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An Approach for Evaluating Journals of Universities or Colleges Based upon Multi-layer Efficiency DEA[1]

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Abstract

After analyzing the characteristics of journals of universities or colleges and the weakness of existing evaluation methods, this paper presents a DEA-based approach to analyze the quality of journals. Then, based on multi-layer efficiency, a DEA method is also provided to classify journals. A real case with 28 journals of Chinese agricultural universities and colleges is employed to illustrate the reasonability of the developed approaches.

Keywords: Data Envelopment Analysis (DEA), Journals of Universities or Colleges, Evaluation, Multi-layer Efficiency;

1. Introduction

Journals of universities and colleges in China are a type of scholarly publications which present their unique characteristics, which focus on reflecting the strength of instruction and research. Therefore, the published papers in these journals are mainly periodic and creative achievements of young instructors rather than the most outstanding papers of the university, which also represent the university's research strength. Currently, an increasing number of Master's and Doctor's papers published in academic journals are consistent with this law. In order to improve the academic standard of journals of universities and colleges, papers from outside the university and high-qualified papers are commonly adopted. It is noticeable that the adoption of papers from outside the university is increasing, which has gradually become one of the key windows for both domestic and international academic exchanges.

However, compared with other professional academic journals, journals of universities and colleges present inherent weakness in three aspects. First, most of journals of universities and colleges are comprehensive academic journals. Their influence is limited because their circulation[1] is much lower than

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that of professional academic journals and they are difficult to be commercialized. Second, journals of universities and colleges mainly consist of papers written by in-service instructors. Only when the research strength of a university meets a high standard, can the quality of papers in these journals be improved. Third, there is a substantial difference in the standard and influence of journals between various universities and colleges, because they differ in the standard of scientific research, studying environment, release phases and circulation. Due to these weaknesses, the objective evaluation of the academic standards must be negatively influenced.

Many academic journals are evaluated by a single index, such as the number of citation, the impact factor, the immediacy index, and the h-index. However, these evaluation measures only demonstrate a single aspect rather than the overall quality of the journal. Particularly, due to the specificity of the readers of journals of universities and colleges, it is hard to assess their quality and influence accurately by these measures. The composite index measure which emphasizes on data analysis is proposed in [4] to evaluate the quality of journals. According to [5], grey relational analysis approach and multi-index notation are proposed to assess the quality of journals. It is worth mentioning that the weight of each index is firstly determined by a method, such as the expert evaluation method and analytic hierarchy process (AHP) method. Then values produced by the multi-index comprehensive evaluation represent the quality of journals [4], [5]. The larger the value is, the better quality of the journal will be. Therefore, the difference in the determined weights will lead to different results.

Based on the multi-index comprehensive evaluation, this paper first analyzes the benchmarking of journals from an efficiency point of view by using DEA method and objective data of each journal. Second, taking the specialty of journals of universities and colleges into account, this paper proposes a journal classification method based on multi-layer efficiency. Third, it proves the reasonability and applicability of the proposed method with an example of journals of agricultural colleges.

2. DEA models for academic journals evaluation

Data envelopment analysis (DEA), proposed by two well-known operations research experts, Charnes and Copper, in 1978, is a mathematical programming approach which analyzes productive efficiency of decision making units (DMUs) with multiple inputs and multiple outputs. DEA has the following distinguished features: it does not need to provide a general relationship relating output and input; it does not require parametric assumptions and weight vectors; it evaluates the relative efficiency of DMUs by maximizing the ratio of the weighted sum of outputs to that of inputs. Due to these features, DEA has become an important and effective mathematical analysis tool applied in Management Science and Systems Engineering.

For computational convenience, consider n $\mathrm{DMU}_j (j = 1, 2, \cdots, n)$ that requires assessment. Each DMU consumes m inputs and produces s outputs, denoted by $X_j = (x_{1j}, x_{2j}, \cdots, x_{mj})^T$, and $Y_j = (y_{1j}, y_{2j}, \cdots, y_{sj})^T$, respectively:

CCR ratio model

$$
\begin{aligned}
&Max\ \rho_0 = \sum_{r=1}^{s} \mu_r y_{r0} \\
&subject\ to \\
&\quad \sum_{i=1}^{m} u_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0,\ j = 1, 2, \cdots, n, \\
&\quad \sum_{i=1}^{m} u_i x_{i0} = 1, \\
&\quad u_i, \mu_r \geq \varepsilon,\ \forall i, r.
\end{aligned} \tag{1}
$$

Model (1) assumes constant returns to scale. A DMU_0 is considered to be efficient if it obtains a score $\rho_0$of 1 and a score ρ_0 of less than 1 implies that it is inefficient. The efficiency in model (1) is a composite efficiency, which consists of both technical efficiency and scale efficiency. If a DMU is efficient, it must be both technical efficient and scale efficient. If journals are regarded as DMUs, and various evaluation index of journal as inputs and outputs, the efficiency score obtained in model (1) can effectively evaluate and benchmark DMUs.

In the evaluation of journals, indexes are attached of different importance. For example, the number of cited articles which reflects the quality of articles weighs more heavily than the number of self-cited articles which can not accurately reflect the quality of articles. Therefore, weight vectors, such as $\mu_2 \geq \mu_1$, must be used in the above model.

Due to the big differences between academic journals, analysis should be conducted not only on the differences themselves, but also on the reasons behind. In addition, benchmark should be found to improve the academic standards of journals with lower ranking. When setting the benchmark, real conditions should be taken into consideration, such as the internal and external factors of journals, and the possibilities of improving the quality. For example, it is almost impossible for the quality of journals of a university to be improved to that of journals of Chinese Academy of Science. In this case, all journals should be effectively classified according to their qualities. Journals with lower ranking can strengthen their academic standards by taking those with higher ranking as a model. Therefore, the stratification DEA model is proposed to realize the classification.

3. Multi-layer DEA models

In the traditional DEA model, a piecewise surface is constructed over all DMUs, so as to be able to calculate efficiencies relative to this surface. In the given units, removing some inefficient DMUs will not change the value of efficiency and the location of the frontier. However, the efficiency of DMUs will change by shifts of frontiers, thus some inefficient DMU will become efficient. Actually, frontiers can be classified into multi layers when taking factors, such as production environment, and input- output ratio, into consideration, thus different DMUs belong to different layers. When evaluating the efficiency, if the first layer and the efficient DMUs are excluded, the remaining DMUs will construct a second frontier and form of new efficient units. Therefore, when all DMUs are efficient on particular layers, p layers of frontiers are constructed. Fig.1 shows the meaning of the multi-layer efficiency.

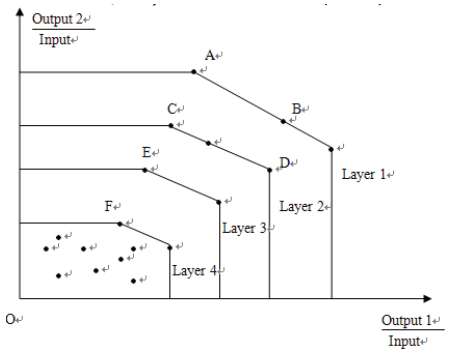

Fig.1 Multi-layer efficiency model

Figure 1 illustrates that efficiency evaluation can be conducted on multi layers. DMUA and DMUB are efficient on the first layer, and efficient of all DMUs, while DMUC and DMUD are efficient on the second layer, DMUE on the third layer, thus all DMUs are efficient on a particular layer.

When calculating the efficiency, efficient DMUs on the first layer are firstly determined. Then remove the efficient DMUs on the first layer and determine the efficient DMUs on the second layer, then the third and the rest. It can be seen that DMUs can be efficiently classified into a particular category according to various frontiers constructed. In the classification of academic journals, the academic standard or the technical efficiency is mainly taken into consideration. Based on the multi-layer efficiency model, this evaluation model shows as follow:

$$
\begin{aligned}
&Max \quad h_0 = \sum_{r=1}^{s} \mu_r y_{r0} \\
&subject\ to \\
&\qquad \sum_{i=1}^{m} u_i x_{ij} - \sum_{r=1}^{s} \mu_r y_{rj} \geq 0, \\
&\qquad \sum_{i=1}^{m} u_i x_{i0} = 1, \\
&\qquad j \in \psi_g, \psi_g = \Omega - \bigcup_{k=1}^{g-1} F_k, \\
&\qquad u_i, \mu_r \geq \varepsilon, \quad \forall i, r.
\end{aligned}
$$

All DMUs are represented by Ω, the present evaluated layer by g. DMUs on the k-th layer are denoted by F_k, and DMUs excluding the efficient DMUs on 1st to g-1th by ψ_g. According to the above analysis, the multi-layer efficiency can be calculated as follow:

Step 1: Set g=1

Step 2: Determine ψ_g, if ψ_g is an empty set, g=g-1 and calculation finishes

Step3: DMU_l, $l \in F_g$ (F_g represents all efficient DMUs on the gth layer)or DMUs on the gth layer can be determined by model (2)

Step 4: g=g+1, back to Step 2

Efficient DMUs on each layer can be determined from the above calculation, and the following definition

can be found in model (2).

Definition 1: DMU_l ($l \in F_g$) calculated by the model (2) are the efficient DMUs on the gth layer.

According to model (2) and Definition 1, efficient DMUs on each layer can be determined. DMUs can be efficiently classified into g categories with efficient DMUs on each layer as a category. Therefore, when evaluating the academic standard of journals based on multi-layer efficiency model, journals can be efficiently classified into g categories, and benchmark for improvement can be reasonably set for journal with lower ranking.

4. Case Study

Due to the differences in majors and subjects among universities and colleges, the evaluation indicators of journals are very different. For example, EI mainly adopts journals and articles in engineering rather than other research fields. This paper analyzes the academic standards of 28 journals of agricultural universities and colleges by setting the number of published articles, the number of citation, and the number of included articles as basic evaluation indicators. Specifically, the number of citation can be divided into two components, namely the number of self-cited articles and the number of citable articles. The number of included articles is determined by that of China Agricultural Science and Technology Literature Database, and China Science and Technology Periodical Database rather than that of SCI, EI, and CABI, where journals are scarcely adopted.

Generally, journals have higher quality with lower number of published articles and higher number of citation and included articles. Based on this assumption, which is opposed to the view of [10], this paper set the number of published articles as an input. In addition, the number of citable articles, which can better reflect the quality of journals, weighs heavily than the number of self-cited articles. Relevant data of journals from 1989-1994 are chosen as showed in Table I.

In Table I, China Agricultural University, Nanjing Agricultural University, Southwest Agricultural University, Northwest Agricultural University, Huazhong Agricultural University, South China Agricultural University, and Shenyang Agricultural University are key universities belonged to the Ministry of Agriculture, while others are general universities. It should be noted that the number of included articles are the sum of the number of China Agricultural Science and Technology Literature Database, and China Science and Technology Periodical Database, which is larger than the number of published articles.

In order to analyze the classification and ranking of journals of agricultural universities and colleges based on multi-layer DEA models, the difference in weight vectors among three outputs should be taken into consideration. Generally, the number of citable scientific articles can be set as a key evaluation indicator, whose weight vector is larger than that of the number of self-cited articles and that of the included number of China Agricultural Science and Technology Literature Database and China Science and Technology Periodical Database. However, the weight vector of the number of included articles should be larger than that of the number of self-cited articles, represented by $\mu_2 \geq \mu_1$, $\mu_2 \geq \mu_3$, $\mu_3 \geq \mu_1$. Then the composite efficiency score can be calculated by using the model (1). To prove the reasonability of the proposed method, comparisons between efficiency with and without weight vectors are given. Rankings in [10] with weight vectors are also provided in Table II.

Taking weight vectors into consideration, the composite efficiency scores of journals of China Agricultural University, Nanjing Agricultural University, and Fujian Agricultural University are 1 which indicate efficient DMUs, both technical efficient and scale efficient. It implies that in a particular scale, the number of included articles of these journals is technical efficient, whose academic standards can be highly recognized. However, the composite efficiency scores are low in journals of Jiangxi Agricultural University, Guangxi Agricultural University, Bayi Agricultural University, Shanghai Agricultural College, Beijing Agricultural College, and Guizhou Agricultural College, which indicate the scholarly standards should be

improved under the present scale. The efficiency score is lowest (0.4500) in journals of Guangxi Agricultural University. Compared this score with that of journals of Henan Agricultural University and Shandong Agricultural University which are similar in the number of published articles, there is a big gap in the number of citations and included articles; therefore, it is relatively lower. Due to the lower number of self-cited articles, the efficiency scores in journals of Northwest Agricultural University and Shenyang Agricultural University are lower than scores of journals of other key universities, and scores of journals of Zhejiang Agricultural University and Jilin Agricultural University which has similar number of published articles.

Table 1 Basic data of journals of universities and colleges

No.	published articles	self-cited articles	citable articles	included articles
1	626	152	146	1066
2	737	274	183	1070
3	855	256	127	1342
4	623	124	88	752
5	743	221	129	1002
6	540	180	76	921
7	661	67	44	905
8	433	157	84	678
9	549	295	98	876
10	615	129	55	706
11	611	127	109	952
12	452	132	70	702
13	738	125	81	1133
14	608	150	59	1001
15	475	117	57	638
16	478	113	58	800
17	561	88	28	956
18	643	133	36	993
19	485	106	16	738
20	474	125	19	349
21	459	96	11	714
22	405	97	71	664
23	405	71	5	431
24	384	88	36	612
25	373	98	21	397
26	283	52	37	163
27	225	33	10	271
28	221	23	4	304
Average	523.6	129.6	62.8	754.9

To further prove the reasonability of the proposed method, a comparative analysis is conducted between efficiency with and without weight vectors. As showed in Table II, the efficiency scores without weight vectors are 1 in journals of South China Agricultural University as well as China Agricultural University, Nanjing Agricultural University, and Fujian Agricultural University. However, according to the data in Table 1, values of each item of journals of South China Agricultural University are lower than that of Fujian Agricultural University which has similar number of published articles; therefore, the efficiency score of journals of South China Agricultural University must be lower than that of Fujian Agricultural University (1.0). In addition, journals of South China Agricultural University do not have obvious competitive advantages when compared with journals of Northeast Agricultural University and Zhejiang Agricultural University. All these prove that there may remain bias in practice if weight vectors are not taken into account. Moreover, if take weight vector into consideration, the efficiency score of Shandong Agricultural University

(0.9301) is higher than that of Hebei Agricultural University (0.9079), and Sichuan Agricultural University (0.9059); if not, the efficiency score is highest in Sichuan Agricultural University (0.9990), following by Shandong Agricultural University (0.9812) and Hebei Agricultural University (0.9652). According to Table1, the number of citation in journals of Sichuan Agricultural University is only a half of Shandong Agricultural University and Hebei Agricultural University. However, lower numbers of citation and included articles indicate that ranking may differ if weight vectors are not considered.

Table 2 Evaluation of Journals of universities and colleges

No.	With weight vectors	Without weight vectors	Weighted ranking
1	1.0000	1.0000	5
2	1.0000	1.0000	2
3	0.9097	0.9232	1
4	0.7044	0.7093	12
5	0.8164	0.8174	3
6	0.9807	1.0000	10
7	0.7415	0.8026	11
8	0.9466	0.9472	16
9	1.0000	1.0000	6
10	0.6536	0.6731	14
11	0.8969	0.9144	7
12	0.9028	0.9145	17
13	0.8496	0.9000	4
14	0.9079	0.9652	8
15	0.7724	0.7877	19
16	0.9301	0.9812	15
17	0.9059	0.9990	13
18	0.8282	0.9054	9
19	0.8092	0.8921	18
20	0.4500	0.4907	23
21	0.8188	0.9120	20
22	0.9405	0.9619	21
23	0.5667	0.6239	24
24	0.8763	0.9344	22
25	0.6113	0.6397	25
26	0.5265	0.5265	26
27	0.6451	0.7062	27
28	0.7198	0.8065	28
AVG	0.8476	0.8111	

It can clearly be seen that the importance of each indicator should be considered when analyzing the quality of journals. From the above analysis, the number of published articles is set higher weight vector. In addition, the difference between the number of citation and self-cited articles is not taken into consideration. Therefore, the produced ranking is not representative, which can be shown from the example of journals of Southwest Agricultural University ranking first, and Guangxi Agricultural University ranking 23th.
Memo: No. in table 1 and table 2 is the number of Journals of universities and colleges, as table 3 shown

Table 3 the number of Journals of universities and colleges

No.	**Journals of universities and colleges**
1	Journals of China Agricultural University
2	Journals of Nanjing Agricultural University
3	Journals of Southwest Agricultural University
4	Journals of Northwest Agricultural University
5	Journals of Huazhong Agricultural University

6	Journals of South China Agricultural University
7	Journals of Shenyang Agricultural University
8	Journals of Northeast Agricultural University
9	Journals of Fujian Agricultural University
10	Journals of Jiangxi Agricultural University
11	Journals of Zhejiang Agricultural University
12	Journals of Anhui Agricultural University
13	Journals of Hunan Agricultural University
14	Journals of Hebei Agricultural University
15	Journals of Henan Agricultural University
16	Journals of Shandong Agricultural University
17	Journals of Sichuan Agricultural University
18	Journals of Jilin Agricultural University
19	Journals of Gansu Agricultural University
20	Journals of Guangxi Agricultural University
21	Journals of Inner Mongolia Institute of Agriculture and Animal Husbandry
22	Journals of Jiangsu Agricultural College
23	Journals of Bayi Agricultural College
24	Journals of Yunnan Agricultural University
25	Journals of Shanghai Agricultural University
26	Journals of Beijing Agricultural College
27	Journals of Guizhou Agricultural College
28	Journals of Heilongjiang Agricultural University

The multi-layer DEA model is used by calculating the number of the efficient DMU on each layer as showed in the Table Ⅳ.

Table 4 Classification of journals of universities and colleges

Classification	Effective Unit	Journals of universities and colleges
1	1, 2, 9	Journals of China Agricultural University, Nanjing Agricultural University, and Fujian Agricultural University
2	6, 8, 22	Journals of South China Agricultural University, Northeast Agricultural University, and Jiangsu Agricultural College
3	3, 11, 12, 16	Journals of Southwest Agricultural University，Zhejiang Agricultural University, Anhui Agricultural University, and Shandong Agricultural University
4	5, 14, 17	Journals of Huazhong Agricultural University, Hebei Agricultural University, and Sichuan Agricultural University
5	4, 13, 24	Journals of Northwest Agricultural University, Hunan Agricultural University, and Yunnan Agricultural University
6	7, 15, 18, 19, 21	Journals of Shenyang Agricultural University, Henan Agricultural University, Jilin Agricultural University, Gansu Agricultural University, and Inner Mongolia Institute of Agriculture and Animal Husbandry
7	10, 20, 23, 25-28	Journals of Jiangxi Agricultural University，Guangxi Agricultural University, Heilongjiang Agricultural University, Shanghai Agricultural University, Beijing Agricultural University,and Agricultural College

As showed in the Table 4 , efficient DMUs on the first layer are journals of China Agricultural University, Nanjing Agricultural University, and Fujian Agricultural University. After excluding these three journals, calculate the efficiency scores of the remaining journals by model (2), and produce efficient DMUs on the second layer, such as South China Agricultural University. According to Table 4 , all journals are classified into 7 categories from the first efficient layer to the sixth efficient layer, and the seventh layer containing the remaining journals. The classification in Table 4 is generally consistent with the results in Table 2. It is notable that the composite efficiency scores of journals of Hebei Agricultural University and

Sichuan Agricultural University are similar to that of Anhui Agricultural University and Zhejiang Agricultural University. However, the former two journals are on the fourth efficient layer, but not the third layer. The academic standards should be improved for the journals of Hebei Agricultural University and Sichuan Agricultural University in order to improve the efficient layer.

5. Conclusion

Journals of universities and colleges present achievements not only in instruction and scientific research of a single university but also of the society. After analyzing journals of agricultural universities and colleges, it can be concluded that open source journals, such as journals of China Agricultural University, and journals of Nanjing Agricultural University, rank higher than those mainly made up of papers simply from one university. Therefore, in order to improve the academic standards of journals of universities and colleges, the scientific research management should be strengthened and the adoption of papers from outside the university should increase. This paper proposes a multi-index comprehensive evaluation method based on DEA, which rank and classify journals by calculating weighted inputs and weighted outputs. The DEA method is proved to be reasonable and applicable by the case study of journals of universities and colleges. Although this method is proposed for journals of universities and colleges, it can also be directly used in evaluation and analysis of other academic journals, which has a high practical value.

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