^{-6}-DF and all other technically efficient universities are inefficient with 10^{-6}-DF.

As can be seen, although, CSP ranked HST in the second level, 10^{-6}-KAM suggests it into 10^{th} level. The inefficient universities AMU, SCT and TOU even ranked higher than some technically efficient universities such as the last four universities in Table 4 by CSP, however, 10^{-6}-KAM ranks them into level 18^{th}-20^{th}. Surprisingly, BEU should be ranked in 6^{th} level, whereas CSP ranked it into 17^{th} level.

CONCLUSION

This paper surveys the ranking of CSP for 20 Chinese universities by applying DEA. The results suggest CSP to review their ranking methodology. Indeed, some universities had high values of outputs, but they simultaneously used the high values of resources too. The technique of DEA by using KAM appropriately represents which university with less inputs values has high values of outputs. Selecting more universities with more number of factors can be a future challenge to rank universities of China.

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