Research on the Evaluation of Comprehensive Level of Compulsory Education Based on Factor Analysis Method

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Abstract. Basic education is one of the key factors to determine the development of education, and studying its quality level is helpful to make more scientific and sensible decisions. During the decade from 2010 to 2020, the popularization of compulsory education in all parts of China has increased significantly. Although it has reached a high level, the level of development is uneven. In order to help improve the compulsory education policy and promote the balanced development of compulsory education, this study takes the comprehensive level of compulsory education as the first-level index, considers from the three aspects of teachers, students and the environment, and, after repeated verification and improvement, constructs a reasonable evaluation index system of the comprehensive level of compulsory education. In addition, we took the data of compulsory education in China in 2020 as an example to carry out the empirical evaluation research, analyzed the empirical evidence, and put forward reasonable suggestions.

Keywords: Statistical analysis · Factor analysis · Compulsory education · Evaluation index system

1 Introduction

Compulsory education is one of the cores of the modern national basic public service system, and it plays a very crucial role in the development of education [1]. Studying the comprehensive level of compulsory education in China plays an important role in policy making and education management. In order to effectively assess the quality of compulsory education and improve education policies, more and more scholars have studied compulsory education comprehensive level evaluation indexes in depth and proposed different evaluation systems. From the available research results, it can be seen that most scholars have constructed compulsory education evaluation indexes from different perspectives. Professor Wang Shanmai and others evaluated the development of compulsory education from the perspective of balanced development between schools in counties, and followed the four principles of "balanced principle of resource allocation", "financial neutrality principle", "weak compensation principle" and "data

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feasibility principle" to construct the evaluation index system [2];Wang Weiyuan initially constructed the evaluation index system of the compulsory education running conditions under the compulsory education stage, and verified and analyzed the index system, and got good feedback [3];Wu Yun extended 19 indicators from the four dimensions of "funding guarantee", "school conditions", "teacher allocation" and "education quality" to build the balanced development of compulsory education index system [4].

The common evaluation indexes are mainly derived from school infrastructure, students' academic performance, teachers' strength and education teaching quality, which become the main reference for measuring the comprehensive level of education [5]. The study of evaluation indicators of the comprehensive level of compulsory education is a long-term task, which requires continuous attention to social changes and the scientific and validity of evaluation indicators, as well as continuous improvement and updating of the indicator system in order to improve the quality of compulsory education and improve education policies [6].

2 Research Methodology

2.1 Factor Analysis Method

Factor analysis is a statistical method of multivariate analysis [7]. Factor analysis is to take multiple factors with complex relationships and find out a few random variables that can summarize the main information of all variables and that are not correlated with each other by studying the internal dependencies of their correlation matrices, so as to simplify the measured data by reducing the dimensionality of variables and finally achieve the purpose of explaining complex problems with a few variables.

2.2 Factor Analysis Model

The idea of factors can be represented by a mathematical model, with P original variables $X_1, X_2, \ldots, X_p$, and each with mean 0 and standard deviation 1. Each original variable is represented by a linear combination of k (k < p) factors $f_1, f_2, \ldots$, and a linear combination of f_k to represent. as follows:

$$\begin{cases} X_1 = a_{11}f_1 + a_{12}f_2 + a_{13}f_3 + ... + a_{1k}f_k + \varepsilon_1 \\ X_2 = a_{21}f_1 + a_{22}f_2 + a_{23}f_3 + ... + a_{2k}f_k + \varepsilon_2 \\ \quad \cdot \\ \quad \cdot \\ \quad \cdot \\ X_P = a_{p1}f_1 + a_{p2}f_2 + a_{p3}f_3 + ... + a_{pk}f_k + \varepsilon_p \end{cases} \tag{1}$$

The factor model is as follows, where a_{ij} is the factor loading, i.e., the loading of the i-th variable on the j-th factor.

$$X_i = a_{i1}f_1 + a_{i2}f_2 + a_{i3}f_3 + ... + a_{ik}f_k + \varepsilon_i \quad (i = 1, 2, ..., p) \tag{2}$$

The covariance model for X_i and F_j can be derived from the above factorial model:

$$\mathrm{Cov}(X_i, f_j) = \mathrm{Cov}\left(\sum_{k=1}^{p} a_{ik} f_k + \varepsilon_i, f_j\right)$$

$$= \mathrm{Cov}\left(\sum_{k=1}^{p} a_{ik} f_k + \varepsilon_i, f_j\right) + \mathrm{Cov}(\varepsilon_i, f_j)$$

$$= a_{ij} \tag{3}$$

Since different indicators have different magnitudes and are not comparable, the raw data need to be standardized to eliminate the effect of magnitudes. The standardization formula is as follows, where X_i is the original data and Z_i is the standardized data.

$$Z_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \tag{4}$$

If the standardization of X_i normalization is done, the standard deviation of X_i is 1 and the standard deviation of F_j is 1, then

$$r_{x_i f_j} = \frac{\mathrm{Cov}(X_i, f_j)}{\sqrt{(X_i)}\sqrt{(f_j)}} = \mathrm{Cov}(X_i, f_j) = a_{ij} \tag{5}$$

The standardized Xi, a_{ij} is the correlation coefficient of X_i and F_j, i.e., the factor loadings are the correlation coefficients of the variable Xi and the factor Fj, provided that the factors are not correlated, reflecting the degree of correlation between the variable Xi and the factor Fj. The larger the factor loadings, the closer the relationship between the i-th variable and the j-th factor.

The factor variance contribution model is as follows:

$$g_j^2 = \sum_{i=1}^{k} a_{ij}^2 \quad (j = 1, 2, 3, ..., k) \tag{6}$$

Let the factor loading matrix be A and call the sum of squares of the elements in the j-th column the sum of the variance contributions of the factors. g^2_j denotes the sum of variance contributions provided by the same factor to each variable, which reflects the explanatory power of the factor to the total variance of the original variable. The higher the value of the factor variance contribution, the higher the importance of the corresponding factor [8].

2.3 Introduction to Data Sources

The data used to analyze during the construction of the index system comes from the China Education Statistical Yearbook (2020) processed and published by the Education Management Information Center of the Ministry of Education. In this paper, the data of compulsory education in 31 provinces, municipalities and autonomous regions (excluding Hong Kong, Macao and Taiwan) in 2020 were selected and summarized, and the above collated data were analyzed by using SPSS software.

3 Construction of Index System

3.1 Preliminary Selection of Evaluation Index Items

The key to constructing an index system with reference value is to select suitable evaluation indicators [9]. This paper refers to the relevant data on the development of education reflected in the 2020 China Education Statistical Yearbook, based on the principles of scientificity, reasonableness and fundamentality, and based on the three key elements of education evaluation, namely, teachers, students and teaching environment, four secondary indicators are refined and decomposed around the primary indicator of the comprehensive level of compulsory education: the level of school conditions, the level of informationization, the level of teachers and the level of students. The level of information technology, teachers' level and students' level are broken down into four secondary indicators. Under the school condition level indicators, four three-level indicators are decomposed, including the number of schools and the building area of school buildings. Under the level of information, the total number of teaching computers and other two indicators. Teacher level is decomposed into the total number of staff and other 6 indicators. Under the student level index, three indicators such as the number of students are decomposed. These 19 indicators were coded to facilitate the data analysis of the subsequent work.

3.2 Deletion and Reorganization of Evaluation Index Items

After the initial selection of 19 evaluation index items, the selected index items were coded. In order to make the index items of the evaluation index system more perfect, more scientific and have certain reference significance for the evaluation of the comprehensive level of compulsory education, this study will collate and summarize the education data of general primary and junior high schools in 31 provinces, municipalities and autonomous regions (excluding Hong Kong, Macao and Taiwan) in China in 2020. After a series of repeated experiments, we finally obtained 12 more reliable evaluation index items to construct the evaluation index system by deleting and reorganizing the originally selected 19 index items appropriately.

3.3 Results of KMO and Bartlett's Sphericity Test

The factor analysis method requires a certain correlation between the original variables, and if the data are independent of each other, then it will not be possible to condense the original variables. Therefore, when using factor analysis to analyze each weight index, it is necessary to use methods such as Bartlett's spherical test and KMO test to test the original data [10]. The KMO test is shown in Fig. 1. As shown in Fig. 1, the KMO test statistic indicates whether the bias correlation between the variables is strong enough, and the Bartlett sphericity test is used to determine whether the correlation matrix is a unit matrix. The p-value of 0.000 derived from the Bartlett sphericity test indicates that the hypothesis of independence of the variables is rejected, i.e., there is a strong correlation between the variables. Meanwhile, the KMO test statistic is 0.890, which indicates that the information overlap among the variables is high and the sample meets

KMO and Bartlett's test		
KMO sampling fitness measure		0.89
Bartlett's sphericity test	Approximate chi-square	1016.122
	Degree of freedom	66
	Significance	0

Fig. 1. KMO and Bartlett's test results

the requirement of reasonable data structure, thus a more satisfactory factor analysis model can be derived.

3.4 Total Variance Explained

The variance contribution and cumulative contribution of each component are represented in Fig. 2. The eigenvalue of the first principal component is 10.685, which means that the first principal component carries 10.685 original variables, and the variance of the first principal component accounts for 89.038 of the variance of all principal components. The cumulative variance contribution of the first three principal components reaches 98.223%, so the first three principal components are chosen to be sufficient to describe the level of compulsory education development.

Factor analysis requires that the extracted common factors have real meanings. In order to make the coefficients in the factor loading matrix more significant, the initial factor loading matrix can be rotated to reassign the relationship between the factors and the original variables so that they can be interpreted more easily. The loadings of the factors after rotation are given in the total variance interpretation, and only the first three factors are selected by default, and all rotations will be based on these three extracted common factors. The variance contribution of each of the three common factors changes after rotation (the gap between them is reduced, the amount of information is redistributed, but the order from largest to smallest is still maintained, and the cumulative variance contribution is still (98.223%).

	Initial eigenvalue			The sum of the load squares was extracted			Sum of the rotating load squares		
ingredient	amount to	variance percentage	accumulate %	amount to	variance percentage	accumulate %	amount to	variance percentage	accumulate %
1	10.685	89.038	89.038	10.685	89.038	89.038	5.807	48.390	48.390
2	.633	5.273	94.311	.633	5.273	94.311	4.300	35.832	84.223
3	.469	3.912	98.223	.469	3.912	98.223	1.680	14.001	98.223
4	.078	.646	98.869						
5	.047	.389	99.259						
6	.041	.345	99.604						
7	.018	.150	99.754						
8	.013	.111	99.865						
9	.010	.085	99.950						
10	.004	.032	99.982						
11	.002	.015	99.997						
12	.000	.003	100.000						

Fig. 2. Total variance interpretation

	ingredient		
	1	2	3
Total value of teaching equipment assets	.919	.226	.242
Total number of teaching computers	.878	.371	.244
Network-multimedia classroom	.787	.542	.265
Number of full-time teachers with a bachelor's degree or above	.771	.540	.310
Books (books)	.733	.588	.274
Building area (total)	.723	.617	.290
Total enrollment	.680	.677	.272
Number of full-time teachers (total)	.673	.659	.324
Number of schools (total)	.266	.910	.281
Total number of graduates	.631	.704	.317
Total number of students	.663	.694	.273
Number of teachers with senior professional titles	.306	.320	.897

Fig. 3. Component matrix after rotation

3.5 Factor Naming

Figure 3 shows the rotated component matrix, and this study names each factor based on the data in this table. It can be seen from the table that the male factor F1 has a large proportion in the teaching information technology equipment and the total value of teaching equipment assets, so it can be named as the level of school conditions factor. Public factor F2 has a relatively even share in the number of students, enrollment and graduates, and is related to students, so it can be named as the comprehensive level factor of students. The factor F3 has the highest percentage of the number of teachers with senior title and the highest percentage of the other two factors related to teachers, so it can be named as the factor of teachers' level.

3.6 Constructing the Index System

The education data of China's compulsory education stage in 2020 were compiled and analyzed, and an evaluation index system with reasonableness was finally constructed by using factor analysis and repeated validation through calculation, testing and analysis of each index item, as shown in Fig. 4. The meanings of each indicator are explained as follows:

Level index of school-running conditions. The level of school conditions can directly reflect the investment of education in each region, and to some extent also reflects the economic development of each region. Combined with the statistical information published on the official website of the Ministry of Education, this paper selected six detailed indicators, such as the total building area of school buildings, the number of schools, to reflect the level of school conditions in each region. In addition to the number of primary schools and the number of middle schools, it also includes all the teaching points in individual underdeveloped areas. Comprehensive level of teachers. Teachers are an indispensable and important part of evaluating the comprehensive level of compulsory education. This paper starts from the number of teachers, teachers' academic qualifications, and their vocational and technical titles, including the total number of teachers in compulsory education, the number of full-time teachers, the number of teachers with

Level 1 indicators	Secondary indicators	weight	Level 3 indicators
Comprehensive level of compulsory education	The level of running conditions	48.390%	Total value of teaching equipment assets
			Total number of teaching computers
			Network-multimedia classroom
			Books (books)
			Building area (total)
			Number of schools (total)
	Comprehensive level of students	35.832%	Total enrollment
			Total number of graduates
			Total number of students
	Comprehensive level of teachers	14.001%	Number of full-time teachers (total)
			Number of full-time teachers with a bachelor's degree or above
			Number of teachers with senior professional titles

Fig. 4. Table of evaluation index system of comprehensive level of compulsory education

bachelor's degree or above, and the number of teachers with senior professional titles (including professional and deputy levels), to reflect the comprehensive level of teachers. Comprehensive level of students. Students are the main object of education and teaching, and they are in the main position in teaching activities. The evaluation of learners is one of the main contents of measuring the comprehensive level of compulsory education. In this paper, three indicators are selected to reflect the comprehensive level of students under the compulsory education stage: the number of enrollment, the number of graduates and the number of students in school in 2020.

4 Analysis of Results

After constructing a comprehensive compulsory education level evaluation index system, the expressions of the factors can be written and the scores of the common factors can be calculated according to the matrix of component score coefficients for further comprehensive evaluation. Since the three factors reflect the overall level of local compulsory education development from different aspects, it is difficult to make a comprehensive evaluation by using one common factor alone, so we consider the proportion of variance contribution ratio of each common factor as the weight to calculate the comprehensive score [11].

A new variable named composite score is generated, and this composite score is calculated with the weight of the variance contribution corresponding to each common factor, calculated as follows:

$$\mathrm{F} = \mathbf{48.390/98.223} \times \boldsymbol{F1} + \mathbf{35.832/98.223} \times \boldsymbol{F2} + \mathbf{14.001/98.223} \times \boldsymbol{F3} \quad (7)$$

By processing the sample data, the comprehensive score is calculated using the variance contribution rate corresponding to each public factor as the weight, and the statistical results shown in Fig. 5 are obtained. From Fig. 5, we can see that Guangdong, Henan, and Shandong [2] are the top three provinces, and the composite scores of these three provinces are all greater than 1. From the comprehensive analysis, firstly, these provinces have more developed economic and social resources, which provide the

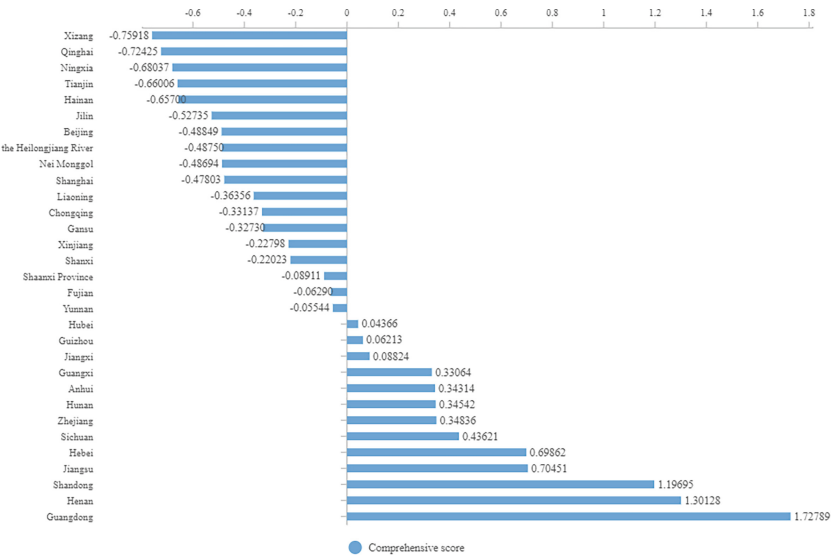

Fig. 5. Composite score

corresponding material and human conditions to support the development of education. Second, these provinces have made certain achievements in education policies, curriculum reform and teacher training, which can well meet the needs of students and teachers and promote the improvement of education quality.

Except for these three provinces, the comprehensive scores of other provinces is less than 1, indicating that the development of the comprehensive level of compulsory education in China in 2020 is unbalanced. Compared with the developed cities of Ningxia, Qinghai and Tibet, the economic development level is relatively backward, which shows that the level of education development is closely related to the level of economic development.

5 Inspiration and Prospect

According to official statistics, 95.2 percent of China's children completed nine-year compulsory education in 2020, with the proportion slightly higher in urban areas than in rural areas. The government should increase the investment in education funds, increase the proportion of financial allocation and the proportion of education expenditure borne by the central and local governments, pay attention to the special education needs of village schools and poor areas, and strengthen the assistance to these areas and schools. Secondly, it is necessary to optimize the allocation of educational resources, and take some measures to optimize the layout and management of educational resources in view of the practical problems such as population flow and urban-rural gap, such as carrying out the balanced development plan of urban and rural compulsory education.

This study is a preliminary attempt to evaluate the comprehensive level of compulsory education in China. A scientific and reasonable index system needs to go through

many tests and corrections before it can be improved and mature. Looking into the future, China's compulsory education should continue to explore the multiple evaluation system, more extensive and in-depth study of students' comprehensive quality, promote educational equity, and adapt to the needs of The Times and the needs of future social development.

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