

## Retraction

# Retracted: The Evaluation and Its Key Influencing Factors Analysis of “Double First-Class” Universities’ Teaching Efficiency in China Based on SBM-DEA and Its Visual Decision Analysis System Development

### Discrete Dynamics in Nature and Society

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article’s content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### References

- [1] H. Li, S. Pang, Z. Zuo, and M. Tao, “The Evaluation and Its Key Influencing Factors Analysis of “Double First-Class” Universities’ Teaching Efficiency in China Based on SBM-DEA and Its Visual Decision Analysis System Development,” *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 4877551, 14 pages, 2021.

## Research Article

# The Evaluation and Its Key Influencing Factors Analysis of “Double First-Class” Universities’ Teaching Efficiency in China Based on SBM-DEA and Its Visual Decision Analysis System Development

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Based on a systematical summary of relevant research on university teaching efficiency, an evaluation index system was built to evaluate teaching efficiency of “Double First-Class” universities in China. The evaluation model to evaluate the teaching efficiency of these universities was built based on Slack-Based Measure model using Superefficiency Data Envelopment Analysis (SBM-DEA). Teaching efficiency of 36 “Double First-Class” universities had been evaluated after their assessment indexes data had been collected. The influencing relations between the teaching efficiency of “Double First-Class” universities and dual prices of each evaluation index had been analysed. It had been proven that teaching efficiency could be greatly improved by increasing the index value with a higher double price. We proceeded to count the frequencies of evaluation indicators with the highest or the second highest dual prices. The indexes with higher total importance were defined as the key factors for the development of teaching efficiency in China’s “Double First-Class” universities. Several countermeasures had been proposed to improve the development of “Double First-Class” universities’ teaching efficiency. Finally, based on the above theoretical research, the evaluation and decision analysis software for teaching efficiency in “Double First-Class” universities in China had been developed by Visual Basic 2015 and MATLAB 2015 with Access database to store the data. It provides a convenient visualization tool to manage the data of the evaluation index system and make the data analysis of the SBM-DEA model.

## 1. Introduction

Not only does the development of the world economy depend on talents but it also depends on the improvement of national and international competitiveness. Universities are the place where talents are taught core subjects. In China, the promulgation of the *Overall Plan for Coordinately Advancing the Construction of World First-class Universities and First-class Disciplines* (OPCACWFUFD) was enacted in 2015, opening the way for the preparatory work to build “Double First-Class” universities. In total, 42 Chinese universities were selected as “Double First-Class” by the Ministry of Education, Ministry of Finance and National

Development and Reform Commission of China in 2017. The Guiding Opinions on Speeding up the Construction of “Double First-Class” Universities was issued in 2018. It emphasizes the first-class undergraduate education as an important content, where multiple comprehensive evaluation criteria must be necessarily adhered. The presented evaluation criteria should combine the qualitative and quantitative, subjective, and objective methods in order to achieve discipline and skill. The construction of evaluation mechanisms should be conducted in parallel with the overall construction of the evaluation system of their university. Chen Baosheng, China’s Minister of Education, pointed out that one of the main directions of education reform and

development in 2018 was to pay attention to the performance management of “Double First-Class” universities and to study and formulate their performance evaluation method. Therefore, discussion on the evaluation theory and promoting methods and strategies of efficient teaching are not only an urgent need for the construction and development of “Double First-Class” universities in China but also an urgent need in promoting the rapid development of high-level undergraduate education.

The paper is divided into 8 sections. After reviewing the relevant research on the input-output efficiency of universities in Section 2, the evaluation index system of teaching efficiency of “Double First-Class” universities was built in Section 3. In Section 4, a Slack-Based Measure model using superefficiency data envelopment analysis (SBM-DEA) was built and was proved to be appropriate in the case of 36 “Double First-Class” universities. The key influencing factors of teaching efficiency in “Double First-Class” universities in China were analysed in Section 5. The visual decision analysis system development to evaluate teaching efficiency in “Double First-Class” universities in China was introduced in Section 6. The countermeasures to improve the teaching efficiency of “Double First-Class” universities in China were presented in Section 7. The research conclusions and related issues to be studied in the future were identified in Section 8.

## 2. Literature Review

Relevant scholars in China and internationally have conducted abundant research and analysis on the input-output efficiency of universities from different perspectives:

- (1) Research on the evaluation index system of universities' input-output efficiency

The input-output efficiency evaluation index systems of universities have been built with different focuses. Basic faculty, daily funding, or equipment funding were selected as input indicators, whereas the number of graduate students or published academic papers as output indicators [1–4]. Ahn et al. [5] chose teacher salary and other cost indicators as input indicators. Johnes [6] paid more attention to the quality of enrollment students and the quality of graduates of universities. Avkiran [7] divided faculty members into academic and nonacademic personnel as input indicators. Kuah and Wong, Gökşen et al., Sagarra et al., Tian et al., and Qiao [8–12] evaluate the comprehensive efficiency of teaching and scientific research of universities. Teaching efficiency is often disregarded since the evaluation index system of input-output efficiency of colleges and universities is mostly about scientific research efficiency or scientific research-teaching efficiency. Furthermore, evidence above shows that the research on the teaching efficiency evaluation index system is relatively few.

- (2) Research on the evaluation method of input-output efficiency of the university

Presently, nearly two-thirds of the literature on the input-output efficiency of universities are based on Data Envelopment Analysis (DEA). The earlier research results used two classic models, CCR-DEA and BCC-DEA [3, 6, 7, 11]. The DEA model had been improved with its theoretical model development. Kempkes and Pohl used the DEA-Malmquist index method [1], and Kuah and Wong and Qiao [8, 12] used the joint DEA model to evaluate the comprehensive efficiency of teaching and research. Ni fully considered the lag between the input-output scales of scientific research and constructed the lagged non-radial Superefficiency DEA model to evaluate the efficiency of scientific research in higher educational institutions [13]. Li and Zeng and Chen and Yue [14, 15] evaluated the scientific research efficiency of universities in China, and comprehensively analysed the internal and external factors that affected their efficiency of scientific research. As a consequence, the evaluation contents are mainly concentrated on scientific research efficiency.

- (3) Evaluation of the construction efficiency of “Double First-Class” universities

The evaluation of first-class universities came from the evaluation of university rankings, whose scopes of comparison were mainly at both national and global level [16]. John Vaughn, executive vice president of the American University Association, thought that a World-First-Class university was a world-renowned one with a wide range of disciplines and top-quality education [17]. The different evaluation index systems for World-First-Class universities have been built by developed countries and many institutions, such as Research Excellence Framework (REF), “United States National Research Council” (NRC), QS World University Rankings, and The World University Academic Ranking (ARWU).

Some scholars in China have studied the evaluation of “Double First-Class” universities, since its overall construction plan was proposed in China in 2015. Scholars expressed their opinions on the construction of “Double First-Class” universities and put forward the guiding ideology, principle, and ways of improvement for its construction and evaluation mechanism [18–22]. The conclusion is that the construction and method to evaluate performance of “Double First-Class” universities had not yet been formed as a unified standard. Zeng et al. [23] pointed out that certain mathematical statistical methods could be adopted to evaluate the world-class universities and disciplines, but no specific evaluation method had yet been given. Although these studies mentioned some evaluation indicators about teaching, they still cannot fully describe the teaching efficiency.

Although China’s “Double First-Class” university has been built more than three years, the research on its teaching efficiency evaluation has not been given enough attention,

and the following problems need to be further explored: (a) It is necessary to give importance to teaching efficiency because undergraduate education is set as the base of university education and four returns to undergraduate education are promoted to accelerate the construction of high-level undergraduate education. (b) The construction goal of “Double First-Class” university in China is to promote a number of high-level universities and disciplines to enter the world’s top or forefront. Therefore, teaching efficiency should be taken in consideration to solve the problem on how to reflect the “world-class.” (c) Teaching efficiency can be obtained by various DEA models scientifically after its evaluation index system has been built. Nevertheless, there is seldom research to discuss how to effectively improve its efficiency. The existing research has put forward corresponding countermeasures to improve the efficiency that has been calculated, albeit it should be further verified their effectiveness. (d) Most of the results had researched the theoretical model to evaluate the efficiency, but seldom result discussed the visual decision analysis system development for them. This paper will attempt to solve all of the above-mentioned problems.

### 3. Building the Evaluation Index System of Teaching Efficiency for “Double First-Class” Universities

It is elementary to establish a scientific and reasonable teaching efficiency evaluation index system of “Double First-Class” universities before we begin to evaluate its efficiency. According to the teaching requirements of OPCACWFUFD and the comprehensive consideration of data availability, the evaluation index of teaching efficiency for “Double First-Class” universities in China will be constructed as follows:

- (1) University aspect: it is emphasized to highlight the priority demand of teaching and increase the motivation of teachers, who hold teaching positions in OPCACWFUFD. Among them, the priority demand of teaching refers to the various needs of teachers in the process of teaching students, including the investment of various hardware and software facilities, as well as the reform of educational systems and the development of educational activities. Therefore, universities must have sufficient funding allocated by the Ministry of Education. In this light, the operational funds are selected as an input indicator.
- (2) Faculty aspect: equivalent number of faculties and academic level of teachers are selected as input indicators to measure the quantity and quality of teaching input. In fact, there are some differences in teaching output among different professional title composition of the faculty of each university, which is not considered by the DEA model. For example, the teaching experience and research level of professors and associate professors are often higher than that of teachers and teaching assistants, resulting in their stronger impact on students in the teaching process. The different professional title composition

of the faculty of each university will affect the teaching efficiency, which is not considered by the DEA model. In order to fully reflect the quantity and quality of teachers in the universities, the weight proportions of different titles of professors, associate professors, lecturers, and teaching assistants are given to calculate the equivalent number of faculties, as shown in Table 1. The National Teaching Achievement Award is selected as the output indicator to measure the contribution of teaching staff in teaching [24].

- (3) Student cultivation aspect: quality of graduates, teaching quality, student competition awards, and student employment rate are selected as the output indicators, and quality of enrolled freshmen is selected as the input indicator. The data on the quality of graduates and teaching quality in 2018 can be found in the quality evaluation index system of university graduates on the website of the Alumni Association of China. Student employment rate can be found in the employment quality report for undergraduates of each university.

The different scores for each item of different degree of award are put according to the following principle: the smaller the proportion of the award, the greater the difficulty, so a higher score should be given. This is shown in Table 1.

To sum up, the evaluation index system of teaching efficiency of “Double First-Class” universities in China has been constructed from three aspects, university, teacher, and student, as shown in Table 2.

### 4. Teaching Efficiency Evaluation Model of “Double First-Class” Universities in China Based on Superefficient SBM-DEA

*4.1. Selection of the DEA Model.* In order to reflect the input-output structure of teaching efficiency in “Double First-Class” universities in China and the characteristics of its multi-output, the DEA was chosen as the evaluation model. This method was founded in 1978 by well-known operational researchers Charnes et al. [25]. It aims at units or departments of the same type with a multiple inputs index and multiple outputs index. In DEA theory, these units or departments are called decision-making units (DMU). This comprehensive evaluation method of relative effectiveness can effectively deal with the complex problems of multiple inputs and outputs indexes [26]. Many scholars have been attracted to discuss DEA theory and its applications in depth [1, 6, 27].

The efficiency measured by two other kinds of methods, the traditional CCR-DEA and BCC-DEA methods, was not accurate enough because the slackness of the input-output cannot be taken into consideration [28]. Tone developed a nonradial and nonangle DEA analysis method based on the measurement of relaxation variables, named SBM model [29]. He further proposed Super-SBM model based on the modified slack variables, which effectively solved a defect

TABLE 1: Different scores for each item of different professional title and degree of award.

Professional title	Level Weight	Professor 1	Associate professor 0.75	Lecturer 0.5	Teaching assistant 0.1
National Teaching Achievement Awards	Degree award Score	Special 30	Gold 2	Silver 1.5	Bronze 1

TABLE 2: The teaching efficiency evaluation index system for “Double First-Class” universities in China.

First-level index	Second-level index	Input/output
University	Operational funds ( $I_1$ )	Input
Faculty	Academic level of teachers ( $I_2$ )	Input
	Equivalent number of faculty ( $I_3$ )	Input
	National Teaching Achievement Award ( $O_1$ )	Output
Student	Quality of graduates ( $O_2$ )	Output
	Teaching quality ( $O_3$ )	Output
	Graduate employment rate ( $O_4$ )	Output
	Student competition awards ( $O_5$ )	Output
	Quality of freshmen enrollment ( $I_4$ )	Input

that was preventing the SBM model to continue to evaluate and sort the effective units [30]. In this model, the evaluated DMUs are removed from the reference set. The efficiency of the evaluated DMUs is obtained by referring to the leading edge of other DMUs. The superefficiency value of the effective DMUs is generally greater than 1, so that the effective DMUs can be distinguished. The greater the efficiency value, the higher the efficiency level. However, the efficiency value of the decision-making units does not reach the effective DEA. Therefore, it is necessary to choose a superefficient DEA.

*4.2. Steps to Construct a Superefficiency SBM-DEA Model.* The efficiency model of China’s “Double First-Class” universities, which is based on the superefficient SBM-DEA model, can be expressed as follows:

- (1) Determining the DMU: there are 36 universities to be evaluated, and each university is denoted as DMU.

- (2) Determining the input-output indicators: there are 36 DMUs with 5 output indexes and 4 input indexes. Let  $x_{ij}$  represent the input vector and  $y_{rj}$  represent the  $j$ -th output vector of the  $j$ th DMU, where  $i = 1, 2, \dots, m$ ,  $r = 1, 2, \dots, s$ ,  $j = 1, 2, \dots, n$ ,  $x_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T \geq 0$  and  $y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T \geq 0$  with  $(X_j, Y_j)^T$  representing the  $j$ th DMU.
- (3) DEA model: select the output-oriented BCC-DEA methods and the output-oriented superefficiency SBM-DEA model to evaluate the construction of the comprehensive efficiency of “Double First-Class” universities, which are shown as (1) and (2). The objective function of model (2) is to maximize the ratio of the sum of weighted output and the sum of weighted input, where each DMU has similar ratio constraints. The fractional programming model can be expressed as (2) for  $k$ th DMU.

max  $\phi$

$$\text{s.t.} \begin{cases} \sum_{j=1}^n X_{ij} \lambda_j + S^+ \leq x_{ik} \\ \sum_{j=1}^n Y_{rj} \lambda_j - S^- \geq \phi y_{rk} \\ \sum_{j=1}^n \lambda_j = 1 \\ \lambda, s^-, s^+ \geq 0 \\ i = 1, 2, \dots, m; r = 1, 2, \dots, q; \\ j = 1, 2, \dots, n, \end{cases} \quad (1)$$

$$\min \rho_{SE} = \frac{1}{1 + 1/s \sum_{r=1}^s s_r^+ / y_{rk}}$$

$$\text{s.t.} \begin{cases} \sum_{j=1, j \neq k}^n X_{ij} \lambda_j \leq x_{ik} \\ \sum_{j=1, j \neq k}^n Y_{rj} \lambda_j - S_r^+ = y_{rk} \\ \lambda, s^+ \geq 0 \\ i = 1, 2, \dots, m; \\ r = 1, 2, \dots, q; \\ j = 1, 2, \dots, n (j \neq k). \end{cases} \quad (2)$$

where  $\lambda_j (j = 1, 2, \dots, n)$  represents the decision variable;  $S^+ = (s_1^+, s_2^+, \dots, s_n^+)$  represents the slack variable; and  $\rho_{SE}$  represents the planning target value.

For Model (1), when  $\phi = 1, S^+ = S^- = 0$ , it means the DMU is effective. When  $\phi = 1, S^+ \neq 0$ , or  $S^- \neq 0$ , it means the DMU is weak effective. When  $\phi < 1$ , it means the DMU is noneffective. For Model (2), when  $\rho_{SE} = 1, S^+ = 0$ , which means the DMU is effective. When  $\rho_{SE} < 1$  for one DMU, it means the DMU is ineffective. The DMU can be improved by reducing the surplus of inputs and increasing the shortage of outputs. The model can also give the projection value of each index of each university [31].

**4.3. Evaluation of Teaching Efficiency.** Among 42 “Double First-Class” universities, 6 universities were excluded from the sample due to insufficient data. In this paper, 36 “Double First-Class” universities were selected as the research objects and listed in Table 3.

We obtained the data of the teaching efficiency evaluation index system in 2018 by consulting various sources as the Internet, statistical yearbooks, Bulletin of National Teaching Achievement Award and National University Students’ “Creative Youth”, and “Challenge Cup” Competition Results Communique, etc. We calculated the evaluation indexes of the teaching efficiency for various “Double First-Class” universities, whose descriptive statistics were shown in Table 4.

The output-oriented BCC-DEA model and the super-efficient output-oriented SBM-DEA model were selected to evaluate the teaching efficiency of “Double First-Class” universities by using Visual Basic 2015 and MATLAB 2015. The results are shown in Table 5.

When the output-oriented BCC model was selected to evaluate the teaching efficiency of 36 “Double First-Class” universities, it was obtained that 22 of the 36 “Double First-Class” universities had a teaching efficiency value of 1. However, it remained difficult to distinguish which universities were more efficient in terms of teaching. In other words, the results of the BCC-DEA standard model evaluation could only classify the effectiveness of the 36 “Double First-Class” universities as effective or ineffective categories, but could not further distinguish among the 22 effective “Double First-Class” universities.

When the superefficient SBM-DEA model was selected, it obtained teaching efficiency of the 36 “Double First-Class” universities that had no repeated value with good discrimination. That is, each university can get a different efficiency score, and the efficient university will also be expressed by a specific efficiency value more than 1. Their teaching efficiency could be put together in a total order.

At the same time, the superefficiency model further widened the difference in teaching efficiency between “Double First-Class” universities by eliminating the ones that had been evaluated as invalid from the reference set. Therefore, in this paper, the superefficient SBM-DEA model was chosen to evaluate the teaching efficiency of the 36 “Double First-Class” universities in China, considering it could effectively distinguish the teaching efficiency among them and verify the effectiveness of the superefficient SBM-DEA model.

**4.4. Analysis of Teaching Efficiency Evaluation Results.** With regard to Table 5, we drew the following conclusions:

- (1) There were obvious differences in teaching efficiency among universities. Among them, the highest efficiency value was from Renmin University of China (1.378), whereas the lowest was in China Agricultural University (0.251), while the overall average was 0.920. Totally, 22 universities had teaching efficiency values greater than 1, 11 universities were between values of 0.5 and 1.0, and only 3 universities were at a teaching efficiency lower than 0.5. 36 “Double First-Class” universities had been achieved full ranking, and the efficiency of the two universities has not been consistent.
- (2) Divide the eastern, central, and western regions where 36 colleges and universities were located and count the efficiency values of the colleges and universities and the average values of the indicators in each region of the 36 “Double First-Class” universities, as shown in Table 6. In Table 6, the eastern, central, and western regions were divided. The efficiency index values of the 36 “Double First-Class” universities in each region were counted and averaged. In terms of average efficiency of universities, the western region (1.018) was

TABLE 3: The “Double First-Class” universities selected to be evaluated.

No.	University	Area of China
U01	Peking University	East
U02	Beihang University	East
U03	Beijing Institute of Technology	East
U04	Beijing Normal University	East
U05	Dalian University of Technology	East
U06	University of Electronic Science and Technology of China	West
U07	Northeastern University	East
U08	Southeast University	East
U09	Fudan University	East
U10	Hunan University	Central
U11	East China Normal University	East
U12	South China University of Technology	East
U13	Huazhong University of Science and Technology	Central
U14	Jilin University	Central
U15	Lanzhou University	West
U16	Nanjing University	East
U17	Nankai University	East
U18	Tsinghua University	East
U19	Xiamen University	East
U20	Shandong University	East
U21	Shanghai Jiao Tong University	East
U22	Sichuan University	West
U23	Tianjin University	East
U24	Tongji University	East
U25	Wuhan University	Central
U26	Xi'an Jiaotong University	West
U27	Northwestern Polytechnical University	West
U28	Northwest A&F University	West
U29	Zhejiang University	East
U30	Ocean University of China	East
U31	University of Science and Technology of China	Central
U32	China Agricultural University	East
U33	Renmin University of China	East
U34	Central South University	Central
U35	Sun Yat-sen University	East
U36	Chongqing University	West

TABLE 4: Descriptive statistics of teaching efficiency evaluation index data.

Statistical variable	$I_1$	$I_2$	$I_3$	$I_4$	$O_1$	$O_2$	$O_3$	$O_4$	$O_5$
Mean	17.051	262.151	2184.567	78.850	9.500	69.642	73.808	96.063	16.431
Standard deviation	11.205	75.713	986.113	8.949	5.426	8.952	8.440	2.506	16.885
Variance	125.553	5732.477	972418.301	80.084	29.443	80.138	71.230	6.281	285.102
Min	0.852	106.350	238.750	60.600	1.500	61.850	63.670	88.660	1.000
Max	51.668	447.320	5356.250	100.000	21.000	100.000	100.000	99.310	80.000

the highest, followed by the eastern region (0.929), and the lowest was the central region (0.806). Although the average value of the operational funds, academic level of teachers, teaching quality, National Teaching Achievement Awards, and student competition awards in the eastern region were higher than that of the western region, the average efficiency of the teaching output in the eastern region was not as high in the western region. This indicated that the “Double First-Class” universities in the eastern region had a problem of excessive input and insufficient output to a certain extent.

### 5. Analysis of the Key Influencing Factors on the Teaching Efficiency of “Double First-Class” Universities in China

5.1. Principles for Selecting the Key Influencing Factors. DEA model shows the projected values of each indicator for each university as an effective production decision scheme for DEA efficiency. Therefore, each university can formulate relevant policies and adjust teaching work arrangements according to the projected values of various indicators. However, in reality, it is impossible for universities to change the teaching policies involved in all evaluation indicators at



TABLE 5: Teaching efficiency and projection values of 36 “Double First-Class” universities.

No.	BCC	Super-SBM	Rank
U01	1.000	1.042	12
U02	1.000	1.000	22
U03	1.000	1.069	8
U04	1.000	1.004	18
U05	0.970	0.392	35
U06	1.000	1.014	15
U07	1.000	1.250	2
U08	0.999	0.923	25
U09	0.976	0.789	26
U10	0.998	0.931	24
U11	1.000	1.098	6
U12	0.944	0.743	28
U13	0.975	0.727	29
U14	1.000	1.017	14
U15	1.000	1.061	10
U16	1.000	1.050	11
U17	0.991	0.632	32
U18	1.000	1.031	13
U19	0.995	1.148	4
U20	0.990	0.955	23
U21	1.000	0.635	31
U22	0.996	1.065	9
U23	1.000	0.703	30
U24	1.000	1.0005	21
U25	1.000	1.0011	20
U26	1.000	1.082	7
U27	1.000	1.119	5
U28	1.000	1.012	16
U29	1.000	1.202	3
U30	1.000	1.004	17
U31	0.948	0.482	34
U32	0.996	0.251	36
U33	1.000	1.378	1
U34	1.000	1.002	19
U35	0.935	0.529	33
U36	0.979	0.775	27

TABLE 6: The efficiency values and average indexes of universities of different regions of China.

Area	East	Central	West
College quantity	23	6	7
Mean score	0.906	0.86	1.018
$I_1$	19.806	14.718	9.998
$I_2$	277.079	268.692	207.496
$I_3$	1943.634	2893.25	2368.76
$I_4$	81.174	78.4	71.6
$O_1$	10.109	7.5	9.214
$O_2$	71.217	69.542	64.553
$O_3$	75.321	74.033	68.64
$O_4$	96.268	96.272	95.211
$O_5$	18.326	13.333	12.857

the same time. Therefore, we must determine evaluation indexes that have a great influence on the teaching efficiency of “Double First-Class” universities in China, which are called the key influencing factors. By improving or modifying the key influencing factors, we can effectively improve

their teaching efficiency. The theoretical background explains that the dual price is a valuation that reflects the optimal production conditions of resources, that is, the amount by which the objective function changes its value when resources increase by one unit. The ratio of the increment of the objective function value to the increment of the resource is the first partial derivative of the objective function’s resource possession (right-side constant term) of the constraint.

This paper first selects the dual price of the teaching efficiency evaluation index of “Double First-Class” universities as the screening criterion. For each of “Double First-Class” universities, the index with the larger dual price is the key influencing factor for the university’s teaching efficiency. Then, the cumulative frequency of the evaluation indicators in the key influencing factors will be counted for the 36 “Double First-Class” universities. The evaluation index with high cumulative frequency will be selected as the key influencing factor on the teaching efficiency of “Double First-Class” universities. The theoretical background explains that the dual price is a valuation that reflects the optimal production conditions of resources, that is, the amount by which the objective function changes its value when resources increase by one unit. The ratio of the increment of the objective function value to the increment of the resource is the first partial derivative of the objective function’s resource possession (right-side constant term) of the constraint.

*5.2. Data Validation for Selecting Key Influencing Factors for Each University.* According to the results obtained by Visual Basic 2015 and MATLAB 2015, the index with the largest dual price can be found after evaluating the indexes of 36 “Double First-Class” universities. Subsequently, these indexes, which are used to evaluate universities’ efficiency, are sorted based on their dual prices from the largest to the smallest. The adjustment rules of the index values are dependent on the index nature. On the one hand, if it is an input index, its value will be reduced by one unit. On the other hand, if it is an output index, its value will be increased by one unit, while in both cases the values of others indices remain unchanged. The teaching efficiency of the 36 “Double First-Class” universities should then be recalculated. To verify the influencing effect of the dual price of each evaluation index on the teaching efficiency of “Double First-Class” universities, the same method was used to adjust the index with the second largest dual price. These results are shown in Table 7.

Two main conclusions can be derived from the results regarding dual prices:

- (1) Almost all of the teaching efficiency of the 36 “Double First-Class” universities have increased once the index values with the largest dual price and the second largest dual price were adjusted. It can be seen that the efficiency values show an upward trend when the data are adjusted. The average efficiency change is 0.0691 when the largest dual price data are adjusted. In the case of the second largest dual price



TABLE 7: Changes in teaching efficiencies of the 36 “Double First-Class” universities with changed index values.

No.	Largest indicator		Second largest indicator	
	Index	Score change	Index	Score change
U01	$O_4$	0.002	$O_3$	0.002
U02	$O_4$	0.002	$I_1$	0.000
U03	$O_5$	0.002	$O_4$	0.002
U04	$O_4$	0.002	$O_4$	0.000
U05	$O_4$	0.047	$O_1$	0.064
U06	$O_1$	0.020	$I_1$	0.019
U07	$O_4$	0.000	$I_2$	0.000
U08	$O_4$	0.079	$O_4$	0.076
U09	$O_2$	0.206	$O_1$	0.002
U10	$O_4$	0.071	$O_4$	0.068
U11	$I_1$	0.013	$O_4$	0.000
U12	$O_4$	0.027	$O_1$	0.016
U13	$O_1$	0.022	$O_3$	0.014
U14	$O_4$	0.005	$O_1$	0.003
U15	$I_1$	0.025	$O_4$	0.000
U16	$O_1$	0.008	$O_3$	0.003
U17	$O_4$	0.155	$O_4$	0.366
U18	$O_1$	0.005	$O_4$	0.002
U19	$O_1$	0.022	$O_4$	0.013
U20	$O_4$	0.047	$O_3$	0.041
U21	$O_4$	0.328	$O_1$	0.016
U22	$O_4$	0.014	$O_1$	0.010
U23	$O_4$	0.298	$O_4$	0.296
U24	$O_4$	0.002	$O_1$	0.000
U25	$O_3$	0.002	$I_1$	0.001
U26	$O_1$	0.007	$O_3$	0.003
U27	$I_1$	0.055	$O_1$	0.010
U28	$O_4$	0.000	$I_2$	0.000
U29	$O_1$	0.014	$O_4$	0.008
U30	$I_1$	0.001	$I_2$	0.000
U31	$I_1$	0.031	$O_1$	0.018
U32	$O_4$	0.750	$O_4$	0.748
U33	$I_1$	0.119	$I_3$	0.000
U34	$O_4$	0.002	$I_1$	0.001
U35	$O_1$	0.034	$O_5$	0.456
U36	$I_1$	0.070	$O_1$	0.039
Average		0.0691		0.0638

adjustment, the average change in efficiency is 0.0638. Therefore, it is demonstrated that the factor controlling the large dual price can greatly improve the teaching efficiency of “Double First-Class” universities in China.

- Once the index values with the largest dual prices are adjusted, the correlation coefficient of the teaching efficiency increasing value and the largest dual price obtained is 0.821. Once the index values with the second largest dual price are adjusted, the correlation coefficient of the teaching efficiency increasing value and the second largest dual price obtained is 0.656. The increasing value in teaching efficiency of “Double First-Class” universities is basically consistent with the dual price of the evaluation indicators. Therefore, it can be explained that the largest evaluation index of the dual price has the most positive effect on teaching efficiency of “Double First-Class” universities.

5.3. *Selection of Key Influencing Factors for All of “Double First-Class” Universities.* To distinguish the different importance of the indicator with the highest dual price and with the second largest dual price, the indicator with the highest dual price is twice important than those with the second largest dual price. Cumulative frequency and the importance of “Double First-Class” universities teaching efficiency evaluation indicators with the largest dual price and the second largest dual price are counted, as shown in Table 8. The higher the total importance of the “Double First-Class” university teaching evaluation indicators, the greater the impact on their teaching efficiency. Therefore, the evaluation indexes with a relatively high importance, such as National Teaching Achievement Award, Student Employment Rate, Graduate Employment Rate, and Operational Fund, are defined as the key factors for the development of teaching efficiency in China’s “Double First-Class” universities.

## 6. The Visual Decision Analysis System Development of Teaching Efficiency of “Double First-Class” Universities

To evaluate teaching efficiency of “Double First-Class” universities and popularize the theoretical model, we developed the visual decision analysis system to manage the data of evaluation system indexes, implement the algorithm of SBM-DEA model, and analyse the key influencing factors analysis of “Double First-Class” universities’ teaching efficiency by using Visual Basic 2015 and MATLAB 2015.

6.1. *Framework and Function Design.* The visual decision analysis system designed the visual interface windows with Visual Basic2015 based on an Access database to store data information. The menu, command button, toolbar, and other visual controls finished the work to input and read the data information and save them after calculating and analyzing. It was made that the complex program processing became simple, convenient, fast to evaluate teaching efficiency of “Double First-Class” universities. The framework and function design are shown in Figure 1.

6.2. *Access Database Design and Its Key Management Technology.* The Access database was designed to contain several kinds of tables to store data information. (1) Table *data* contained the fields such as the number ID, university name, the evaluation indexes, the teaching efficiency, the dual price of each evaluation index, efficiency change of each evaluation index to store the values of the evaluation indexes, evaluation results, the dual price of each evaluation index, and the efficiency change when an index value was changed. (2) Table *key influencing factor* selected the number ID, the evaluation index name, the times with the highest dual price, the times with the second largest dual price, and the total important as fields to store the information of the key influencing factor. *Microsoft Office 16.0 Object Library* was selected in Visual Basic 2015 project by adding the reference and “*Imports System.Data. OLEDB*” in the first line of form code [32]. *OLEDBConnection, OLEDBDataAdapter,*

TABLE 8: Frequency statistics of indicators related to the largest and second largest dual price.

No.	Index	Indicator with the highest dual price	Indicator with the second largest dual price	Total importance
1	National Teaching Achievement Award	8	10	26
2	Student employment rate	7	10	24
3	Graduate employment rate	11	2	24
4	Operational funds	7	4	18
5	Teaching quality	1	5	7
6	Teachers' academic level	0	3	3
7	Student competition	1	1	3
8	Graduate quality	1	0	2
9	Equivalent number of teachers	0	1	1

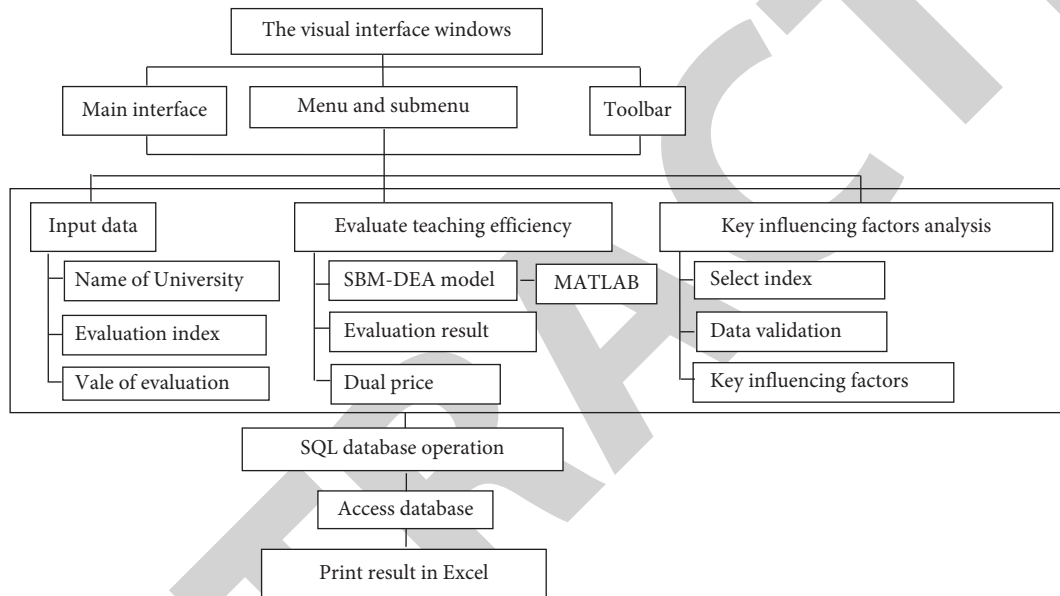


FIGURE 1: Framework and function design of the visual decision analysis system.

OLEDB Command, and other classes were used to read and write Access Data through SQL Data manipulation commands. Microsoft Excel 16.0 Object Library was also selected in Visual Basic project by adding the reference to facilitate data editing and printing in Excel Application. It could import data from Excel sheet into Access database or export them from Access database into Excel sheet. DataGridView Control was selected as cache data space in the visual interface windows by using TableAdapter as communication mechanism to provide communication between the application and the database with SQL statements command [33].

6.3. Implementation of SBM-DEA Model Algorithm with MATLAB 2015. SBM-DEA model was realized by MATLAB 2015 programming language. In Visual Basic 2015, MATLAB Application (Version 9.6) Type Library was selected in Visual Basic 2015 project by adding the reference. The command MATLAB = CreateObject ("Matlab.Application") was used to call the MATLAB 2015 after the code of SBM-DEA model was converted into text. The SBM-DEA model is executed through EXECUTE, a method of executing specific

commands in MATLAB server. And the data exchange method GetFullmatrix among MATLAB servers was used to extract the results such as the evaluation efficiency and dual price and so on [34]. Based on SBM-DEA model, the key influencing factors were analysed by reducing and increasing the value of the indexes with the largest and the second largest dual price [35].

6.4. Main Interface of the Decision Analysis System. The visual decision analysis system had three interfaces:

- (1) Interface for Inputting Data. It is shown in Figure 2. The values of the evaluation indexes would be inputted by adding new input or output index and a new university. It could be imported from an Excel file. An index or a university could be deleted when it was selected by deleting buttons.
- (2) Interface for Evaluating Teaching Efficiency. The programming would read the data to show the input and output index and universities to be evaluated. Then, the teaching efficiency of "Double First-Class"

The screenshot shows a software window titled "To evaluate and analyze teaching efficiency of 'Double First-Class' universities in China". The interface is divided into several sections:

- Input data:** Includes tabs for "Evaluate teaching efficiency" and "Key influencing factors analysis".
- Input through:**
  - Input data directly: Includes text boxes for "Input the name of an Index" (containing "AcademicLevelofTeachers") and "Input the name of a University" (containing "newuniversity"). Buttons for "Add input index", "Add output index", "Delete index", "Add university", and "Delete university" are present.
  - Import from Excel file: Includes buttons for "Export the template of the table", "Open the Excel file", "Compare the structure of the", "Input the data", and "Save".
- Index Table:** A table with columns: Nub, index, abbreviation, Input/Output.
 

Nub	index	abbreviation	Input/Output
1	OperationalF...	I1	1
2	AcademicLeve...	I2	1
3	EquivalentNu...	I3	1
4	NationalTeac...	I4	1
5	QualityofGra...	01	2
- Data Table:** A table with columns: Nub, universityname, OperationalFund, AcademicLevelof, EquivalentNumber, NationalTeachin, QualityofGradua, TeachingQuality.
 

Nub	universityname	OperationalFund	AcademicLevelof	EquivalentNumber	NationalTeachin	QualityofGradua	TeachingQuality
1	Peking Unive...	100.000	12.000	9.000	98.070	100.000	95.200
2	Beihang Univ...	69.440	6.000	15.000	98.650	64.900	86.900
3	Beijing Inst...	67.420	4.500	73.000	97.900	63.900	79.700
4	Beijing Norm...	73.470	13.500	7.000	99.310	68.910	82.700
5	Dalian Unive...	67.600	9.000	5.000	94.700	64.600	72.900
6	University o...	65.210	9.000	12.000	96.330	62.500	73.800
7	Northeastern...	67.610	3.000	14.500	95.600	64.610	66.500

FIGURE 2: Interface for inputting data.

universities would be got, after the button *evaluate* was clicked, which is shown in Figure 3.

- (3) *Interface for the Key Influencing Factors Analysis.* It could be analysed by one university or by all of universities. The results should be obtained that the indicator with the highest dual price and with the second largest dual price and how much the efficiency could be changed when their index value was adjusted for everyuniversity. It is shown in Figure 4.

## 7. Countermeasures to Improve Teaching Efficiency of "Double First-Class" Universities in China

Based on the results of evaluations and analyses, the following countermeasures and suggestions have been proposed to increase the teaching efficiency of "Double First-Class" universities:

**7.1. Improving the Cultivation System.** In the new situation, all of "Double First-Class" universities, especially those with insufficient output of National Teaching Achievement Awards, should construct its own cultivation system according to the requirements for "cultivating top innovative talents" in the "overall plan of construction".

First of all, we should strengthen the quality of the teaching staff, so as to lay a good foundation for the cultivation of the National Teaching Achievement Award. Second, a perfect teaching evaluation system should be established to stimulate the teacher's enthusiasm for teaching research. Third, the selection of teaching achievement award cultivation is selected to improve the quality of talent training. Fourth, the rich resources must be matched with the cultivation of the National Teaching Achievement Award. It can be developed into the teaching practice, reform, guidance, and encouragement in the study of function and implementation of refining methods of education and teaching, promoting the national teaching achievement of philosophy and sublimation theory [36].

**7.2. Improving the Quality of Freshman Enrollment.** At present, "Double First-Class" universities have obvious teaching advantages, such as their reputation is constantly improving, and their attraction to excellent students is increasing. However, there are still some deficiencies in absorbing excellent students, and they cannot give full play to the unique advantages of "Double First-Class" universities in education level and talent quality training. For example, the number of freshmen who take the "Double First-Class" universities as the first choice when selecting universities is insufficient, and the quality span of students is large.

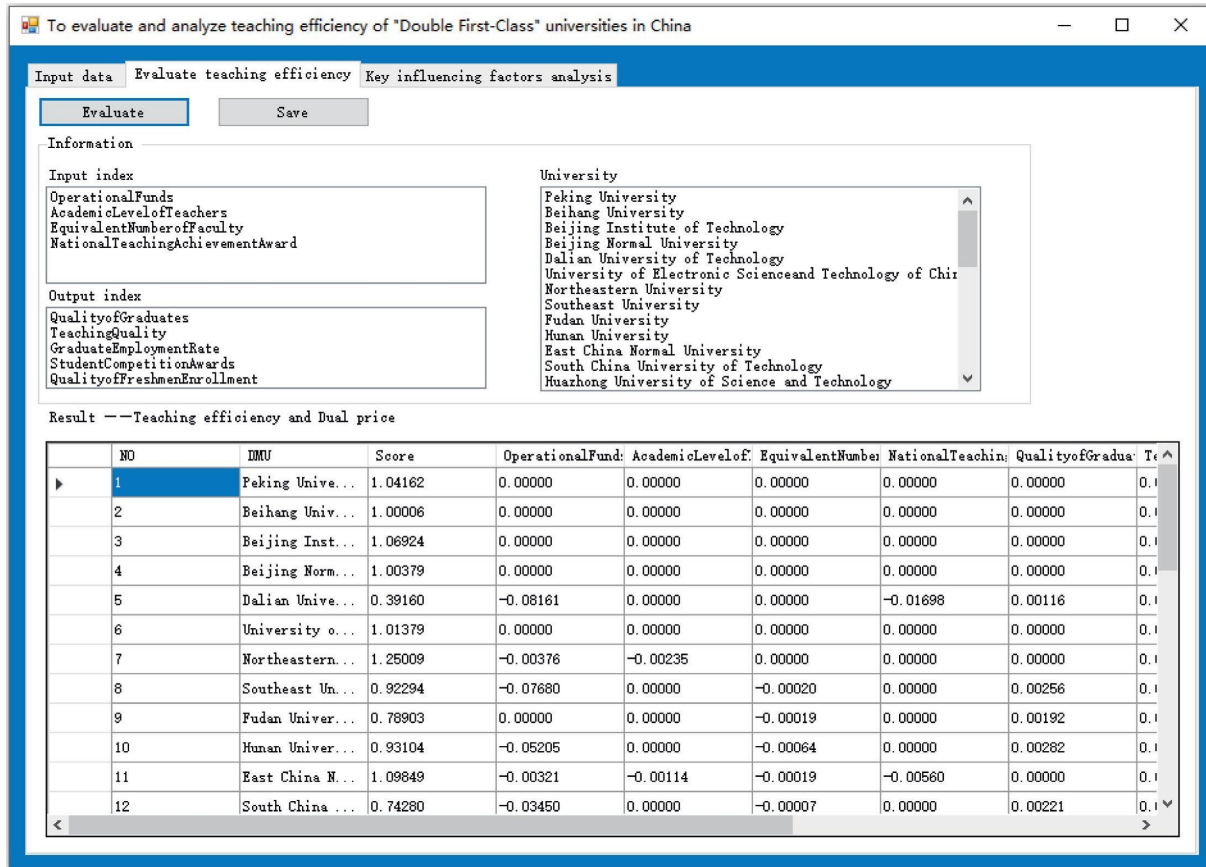


FIGURE 3: Interface for evaluating teaching efficiency.

It is suggested that “Double First-Class” universities could take the following measures: firstly, the number of independent recruitments should be expanded and its standards for independent recruitment must be improved with strict selection of admission, higher innovation ability, and scientific research potential. Second, all kinds of recruitments propaganda must be expanded by campus network, the education information network, the provincial education television, and other media. Third, the quality of recruitments’ consultation must be improved on the onsite meetings that are held in various provinces by designing special consultation points, opening a number of recruitment hotlines, as far as possible to timely reply to the consultation of students and their parents.

**7.3. Improving Graduate Employment Rate.** The employment rate of the “Double First-Class” universities is above 90% through the “top leadership project”, the establishment of relevant career planning courses, and the joint education projects with enterprises, universities, and research institutes. All of that aim to expand the employment opportunities for students. The traditional drivers of employment are being replaced by new ones, such as the development of the new infrastructure, new engineering constructions, high-quality development, and the other series of major national strategy and projects to improve students’ employment rates, the “Double First-Class” universities should take the

following measures: first, teaching cultivation plan and syllabus must be updated by adding in the professional courses subject systems, which cover the above-mentioned major strategic development and meet the national need. Second, student’s career planning can be made as soon as possible to let students know the orientation for which future development direction they should engage their research. As a consequence, students could then adjust their course to train and strengthen the professional competence and skills needed to match their career planning. Third, to improve the employment rate, a professional training program should be rebuilt to cultivate students to meet the needs of enterprises and industries by university-enterprise cooperation and industry-university-research cooperation, with the direction combining the need for enterprises and industries with the development of professional knowledge.

**7.4. Increasing Operational Funds.** The diversified financing mechanisms need to be constructed, although a lot of money has already been invested in the construction of “Double First-Class” universities. There are mainly the following ways: first, the government appropriation for targeted planning of the special construction fund should be increased. Second, the advantages of scientific and technological achievements, such as patent, and other technology should be given full play to. Third, the outstanding alumni can be guided

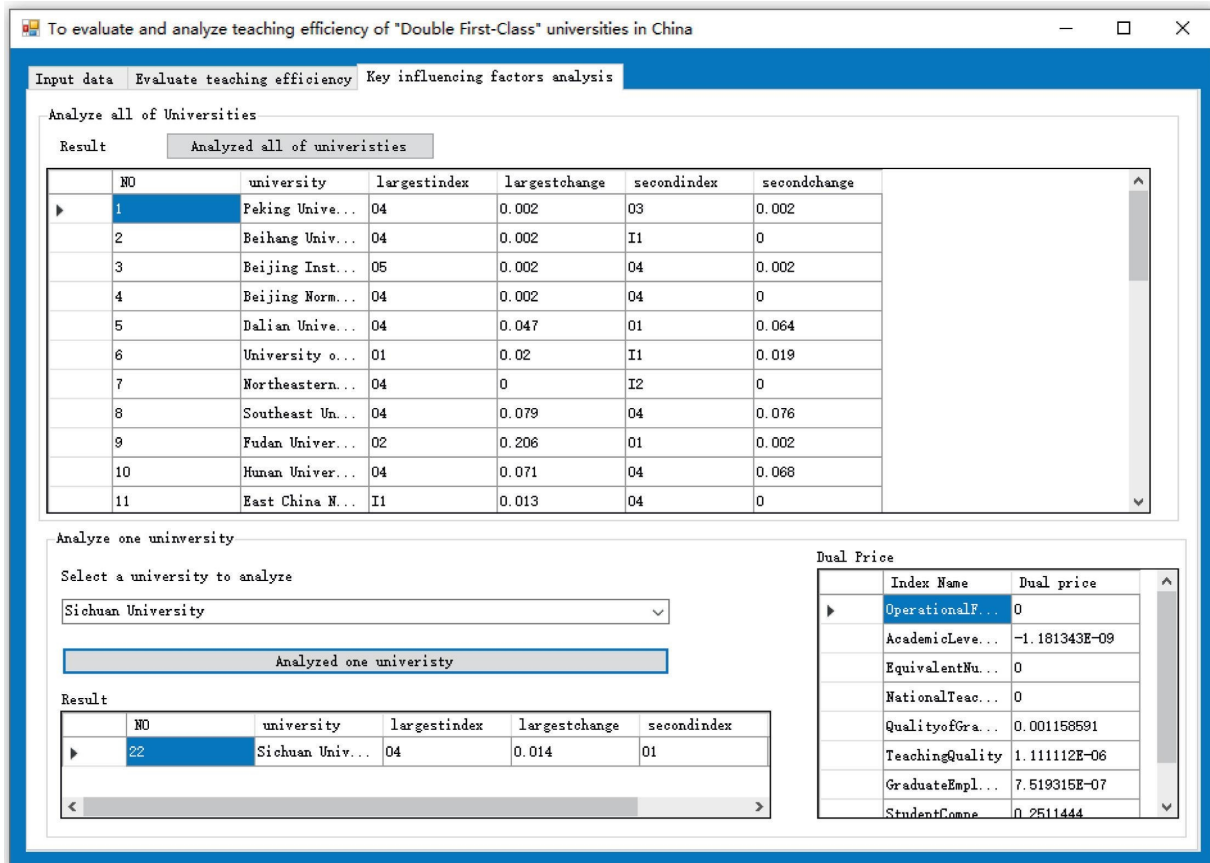


FIGURE 4: Interface for the key influencing factors analysis.

to donate to the university where they had graduated, to improve the school running level and education quality. "Double First-Class" universities should strengthen the cohesion of alumni through recognizing, classifying, communicating and cooperating with them. Those who have graduated and left a university should deepen their sense of identity and belonging to their alma mater [37]. This way, a virtuous circle can be formed between the service and return so that one may truly achieve a win-win situation between the university and alumni [38]. Finally, the marketing of some parts of the logistics of "Double First-Class" universities can be implemented properly to increase sales and service income for universities and become the important aspect of diversified financing [39]. The joint construction mechanisms of government, society, and universities can be built and improved to form a pattern of the diversified investment and joint support to build "Double First-Class" universities by the above approaches.

**7.5. Improving the Efficiency of the Use of Educational Funds.** The effective management and utilization of educational funds are the objective requirements to improve the teaching quality, teaching efficiency, and strengthen the core competitiveness of universities. Therefore, "Double First-Class"

universities should make reasonable financial plans, make full use of various resources, and improve the utilization efficiency of all kinds of resources.

First, the importance of a scientific budget must be clarified to the management of special education funds. Once approved, the special funds for the construction of "Double First-Class" universities should be well budgeted. Second, the perfect performance management system must be established to appraise and manage the whole process of performance for the purposes of using funds management. The performance evaluation mechanism of the funds should be constructed by combining the qualitative and quantitative indexes to form the perfect performance appraisal index system and be able to assess it regularly. Accordingly, any corresponding improvement plans could then be formulated to strengthen its weak links. Third, the internal management should be strengthened to improve transparency in the use of funds. A reasonable fund supervision system could be established to ensure that funds are used for the special purposes of constructing "Double First-Class" universities. Fourth, external supervision should be strengthened. Improving the supervision system of education funds could effectively prevent the problems in the supervision of university education funds.



## 8. Discussion and Conclusion

In this paper, the evaluation index system has been established to tackle with teaching efficiency in “Double First-Class” universities in China. The teaching efficiency evaluation model is constructed based on the superefficient SBM-DEA method. It is proved by an empirical study that the evaluation index system and model are applicable to a sample of 36 “Double First-Class” universities in China. Furthermore, the selected model can effectively distinguish their teaching efficiency. Subsequently, the influencing relations between their teaching efficiency and dual price of each evaluation index have been analysed. It has been proven that the teaching efficiency can be improved greatly by improving the index value with a higher dual price. The frequencies of evaluation indicators with the highest or the second highest dual prices are taken into account. The higher frequency indexes, such as National Teaching Achievement Award, Freshmen Enrollment, Graduate Employment Rate, and Operational Funds, are defined as the key factors of teaching efficiency of development of “Double First-Class” universities in China. Finally, several countermeasures have been purposed to improve the teaching efficiency of “Double First-Class” universities. At the same time, the visual decision analysis system of teaching efficiency of “Double First-Class” universities has been developed.

Having in mind future research concerning this topic, we aim to focus on increasing the time period of our sample. In this paper, the teaching efficiency of “Double First-Class” universities is evaluated only for 2018. In the future, we intend to collect data of their index values for one more year and give a deeper analysis of development tendencies regarding teaching efficiency.

### Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

### Conflicts of Interest

The authors declare that they have no conflicts of interest.

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