Empirical Research on Talent Training Mode Based on DEA Data Model

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Abstract. Since improving the quality of education is an important task for the development of the vocational education service industry, the talent training mode has become a research hotspot nowadays. Previous research on the evaluation of training modes is carried out from the perspective of educational macro-management. To this end, this research uses the DEA (data envelopment analysis) data model to construct the performance evaluation index of vocational education talent training, evaluates the effectiveness through empirical research, and provides a good identification method and improvement plan for the problems of redundant input resources and low talent output rate in the school talent cultivation, thereby proposing measures to solve the problems.

Keywords: DEA model · data analysis · the cultivation of talents · empirical research

1 Introduction

Cultivating high-quality technical and skilled personnel through vocational education is an effective way to realize a skills-based society. Many countries give full play to the function of vocational education and form their own unique talent training modes. The following are four representative modes: In the American CBE model [1], schools are in dominant positions, and the curriculum and teaching organization are based on the needs of vocational jobs and the development of students' abilities as the fundamental points; the German "dual system" model] is one in which enterprise training is the main focus and schools provide the theoretical instruction to train professional and technical workers for the enterprise; the Australian TAFE model is to combine industry, government, and schools under the national framework system, and schools adopt a modular curriculum system to cultivate multi-level comprehensive talents serving the society; the French industry-education integration training model for engineers is to establish a stable school-running mechanism for school teaching and enterprise internship, and students will have 2–3 internship opportunities in enterprises during school.

In this paper, we take the training practice of vehicle maintenance and repair major in secondary vocational education of the Open University of China as an example, empirically study the "school-enterprise-industry collaboration" talent training model of "Secondary Education + Vocational Skills Training + Enterprise Order Class Training + Association Assessment and Certification", and use DEA model to evaluate the performance of talent cultivation.

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2 Empirical Research

The "school-enterprise-industry collaboration" training mode takes the development of the service industry as the purpose and the employment of students as the guidance [2]. Secondary vocational schools unite skill training schools, automobile enterprises, and industry associations to carry out cooperative education through "inter-school cooperation", "school-enterprise cooperation" and "school-industry cooperation".

Inter-school cooperation is carried out around the "Academic degree learning + Skill learning". Secondary vocational schools and training schools cooperate to set up vehicle maintenance and repair majors to cultivate students, and jointly formulate talent training programs and teaching plans. Students complete their academic studies and skills training during their two years in school and graduate with academic and training certificates.

School-enterprise cooperation is carried out by "Skills learning + Pre-job practical training" [3]. Training schools and automobile companies enter into the Cooperative Orientation Training Agreement, set up "order class" for the vehicle maintenance and repair specialists, and jointly build on-campus and off-campus practical training bases equipped with practical training teachers. Students go to work in enterprises once they graduate.

School-industry cooperation is carried out through "Skills training + Industry certificates". Training schools and the motor vehicle maintenance association jointly establish an industry assessment base and compile a question bank. Students attend the school's theoretical study and skill training and obtain the vehicle maintenance and repair qualification certificate by taking the association examination before graduation.

One of the characteristics of the "school-enterprise-industry collaboration" training model is to carry out rolling practical training. Every semester, students conduct skills training or on-the-job internship at the training base inside and outside the school to cultivate professional quality and master job skills. The other characteristic is to achieve a win-win situation through multi-party cooperation. All parties will benefit from the collaborative cooperation of schools, enterprises, and associations: students will be employed and fostered, schools will achieve their training goals, enterprises will solve their employment problems, and associations will guarantee talents in industries. Significant achievements have been made in personnel training, with a cumulative enrollment of 1.63 million and a number of graduates of 0.99 million from 2019 to 2021 for secondary vocational education at the Open University of China. Both enrollment and the number of graduates increased, as shown in Fig. 1. The student employment rate is 100%, and their salary is 10% higher than the average monthly income of the same position in the region.

3 Method

3.1 Data Envelopment Analysis (DEA)

In this paper, we use the DEA model to analyze the talent training data from 10 secondary vocational schools to evaluate the performance of the "school-enterprise-industry collaboration" mode scientifically and objectively.

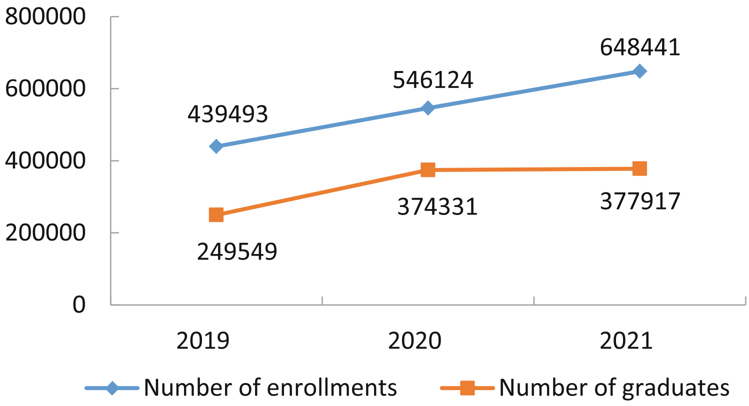

Fig. 1. 2019–2021 Number of enrollment and graduates change chart [self-drawn]

The DEA model divides the resource allocation of the talent development process into two dimensions: input and output. The indicators of the investment dimension include the total value of professional teaching equipment, the per-student teaching, and research investment cost, and the number of full-time teachers; the indicators of the output dimension include the number of graduates, employment rate, training output value, and student satisfaction.

DEA quantitatively analyzes the use and output of various inputs (i.e., resources), and divides the evaluated groups into DMU units (secondary vocational schools). The indicators for each DMU unit (secondary vocational school) are entered and weighted to compare the input-to-output ratio.

$$\text{DMUj (j} = 1, 2, \ldots, \text{n) [4]}$$

The input of $DMUj$ is $X_j = (X_{1j}, X_{2j}, \ldots, X_{mj})^T$
The output of $DMUj$ is $X_J = (X_{1j}, X_{2j}, \ldots, X_{mj})^T$

Where **m** is the number of input indicators and **n** is the number of output indicators.

The DEA model treats the 10 schools to be evaluated as decision-making units DMUs, and there are 10 DMUs in the performance analysis. Supposing that there are n evaluation units, each with m types of inputs and s types of output, the available data are shown in Table 1.

Where $\boldsymbol{\alpha_{ij}}$ is the occupation of j inputs by the i-th decision-making unit, $\boldsymbol{b_{ij}}$ is the contribution of the i-th decision unit to the j-th output, $\boldsymbol{v_i}$ represents the weight of the i-th input, and $\boldsymbol{\upsilon_i}$ denotes the weight of the i-th output quantity. Then each decision unit DMU has its efficiency evaluation index:

$$\text{Ai} = (\boldsymbol{\alpha}_{\text{i1}}, \boldsymbol{\alpha}_{\text{i2}}, \ldots \boldsymbol{\alpha}_{\text{im}}.)\ \ \text{Bi} = (\mathbf{b}_{\text{i1}}, \mathbf{b}_{\text{i2}}, \ldots \boldsymbol{\alpha}_{\text{is}}.)$$

Its vector expression is:

$$E_i = \frac{B_i U^T}{A_i V^T}{}_{i=1,2,\ldots,n}$$

Table 1. DEA model data sheet [self-drawn]

Evaluation unit	Amount of input				Amount of output			
	$\boldsymbol{\nu_1}$	$\boldsymbol{\nu_2}$	…	$\boldsymbol{\nu_m}$	$\boldsymbol{\upsilon_1}$	$\boldsymbol{\upsilon_2}$	…	$\boldsymbol{\upsilon_s}$
$\boldsymbol{DMU_1}$	α_{11}	α_{12}	…	α_{1m}	$\mathbf{b}_{11}$	$\mathbf{b}_{12}$	…	$\mathbf{b}_{1s}$
$\boldsymbol{DMU_2}$	α_{21}	α_{22}	..	α_{2m}	$\mathbf{b}_{21}$	$\mathbf{b}_{22}$	…	$\mathbf{b}_{2s}$
…	…	…	…	…	…	…	…	…
$\boldsymbol{DMU_n}$	α_{n1}	α_{n2}	…	α_{nm}	$\boldsymbol{b_{n1}}$	$\mathbf{b}_{n2}$	..	$\mathbf{b}_{ns}$

The optimal set of models for relative efficiency evaluation can be obtained as:

$$\max E_{i0} = \frac{B_{i0}U^T}{A_{i0}V^T}$$

$$s.t.\ \frac{B_iU^T}{A_iU^T} \leq 1_{i=1,2,\ldots,n}$$

$$U = (u_1, u_2, \cdots u_s) \geq 0$$

$$V = (v_1, v_2, \cdots v_m) \geq 0$$

where $A_i = (\boldsymbol{\alpha_{i1}}, \boldsymbol{\alpha_{i2}}, \ldots, \boldsymbol{\alpha_{im}})$ and $B_i = (\boldsymbol{b_{i1}}, \boldsymbol{b_{i2}}, \ldots, \mathbf{b}_{is})$ refer to the presence of at least one non-zero vector.

$$\max E_{i0} = B_{i0}^{\mu T}$$

$$s.t.\ \ A_i\omega^T - B_i^{\mu T} \geq 0 \ \ i = 1, 2, \ldots, n$$

$$A_{i0}^{\omega T} = 1$$

$$\omega \geq 0.\ \ \mu \geq 0$$

The equation is fractional programming, which can be deformed into an equivalent linear programming problem using Charnes–Cooper:

$$E_i = \frac{B_iU^T}{A_iV^T}$$

$$\frac{B_iU^T}{A_iU^T} \leq 1$$
$$i = 1, 2, \ldots, n$$

In this model, the measurements and economic significance of ω and μ relative to V and U remain unchanged. We find its dual programming, after which we obtain:

$$\min E_{i0} = \theta$$

$$\text{s.t. } \lambda A_j - a_{ioj}\theta \leq 0 \;\; \text{j=1,2,...,m}$$

$$\lambda B_j - B_{ioj} \geq 0 \;\; \text{j=1,2,...,s}$$

$$\lambda = (\lambda_1, \lambda_2, \cdots \lambda_n) \geq 0$$

$$A_j = (a_{1j}, a_{2j}, \cdots a_{nj})^T$$

$$B_j = (b_{1j}, b_{2j}, \cdots \mathrm{b}_{nj})^T$$

If the optimal solution $\theta^*$of the model is $\lambda_1, \lambda_2, ..., \lambda_n$, then θ^* represents the relative maximum probability of reducing input $\boldsymbol{A_{i0}}$ by the same proportion when output $\lambda_1, \lambda_2, ..., \lambda_n$ remains unchanged in the production possibility set. If the input $\boldsymbol{A_{i0}}$ cannot be reduced, that is, $\theta^* = 1$, the evaluation unit DMU_{io} is called DEA weakly efficient C^2RIf the evaluation unit is weakly efficient while the values of the remaining variables and the slack variables are zero, the evaluation unit *DEA* is said to be effective, indicating that the evaluation unit is of "scale efficiency" and "technical efficiency". If the input $\boldsymbol{A_{i0}}$ can be reduced by the same proportion, i.e.,

$\theta^* < 1$, it means that the evaluation unit cannot be "scale efficient" and "technical efficient" at the same time, and the evaluation unit *DMU* can be called *DEA* inefficient C^2R. The relative input-output efficiency is the economic meaning of the θ^* value, that is, the minimum input ratio of the given output of the unit is obtained relative to the evaluation unit with the optimal efficiency $\lambda_1, \lambda_2, ..., \lambda_n$.

The following represents changes in scale gains: T < 1 indicates that the scale of the evaluation unit has an increasing return; T = 1 indicates that the scale income of the evaluation unit remains unchanged; T > 1 indicates that the scale of the evaluation unit has diminished returns. The model is normalized by introducing slack variables and remaining variables to obtain a model with non-Archimedean infinitesimals:

$$\mathrm{A_{i\,o}A_{i\,o}}$$

This paper uses a C^2R model formula to evaluate the scale and technical efficiency. In the model, $\boldsymbol{A_{i0}}$ is the slack variable, and $\boldsymbol{t_j}$ is the remaining variable.

3.2 Data Analysis

The statistics of talent training data of 10 schools using the DEA model are shown in Table 2.

Using DEAP software, the overall efficiency, pure technical efficiency, economies of scale, and redundancy values of each input and output of the professional talent training in the 10 schools were derived, and the talent training performance evaluation table was formed as shown in Table 3.

From the analysis of the performance table of professional talent training, we can see that the technical efficiency value of the five schools of ADEHG is 1, which is at

Table 2. Statistics table of talent training data of 10 schools [self-drawn]

major in school	X_1 /ten thousand yuan	X_2 /yuan	X_3 /unit	Y_1 /person	Y_2 /%	Y_3 /ten thousand yuan	Y_4 /%
A	595	621	25	2721	90	221	98
B	824	544	39	4367	84	409	93
C	621	695	42	2945	91	443	92
D	583	480	30	6278	95	845	95
E	721	522	35	4744	89	398	98
F	632	665	42	5650	87	406	95
G	609	597	40	5075	85	578	96
H	845	652	41	6199	89	521	97
I	769	552	38	3890	90	290	95
J	609	597	29	2089	95	175	96

Table 3. Performance evaluation table of professional talent training in 10 schools [self-drawn]

Secondary vocational school Major	Overall efficiency	Pure technical efficiency	Scale efficiency	Increases or decreases in scale efficiency	Technical efficiency
A	1.000 = 1	1.000	1.000	Unchanged	Efficient
B	0.864 < 1	0.951	0.908	Decrease	Inefficient
C	0.908 < 1	0.961	0.944	Decrease	Inefficient
D	1.000 = 1	1.000	1.000	Unchanged	Efficient
E	0.949 < 1	1.000	0.949	Decrease	Efficient
F	0.921 < 1	0.989	0.931	Decrease	Inefficient
G	0.964 < 1	0.997	0.967	Decrease	Inefficient
H	0.752 < 1	1.000	0.752	Decrease	Efficient
I	0.870 < 1	0.980	0.887	Decrease	Inefficient
J	0.986 < 1	1.000	0.986	Decrease	Efficient
Mean value	0.921	0.988	0.932		

the frontiers of efficiency; the average efficiency value is 0.921, and the difference in efficiency value between schools is small, indicating that the standardization level of secondary vocational education is relatively high with a good overall talent training performance.

The scale efficiency and pure technical efficiency of the three schools BCF are inefficient, and the scale efficiency is decreasing.

Eight of the 10 schools are in the state of diminishing scale efficiency and two have a scale efficiency of 1. This indicates that the overall scale of secondary vocational education is large, with more investment in teaching and practical training equipment and sufficient faculty. However, as the investment in education continues to expand, the output values such as the number of graduates and the employment rate of students have grown slowly, indicating that the school is expanding its inputs at an inappropriate scale.

By comparing the number of times the schools with an efficiency value of 1 have been referenced on the forefront, the pros and cons of the schools' professional talent training performance are shown in Fig. 2.

The professional talent cultivation model of school D was referred to the most, indicating the best efficiency of talent cultivation. Through the comparison of the original survey data, school D and its major correspond to the Open University of China and the secondary vocational vehicle maintenance and repair major. Referring to school D to optimize the talent training model of other schools, the results of data model calculation were obtained as shown in Table 4.

Optimization results: School B saved 1.1289 million yuan in teaching equipment, 25.011 yuan in teaching fees per student, reduced 5 full-time teachers, increased 263 graduates, and raised the student employment rate by 51.108 percentage points.

School C saved 239,000 yuan in teaching equipment, 145.803 yuan in teaching expenses per student, and 13 full-time teachers, and increased the number of graduates by 835.

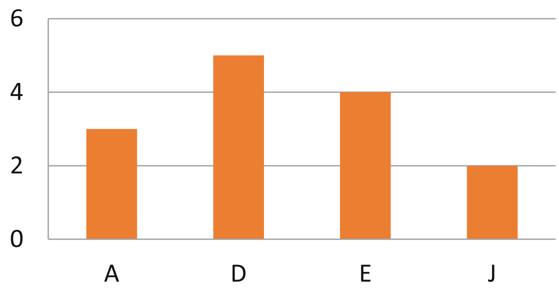

Fig. 2. Talent training model performance statistical chart [self-drawn]

Table 4. Distribution of slack variables and remaining variables of technical inefficient school majors [self-drawn]

major in school	S_1	S_2	S_3	t_1	t_2	t_3
B	112.893	25.011	4.358	263.279	1.108	-
C	23.900	145.803	12.842	835.285	-	-
F	-	169.322	11.255	-	4.855	272.408
G	-	73.023	11.485	-	7.442	27.430
I	103.949	7.966	5.723		-	73.547

School F saved 169.322 yuan in teaching costs per student, reduced 11 full-time teachers, increased the employment rate of students by 4.855 percentage points, and the training output value by 2.72408 million yuan.

School G saved 73.023 yuan in teaching costs per student and 11 full-time teachers, and increased the employment rate of students by 7.442 percentage points and the training output value by 274,300 yuan.

School I saved 1.03949 million yuan in teaching equipment, 7.966 yuan in teaching costs per student, and 6 full-time teachers, and improved training output value by 735,470 yuan.

The performance evaluation analysis shows that the talent training mode of "school-enterprise-industry collaboration" has high output efficiency concerning the number of graduates and student employment rate under the condition of low investment in teaching equipment and full-time teachers, which is an effective way to improve the quality of talent training.

4 Conclusions

DEA data model has a scientific guiding role in talent training, evaluates the effectiveness through empirical research, and provides a good identification method and improvement plan for the problems of redundant input resources and low talent output rate in the school talent cultivation, thereby proposing measures to solve the problems.

5 Recommendation

Building an open and shared online education resource platform

Secondary vocational schools cooperate further with enterprises and associations to build an online course platform integrating a professional resource system, teaching management, teacher-student interaction, and a combination of theory and reality. The platform system consists of a basic network system, a public support system, and a teaching (practical operation, practical training) service system to meet the learning needs of students; it provides learning services for the continuous education of industry practitioners and the learning skills of the public through opening up to the community, thus optimizing talent cultivation.

Building a "seven-in-one" multi-functional training base jointly

Schools, together with enterprises and associations, build a "seven-in-one" modern multi-functional on-campus training base, which has the comprehensive functions of on-site teaching, on-the-job training, skill appraisal, skill competition, product scientific research, and student entrepreneurship practice.

Creating an "industry-university-research-innovation" mixed-ownership platform

To integrate school education resources, enterprise training resources, and industry association social resources by means of a professional chain docking industrial chain, a joint technology center is established by enterprises, associations, and schools to create a four-in-one independent platform of "industry, university, research, and innovation". In this way, it is available to carry out professional construction, research and development of new products, innovative technologies and processes, and explore the development direction of the industry.

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