Research on Input-output Efficiency of Junior High School -A Case Study of DEA-OLS Model

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Abstract. Junior high school education has a strong influence on students' first major decision in life, which leads to a large proportion of their investment in educational resources, so it is necessary to evaluate their comprehensive efficiency. Based on the questionnaire data of principals from 2014 school year to 2015 school year of China Education Tracking Survey, this paper uses DEA-OLS model to calculate and analyze the input-output efficiency of junior high schools, and finds that the input-output efficiency of junior high schools is low on average. Compared with computer students, the efficiency of teacher-student ratio has a significant negative impact. According to this, it is proposed that junior high schools should make their own adjustment plans in combination with teachers' teaching quality and the amount of teachers' resources, as well as the curriculum arrangement of students' computer skills training and the amount of computer resources.

1. Introduction
With the increasing emphasis on compulsory education, the input of various educational resources is also increasing. Therefore, we have to examine a question, whether the educational resources have been fully utilized. Therefore, it is necessary to establish a comprehensive evaluation model to examine the input-output efficiency of educational resources to ensure that educational resources are not wasted. Junior high school is the most important stage in compulsory education. Students will be faced with the choice of future life, whether to continue to study in senior high school or go to vocational school to learn vocational skills. This stage is the key stage of investment in educational resources, especially in the digital age, where data availability is high, and efficiency evaluation is carried out through the analysis of a large number of data [1], so it is necessary to establish a comprehensive evaluation model to evaluate input-output efficiency. This paper draws lessons from the evaluation methods of scholars at home and abroad, that is, to study the input-output efficiency of junior high school through DEA model [2-7], to investigate whether educational resources are fully utilized or excessively wasted at present, and to study the influence of various educational resources on the input-output efficiency of junior high school by combining the least square method.
2. Establishing DEA model of input-output efficiency in junior high school

2.1. Data source
The data in this paper comes from the questionnaire data of junior high school principals from 2014 to 2015 in China Education Tracking Survey. After eliminating invalid and missing data, the data of 60 junior high schools were retained as sample data.

2.2. Establish an input-output index system
According to the human, material and financial resources invested in junior high school, this paper takes the human, material and financial resources as indicators. Different from the traditional literature, which takes the absolute number of human, material and financial resources as input indicators directly, the input indicators in this paper are all relative, so the advantage of this treatment is that the scale problem can be taken into account. Then the ratio of the number of teachers to the number of students is taken as the index of manpower input; The ratio of the number of available computers to the number of students and the ratio of the number of seats to the number of students are taken as indicators of material and financial resources. The output index is the comprehensive score of junior high school. See table 1 for index design.

| Indicator category      | Index composition          |
|------------------------|---------------------------|
| Input index            | Teacher-student ratioX1   |
|                        | Computer student ratioX2  |
|                        | Seat-student ratioX3      |
| Output indicators      | Comprehensive score of junior high schoolY1 |

2.3. Modeling algorithm
In this paper, a comprehensive evaluation model C²R is adopted to evaluate the pure technical efficiency and scale efficiency of each decision-making unit at the same time, which is used to evaluate the input-output efficiency of junior high school. The formula for constructing the algorithm is as follows:

\[
\begin{align*}
\min & \quad \theta - \varepsilon (e^T S^- + e^T S^+) \\
\text{s.t.} & \quad \sum_{i=1}^{n} X_i \lambda_i + S^- = \theta X_o \\
& \quad \sum_{i=1}^{n} Y_i \lambda_i - S^+ = Y_o \\
& \quad \lambda_i \geq 0; S^-, S^+ \geq 0
\end{align*}
\]

Where \( \theta \) is the efficiency of each decision unit; \( S \) represents the input slack; \( S^+ \) represents the remaining quantity of output.

3. Empirical analysis of DEA model of input-output efficiency in junior high school

3.1. Descriptive statistical analysis of each input-output index in junior high school
The descriptive statistical summary of the mean value of input and output indicators in this paper is shown in Table 2. From Table 2, we can find that the average comprehensive score of the sample is 2.9167, the average ratio of teachers to students is 0.0963, the average ratio of computer students is 0.1752, and the average ratio of seat students is 2.9133.

| Variable                           | Average | Standard Deviation | Minimum | Maximum |
|------------------------------------|---------|--------------------|---------|---------|
| Output indicators:                 |         |                    |         |         |
| Comprehensive score of junior high school | 2.9167 | 0.8886             | 1       | 4       |
| Input indicators:                  |         |                    |         |         |
| Teacher-student                     | 0.0963  | 0.0451             | 0.0435  | 0.3333  |
3.2. Calculation results of DEA model of input-output efficiency in junior high school

In this paper, based on C²R, the input-output efficiency of junior high school is measured from the input point of view, and further decomposed into pure input-output efficiency and scale efficiency. See table 3 for calculation results.

Table 3 Calculation results of input-output efficiency in junior high school

| DMU    | CCR-I-TE | BCC-I-PTE | SE    | Returns to scale |
|--------|----------|-----------|-------|------------------|
| School 1 | 0.3940   | 0.4380    | 0.8995| -                |
| School 2 | 0.6317   | 0.6944    | 0.9097| -                |
| School 3 | 0.4603   | 0.4983    | 0.9237| -                |
| School 4 | 0.7720   | 0.8472    | 0.9112| -                |
| School 5 | 0.4478   | 0.4903    | 0.9133| -                |
| School 6 | 0.8622   | 0.8622    | 1.0000| -                |
| School 7 | 0.8636   | 0.8636    | 1.0000| -                |
| School 8 | 0.2548   | 0.3235    | 0.7876| IRS              |
| School 9 | 0.0850   | 0.2889    | 0.2942| -                |
| School 10 | 0.6064   | 0.6667    | 0.9096| -                |
| School 11 | 0.9483   | 1.0000    | 0.9483| DRS              |
| School 12 | 0.6963   | 0.7006    | 0.9939| -                |
| School 13 | 0.1882   | 0.3155    | 0.5965| -                |
| School 14 | 0.7191   | 0.7905    | 0.9097| -                |
| School 15 | 0.8945   | 0.8945    | 1.0000| -                |
| School 16 | 0.2623   | 0.3435    | 0.7636| -                |
| School 17 | 0.2609   | 0.3478    | 0.7501| IRS              |
| School 18 | 0.6345   | 0.6926    | 0.9161| -                |
| School 19 | 0.7500   | 1.0000    | 0.7500| IRS              |
| School 20 | 0.4821   | 0.5838    | 0.8258| -                |
| School 21 | 0.1652   | 0.3285    | 0.5029| IRS              |
| School 22 | 0.2972   | 0.5441    | 0.5462| -                |
| School 23 | 0.6337   | 0.6966    | 0.9097| -                |
| School 24 | 0.7169   | 0.7812    | 0.9177| -                |
| School 25 | 0.7829   | 0.7829    | 1.0000| -                |
| School 26 | 0.2935   | 0.3888    | 0.7549| -                |
| School 27 | 0.3500   | 0.4482    | 0.7809| IRS              |
| School 28 | 0.2491   | 0.8214    | 0.3033| -                |
| School 29 | 0.5467   | 0.6010    | 0.9097| -                |
| School 30 | 1.0000   | 1.0000    | 1.0000| -                |
| School 31 | 0.0372   | 0.1404    | 0.2650| IRS              |
| School 32 | 0.7117   | 0.7824    | 0.9096| -                |
| School 33 | 0.8163   | 0.8507    | 0.9596| -                |
| School 34 | 1.0000   | 1.0000    | 1.0000| -                |
| School 35 | 1.0000   | 1.0000    | 1.0000| -                |
| School 36 | 1.0000   | 1.0000    | 1.0000| -                |

Note: The data are all from the questionnaire data of principals from 2014 school year to 2015 school year of China Education Follow-up Survey.
Through the calculation results in Table 3, it can be found that the average comprehensive input-output efficiency of samples is 0.5794; The average net input-output efficiency is 0.6844; The average scale efficiency is 0.8134. This shows that the input-output efficiency of junior high school is low as a whole, and there may be a waste of input resources. Further analysis of comprehensive input-output efficiency, pure input-output efficiency and scale efficiency shows that only 8 junior high schools in 60 junior high schools have reached an effective state; Only the pure input-output efficiency of 10 junior high schools has reached an effective state; Only 16 junior high schools have achieved effective scale efficiency; Most junior high schools are in the state of constant returns to scale, only 13 junior high schools are in the state of increasing returns to scale, and even 2 junior high schools are already in the state of decreasing returns to scale. All of them indicate that there is a waste of resources input at present, so it is necessary to further analyze the impact of current educational resources input on input-output efficiency by econometric methods, and consider the causal relationship between input and output.

3.3. Analysis of influencing factors of input-output efficiency in junior high school

In this paper, the comprehensive input-output efficiency, pure input-output efficiency and scale efficiency are divided into dependent variables, each input index is taken as independent variable, and an empirical model is established by using the least square method to further analyze the causal relationship between each input index and efficiency. Establish models separately:

\[
CCRTE_i = C_i + \frac{\text{Teachers}}{\text{students}_i} + \frac{\text{Computers}}{\text{students}_i} + \frac{\text{Seats}}{\text{students}_i} + \epsilon_i
\]

\[
BCCPTE_i = C_i + \frac{\text{Teachers}}{\text{students}_i} + \frac{\text{Computers}}{\text{students}_i} - \frac{\text{Seats}}{\text{students}_i} + \epsilon_i
\]
\[ SE_i = C_i + \frac{\text{Teachers}}{\text{students}_i} + \frac{\text{Computers}}{\text{students}_i} + \frac{\text{Seats}}{\text{students}_i} + \epsilon_i \]

CCRT\text{E}_i, \ BCCP\text{TE}_i, \ SE_i representing the comprehensive input-output efficiency, pure input-output efficiency and scale efficiency of the decision-making unit; \( C_i \) represents a constant term; \( \frac{\text{Teachers}}{\text{students}_i}, \frac{\text{Computers}}{\text{students}_i}, \frac{\text{Seats}}{\text{students}_i} \) teacher-student ratio, computer-student ratio and seat-student ratio, which represent the first decision unit respectively; \( \epsilon_i \) represents a random interference term. See table 4 for specific calculation results.

| Variable               | CCR-I-TE  | BCC-I-PTE | SE    |
|------------------------|-----------|-----------|-------|
| Teacher-student ratio  | -2.4206** | -2.1385***| -0.9808|
|                        | (0.9493)  | (0.7113)  | (0.9178)|
| Computer student ratio | -0.7654***| -0.5956***| -0.4081**|
|                        | (0.1798)  | (0.1347)  | (0.1738)|
| Seat-student ratio     | 0.0015    | -0.0004   | -0.0046|
|                        | (0.0053)  | (0.0040)  | (0.0052)|
| Constant               | 0.9424*** | 0.9959*** | 0.9927***|
|                        | (0.0802)  | (0.0601)  | (0.0776)|
| \( R^2 \)              | 45.98%    | 52.59%    | 24.44% |

Note: 1. Standard error in brackets; 2**, ***, **** are expressed as \( p < 0.1, p < 0.05 \) and \( p < 0.01 \) respectively.

According to the calculation results in Table 4, it can be found that the comprehensive input-output efficiency of teacher-student ratio has a negative impact on the significance level of 5% and its value reaches -2.4206, which shows that every unit increase in teacher-student ratio will reduce the comprehensive input-output efficiency by 2.4206; The pure input-output efficiency of teacher-student ratio has a negative impact on 1% significance level and its value reaches -2.1385, which shows that every unit of teacher-student ratio increases will reduce the pure input-output efficiency by 2.1385, which further proves that the current teacher-student ratio is over-invested after removing the scale efficiency factor; Although the impact of teacher-student ratio on scale efficiency is not significant, the direction is negative. Combined with its standard error, it can be judged that there must be a negative impact on scale efficiency of teacher-student ratio. It shows that teacher-student ratio will have a negative impact on comprehensive input-output efficiency, pure input-output efficiency and scale efficiency. This inefficiency may be due to the lack of teachers' level, which leads to the lack of input-output efficiency, or it may be due to the waste of resources caused by excessive investment, which requires junior high schools to make decisions according to the specific conditions of teachers.

According to the calculation results in Table 4, it can be found that the comprehensive input-output efficiency of computer students is negatively affected at the level of 1% significance and its value reaches -0.7654, which shows that the comprehensive input-output efficiency will decrease by 0.7654 for every unit increased by computer students; The ratio of computer students to pure input-output efficiency has a negative impact on the significance level of 1% and its value reaches 0.5956, which shows that the ratio of computer students will decrease the pure input-output efficiency by 0.5956 for every unit increase; The scale efficiency of computer student ratio has a negative impact on 5% significance level, and its value reaches 0.4081, which indicates that the scale efficiency will decrease by 0.4081 when the computer student ratio increases by one unit. It shows that computer student ratio will have a negative impact on comprehensive input-output efficiency, pure input-output efficiency and scale efficiency. This inefficiency may be caused by the lack of training for students' computer skills and the opportunity to use computers, or by the waste of resources caused by excessive investment, which requires junior high schools to make decisions according to the specific conditions of teachers.

According to the calculation results in Table 4, it can be found that the ratio of seated students has no significant influence on comprehensive input-output efficiency, pure input-output efficiency and scale efficiency, which indicates that the current ratio of seated students, that is, the average space input
enjoyed by students, is in an effective state. Students are neither in a crowded state nor in a state of excessive waste of space.

4. Conclusion
By constructing DEA-OLS model, this paper finds that the average input-output efficiency of junior high school is in an ineffective state and needs to be improved. Furthermore, the empirical analysis of comprehensive input-output efficiency, pure input-output efficiency and scale efficiency is carried out by least square method. It is found that the ratio of teachers to students leads to the decline of efficiency, which may be related to the quality of teachers or excessive investment. It is necessary for junior high schools to analyze whether to improve the overall teaching level of teachers or control the amount of teachers' input according to their actual situation. It is found that the ratio of computer students also leads to the decline of efficiency, which may be related to the lack of training and guidance for students' skills in using computers, or to excessive investment. It is necessary for junior high schools to analyze whether to adjust computer course education or control the amount of computer resources; It is found that the ratio of seated students has no significant influence on efficiency, which indicates that students are neither in a crowded state nor in an excessive waste of space.

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