Evaluation of Operational Efficiency of Grassroots CDC Laboratories- A Case Study in China

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Evaluation of operational efficiency of Grassroots CDC laboratories- a case study in China

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Abstract

Background： Grassroots CDC laboratory efficiency can reflect and influence a country's capacity for disease control and prevention, improving the efficiency of the grassroots CDC laboratory is very important to national CDC system, this article is based on DEA method, on the basis of clearly defining the concept of efficiency, more methods to build grassroots CDC laboratory efficiency evaluation index, taking China as an example, the grassroots CDC laboratory efficiency study, discusses the current problems in the development of grassroots CDC laboratory operation efficiency.

Methods： Using data from China National Health Development Research Center, combined with some public data from National Bureau of Statistics and China Health Statistics Yearbook data, use data envelopment analysis (DEA) to analyze the operation of China's grassroots CDC disease control laboratories from 2017 to 2019 Efficiency, input-output improvement value and total factor productivity changes.

Results： From 2017 to 2019, the operational efficiency of grass-roots CDC laboratories in China showed a downward trend, and there was a serious problem of insufficient output, especially the grass-roots CDC laboratories in western China, which had the lowest operational efficiency. By analyzing the change of total factor productivity, it is found that the total factor productivity of grass-roots CDC laboratories in China generally shows a downward trend, and the technical level and management efficiency have declined to a certain extent, and the working ability of CDC laboratories has not been effectively improved.

Conclusions： The operational efficiency of grass-roots CDC laboratories is declining, and the technical level and management efficiency are declining. The unreasonable utilization of laboratory resources and unbalanced development are still outstanding, and the operational efficiency of laboratories needs to be further developed. Policymakers should pay attention to the imbalance of resource utilization and development of grass-roots CDC laboratories, give certain policy support to inferior CDC laboratories, and urge grass-roots CDC laboratories to strengthen management, improve technical level and management efficiency, increase the actual output of laboratories, and further enhance the working ability of grass-roots CDC laboratories.

Keywords： CDC；laboratory；operational efficiency；DEA

Background

With the gradual acceleration of the process of economic globalization and the strengthening of global mobility, public health issues have become a global concern[1]， from H1N1, Ebola virus, dengue fever, and measles in previous years to 2019 .The new type of coronavirus pneumonia, a series of major public health emergencies have had a huge impact on the health and life safety of the public in various countries and even the world[2-6] As the grassroots CDC laboratory of the national disease control system, it is the largest number of experimental testing institutions in a country's CDC. It is the first to undertake testing tasks every time, and the numerous grassroots CDC laboratories are like the nerve endings and organizational units of the disease control system of the entire country, forming a huge and complex disease control network in daily life. The important role of testing and disease screening in responding to major public health emergencies has gradually become prominent. Operational efficiency is a good indicator to measure the working ability of an organization[7]. The operating efficiency of a CDC laboratory can reflect the laboratory's work and response capabilities. If the CDC laboratory at the grassroots level has higher operational efficiency, then the laboratory can complete more tasks faster, thereby helping the grassroots disease control system and the disease control system of the entire country have a stronger ability to respond to public health risks.

Operational efficiency is a concept derived from the term efficiency. It pays more attention to the organization's ability to work within a certain period of time. It usually indicates whether the organization can achieve the maximum output at the lowest cost (including time cost and capital cost)[8-11].In this study, in order to more accurately express the operational efficiency of CDC laboratories at the grassroots level, we defined the number of operational efficiency primary disease prevention and control laboratories, expressed as the ratio of effective output per unit time (year) to effective input. The operating efficiency of the grassroots CDC refers to the actual workload per unit time of the laboratory under the same resource input. We checked the progress of research on the efficiency of CDC laboratories at the grassroots level in various countries, and found that few people pay attention to research in this field. In the study of public health issues in various countries, there is a lack of scientific evaluation of the operating efficiency of basic CDC laboratories. This is very detrimental to the development of disease control systems in various countries. The laboratory is the core department of the CDC, and its operational efficiency can be a good measure of the laboratory's working ability. Through the in-depth understanding of the laboratory operation efficiency of the National Center for Disease Control and Prevention, it is found that countries have similar problems in the development of laboratory operation efficiency, which can provide an effective reference for further improving the operation efficiency of the grassroots CDC laboratory. Promote the grassroots disease control system, and even the disease control system of the entire country.

Because the grassroots CDC laboratory is an organization with "multiple input and multiple output" characteristics, its operating efficiency is the result of a comprehensive evaluation. Therefore, in order to more effectively evaluate the operating efficiency of the grassroots CDC laboratories, this study uses data envelopment analysis (DEA) to evaluate the operating efficiency of the grassroots CDC laboratories. The choice of evaluation indicators is very important to the evaluation results of this study. We found that when using the DEA method to conduct evaluation research on previous articles, many scholars just listed the evaluation index set directly based on a large number of literature studies when constructing evaluation indicators, without considering the correlation between the evaluation indicators, and did not use Statistical methods to determine the correlation between evaluation indicators. When Lamovek (2020), Siamak (2019) and other scholars used the DEA method to study the efficiency of biomedical laboratories or hospital laboratories, the construction of evaluation indicators did not undergo rigorous indicator screening and lacked support for the rationality of indicators[12, 13] This is actually not strict, and the construction of evaluation indicators should require multiple methods to screen and determine. Based on the analysis of all the above research backgrounds, this study takes China's grassroots CDC laboratory as an example. Based on the concept of laboratory operating efficiency, a combination of quantitative and qualitative methods is used to construct laboratory operating efficiency evaluation indicators. The DEA method is used to evaluate the operating efficiency of CDC laboratories at the grassroots level, hoping to provide reference for the construction of disease control systems in countries around the world.

Methods

Data

The data of this study is mainly derived from the basic-level CDC laboratory survey data of the China National Health Development Research Center in 2020, and also combines part of the annual data of the National Bureau of Statistics and the data of the health statistics yearbook. When choosing a specific sample, economic and geographic factors should be considered. Therefore, in the eastern, central and western regions of China, we randomly selected a province in each region according to the per capita GDP level and geographic location of each region, and finally selected Anhui, Guangdong and Sichuan provinces. In order to ensure the fairness of the sample size selected by each province when selecting the grassroots CDC laboratory samples, we use the number of all county-level cities in each province multiplied by a weight coefficient of 0.05 (the weight coefficient is the result of experts). Consultation) Finally, based on the calculation results and the principle of random selection, the number of grassroots CDC laboratories was determined: 5 in Anhui Province, 6 in Guangdong Province, 8 in Sichuan Province, a total of 19 grassroots CDC laboratories

Research problem

In this article, we use the laboratory data of China's grassroots CDC to carry out operational efficiency research and accomplish the following specific goals: a) Explore the best evaluation indicators for the operation efficiency of grassroots CDC laboratories based on the DEA model; b) Estimate the Technical Efficiency (TE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE) of China's grassroots CDC laboratories from 2017 to 2019; c) Analyze the relative surplus of input and relative shortage of output of non-effective units in grassroots CDC laboratories from 2017 to 2019. d) Analyze the efficiency changes of the grassroots CDC laboratories from 2017 to 2019.

Statistical methods

Data Envelopment Analysis

Data Envelopment Analysis (DEA) was first proposed by the famous American operations research expert Charnes and others[14]. This is a non-parametric statistical method based on relative efficiency calculations[15-17], used to evaluate the same type of decision-making unit (DMU) with multiple input and multiple output characteristics[18].Because DEA can easily accommodate multiple inputs and outputs, it does not require a common denominator measurement, so it is particularly suitable for analytical laboratories with multiple inputs and multiple outputs. In DEA, DMU is technically effective, with a score of 1 or 100%, while inefficient DMU scores are lower, that is, less than 1 or 100 [19].

DEA efficiency evaluation is mainly carried out from the three perspectives of Technical Efficiency (TE), Pure Technical Efficiency (PTE) and Scale Efficiency (SE). The effective TE means that the PTE and SE are effective at the same time. Effectiveness of PTE refers to achieving the maximum output with the existing resource input, that is, the various inputs of the CDC have been fully utilized to reach its optimal output value. The effective SE is also called the unchanged SE, which means that under the current technical conditions, the CDC's production scale is in the best condition. The laboratory operation efficiency evaluated in this study is TE. In terms of evaluation models, there are mainly CCR model (the model is named by the proponents such as A.Charnes, WWCooper and E.Rhodes) and BCC (the model is named by the proponents such as RDBanker, A.Charnes, WWCooper named) model. The CCR model assumes that the return to scale remains unchanged, and the technical efficiency obtained includes the SE component, so it is usually called comprehensive technical efficiency, which is the overall efficiency; the BCC model is based on the variable return to scale, and the technical efficiency obtained Excluding the impact of scale, it is called Pure Technical Efficiency (PTE) [20, 21],Considering that the CDC focuses on how to use existing input resources to provide more public health services to the public, this study adopts production-based The oriented CCR model calculates the overall efficiency, and the BCC model is used to calculate the pure technical efficiency.

Correlation Analysis

This research mainly uses correlation analysis to find the typical indicators of different subcategories of input and output indicators, which provides a basis for subsequent screening and determination of evaluation indicators included in the DEA model[22]. The selected method is: Calculate the average (R_i^2)， of the correlation coefficients of each indicator and other indicators in each category. The calculation formula is:R_i^2= （$\sum r_{ij}^2$）/(m － 1)

Where i =1, 2, ..., m. m is the total number of indicators in the category of the indicator. The larger theR_i^2, the more typical the indicator.

Clustering analysis

Clustering analysis is to divide similar objects into different groups or more subsets through static classification, so that the member objects in the same subset have similar attributes[23], including various typical cluster models. This study uses the centroid model to cluster the input and output indicators, classifies the evaluation indicators from the evaluation indicator data set, and then combines the results of the correlation analysis to select the most suitable indicator for evaluating the efficiency of laboratory operations.

Projection analysis

Projection analysis is to calculate the target value and the required improvement value that the multi-input multi-output unit should reach when the effective frontier is reached and the required improvement value when the output is not fully effective compared with the reference unit, to calculate the need to increase or Reduced input and output value. This study uses projection analysis to determine the number of over-input and under-output of ineffective laboratories in county-level disease control laboratories. The improvement value includes the proportional improvement value and the relaxation improvement value[24], and the formula is:

Target value (projection value) = original value + improved value = original value + proportional improvement value + relaxation improvement value

Malmquist index analysis

DEA-Malmquist model index is generally used to evaluate the production and operation performance of decision-making units with multiple inputs and multiple outputs. As a tool to study the effectiveness of production, it is widely used in various fields such as financial investment, industrial manufacturing, and medical services. It mainly reveals productivity changes through efficiency changes and technological changes[25],which can be expressed as:

$$M(x^{t+1},y^{t+1},x^t,y^t)=\frac{E^{tU(t+1)}(x^{t+1},y^{t+1})}{E^{tU(t+1)}(x^t,y^t)}$$

$$=\frac{E^{t+1}(x^{t+1},y^{t+1})}{E^t(x^t,y^t)}\left(\frac{E^{tU(t+1)}(x^{t+1},y^{t+1})}{E^{t+1}(x^{t+1},y^{t+1})}\times\frac{E^t(x^t,y^t)}{E^{tU(t+1)}(x^t,y^t)}\right)$$

$$=TEC\times TC$$

Among them, $(x^t,y^t)$and(x^{t+1},y^{t+1}) are the input-output relationship of the t period and the t+1 period respectively, TEC is the efficiency change, and TC represents the technological change.

We use Malmquist index analysis to calculate the Total Factor Productivity (TFP) of grassroots CDC laboratories from 2017 to 2019. TFPCH refers to the "efficiency of production activities in a certain period of time", which is a productivity index that measures unit total input and total output, that is, the ratio of total output to total factor input. TFPCH has three sources: (1) technological progress; (2) efficiency improvement; (3) scale effect. Therefore, TFPCH can be further decomposed into Technological Change (TC) and Technological Efficiency Change (TEC). TEC represents the degree of effective utilization of existing technologies. Under the condition of the same overall return to scale, it can be decomposed into the Scale Efficiency Change (SEC) and the Pure Technical Efficiency Change (PEC). SEC reflects whether the increase in medical output is consistent with the increase in input, while PEC can reflect the changes in the management level of disease control institutions[26-28], In summary, the result of decomposing the Malmquist exponent is expressed as:

$$TFP=TC\times TEC=TC\times SEC\times PEC$$

When the TFP operation result is greater than or equal to 1, it indicates that the actual output of the disease control agency is effective, and the overall level of CDC resource input performance is relatively high. On the contrary, when the TFPCH result is less than 1, it indicates that the actual government output is invalid and the overall CDC resource input performance is relatively low.

Statistics Software

Use Excel2019 for data sorting, use SPSS23.0 software for statistical analysis, mainly including descriptive analysis, correlation analysis, cluster analysis, projection analysis, Malmquist index analysis. We use the MaxDEA6.0 for DEA efficiency analysis, DEAP2.1 software for Malmquist analysis.

Results

Index screening

When evaluating the efficiency of DEA, the selection of evaluation indicators should consider the correlation between the indicators and select the optimal indicators. Therefore, this study uses a combination of association analysis and cluster analysis to use the data of the primary CDC laboratory of the sample in 2019. As a representative, a quantitative screening of the operation efficiency evaluation indexes of the grassroots CDC laboratory was carried out to determine the final operation efficiency evaluation indexes of this study.

Preliminary establishment of candidate data sets for evaluation indicators

Through the method of literature research, consult the research literature on the evaluation index of CDC laboratory operation efficiency in various countries around the world, and summarize and summarize the content of the relevant evaluation index system. We have listed the preliminary set of operational efficiency evaluation indicators related to this topic, and combined with the "Guiding Opinions on Provincial, Regional, and Grassroots CDC Laboratory Construction" issued by the Ministry of Health of China in 2004, it is clear that the grassroots CDC.The responsibilities and functions of the CDC further determined the operational efficiency evaluation index data set of the grassroots CDC. We combined the results of expert consultation, and finally, the initially determined input indicators have 3 categories and a total of 17 indicators, and the output indicators have 2 categories and a total of 7 indicators. See Table 1.

Table 1 Evaluation Index Set of Operational Efficiency of CDC Laboratory at the Basic Level

Category		Index
Input		
Manpower	Number of people	X1 Total staff
		X2 Number of staff with establishment
		X3 Number of laboratory inspectors
	Human structure	X4 Number of inspectors for middle and high professional titles
		X5 Number of inspectors with bachelor degree or above
		X6 Comprehensive quality of laboratory inspectors
Financial resources	Institutional investment	X7 Total fixed assets of the institution
		X8 The total amount of institutional special funds
		X9 Personnel expenses
	Laboratory costs	X10 Laboratory investment
		X11 Actual laboratory use cost
Material resources	Building scale	X12 Total surface area
		X13 Laboratory building area
		X14 Ratio of laboratory area to total area
	Equipment scale	X15 Number of equipment in the laboratory above 10,000 yuan

	X16 Number of effective equipment in laboratory
	X17 Number of laboratory verifications or calibrations
Output	
Inspection ability	Y1 Proportion of public function projects that should be carried out
	Y2The extent of public function projects that have been carried out
	Y3 Completion of public function projects
Test result	Y4 Number of laboratory test samples
	Y5 Number of test reports issued
	Y6 Laboratory test report ratio
	Y7 Emergency degree of satisfaction

Note: Comprehensive quality of inspectors = ratio of inspectors with medium and high professional titles * ratio of inspectors with bachelor degree or above；The proportion of public function projects that should be carried out = the number of public function projects that can be carried out / the number of public function projects that should be carried out; The proportion of public function projects that have been carried out = the number of public function projects actually carried out/the number of public function projects that are capable of carrying out; Completion of public function projects = the degree of public function projects that have been carried out * the proportion of public function projects that should be carried out; Laboratory test report ratio = number of test reports issued/number of laboratory test samples.

Initial screening index

In accordance with the principle of simplification of indicators, the correlation analysis of input and output indicators is carried out. An indicator from each category of the evaluation indicator candidate data set is selected as a typical indicator and included in the DEA evaluation model for the operation efficiency of the grassroots CDC laboratory. R_i^2 and CV (coefficient of variation, the greater the sensitivity, the higher the sensitivity) is the representativeness of the index and the sensitivity to select the evaluation index[29, 30].After reclassification, the sumR_i^2 and CV value of each category evaluation index are shown in Table 2 and Table 3. The input indicators with better effects selected according to the above methods include 6 indicators: X3, X4, X7, X10, X13, and X16, and output indicators include 3 indicators, including Y3, Y4, and Y5. See Table 2 and Table 3.

Table 2 R_i^2 value and CV value statistics table of various input indicators

Category	Index	$R(X_i)^2$	CV	Category	Index	$R(X_i)^2$	CV
Number of people	X3	0.471	0.812	Laboratory costs	X11	0.409	1.088
	X1	0.448	0.662		X10	0.396	1.536
	X2	0.378	0.603	Building scale	X12	0.331	0.508
Human structure	X4	0.506	0.989		X13	0.288	0.623
	X5	0.466	0.844		X14	0.127	0.349
	X6	0.044	0.520	Equipment scale	X16	0.256	0.754
Institutional investment	X7	0.398	1.215		X15	0.228	1.432
	X9	0.378	1.076		X17	0.196	1.474
	X8	0.223	2.067				

Table 3 R_i^2 value and CV value statistics table of various output indicators

Category	Index	$R(Y_i)^2$	CV	Category	Index	$R(Y_i)^2$	CV
Inspection ability	Y3	0.243	0.385	Test result 1	Y4	0.134	1.107

Y1	0.161	0.264		Y6	0.078	0.820
Y2	0.126	0.217	Test result 2	Y5	0.041	1.301
				Y7	0.025	0.395

In order to further measure the rationality of the evaluation index, cluster analysis is used to cluster the evaluation index candidate data set.The cluster analysis result is compared with the correlation analysis result, and a more appropriate laboratory operation efficiency evaluation index is comprehensively selected[31]. (Figure 1, Figure 2).

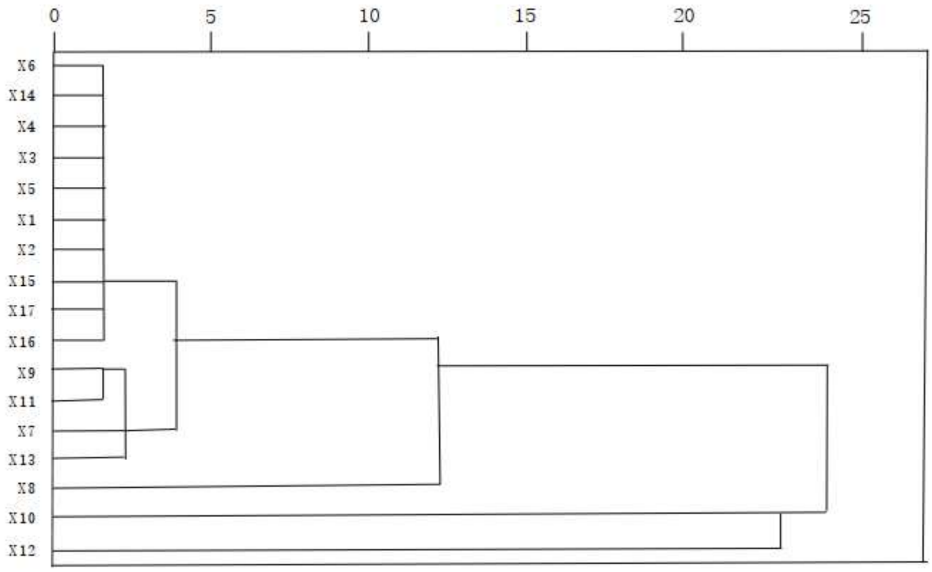

Fig.1 Cluster tree diagram of input indicators

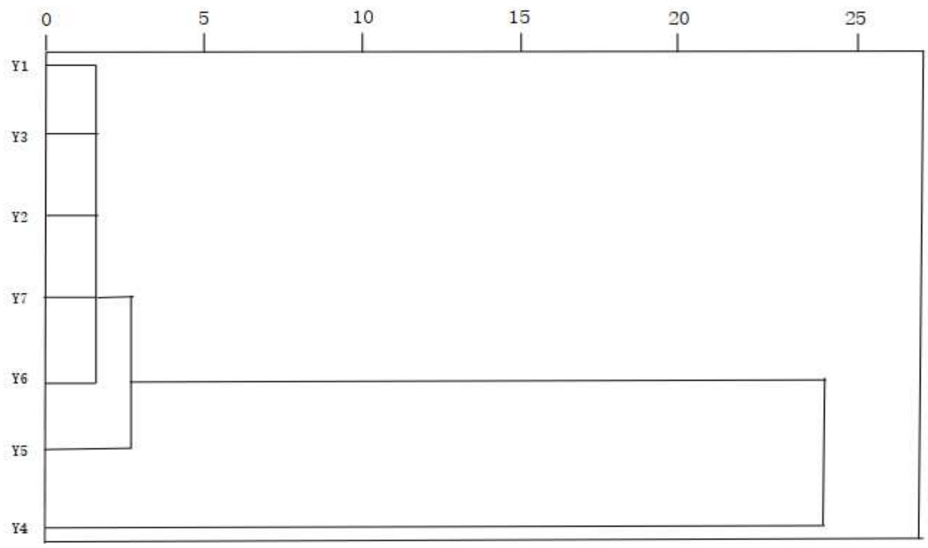

Fig.2 Cluster tree diagram of output indicators

Determine the index

With reference to the data results of association analysis and cluster analysis, and based on the principle that the evaluation indicators need to be "realistically meaningful and able to reflect the actual situation".The final input and output indicators for laboratory operation efficiency evaluation are six input indicators. 3 output indicators. See Table 4.

Table 4 Evaluation indicators for the final operating efficiency of primary CDC laboratories

Category	Number	Index
Input	X3	Number of laboratory inspector
	X4	Number of inspectors for middle and high professional titles
	X7	Total fixed assets of the institution
	X10	Laboratory investment
	X13	Laboratory building area
	X16	Number of effective equipment in laboratory
Output	Y3	Completion of public function projects
	Y4	Number of laboratory test samples
	Y5	Number of test reports issued

Operational efficiency results

Sample description method

In order to facilitate subsequent statistical analysis and result display, we assign values to the sample CDC laboratories and operational efficiency evaluation indicators respectively. Taking into account the confidentiality and security of the CDC, we will not display the CDC name, so the assignment situation is: Anhui There are a total of 5 sample CDC laboratories in the province, denoted by Ai; a total of 6 sample CDC laboratories in Guangdong Province, denoted by Gi; a total of 8 sample CDC laboratories in Sichuan Province, denoted by Si; a total of 6 investment indicators, denoted by Xi. There are 3 output indicators, denoted by Yi.

Overall operating efficiency

The DEA model was used to evaluate the operating efficiency of China's grassroots CDC laboratories. The results found that from 2017 to 2019, the TE of China's grassroots CDC laboratories were 0.836, 0.766, 0.765, PTE was 0.973, 0.920, 0.920, and SE was 0.852, 0.832, 0.833. The TE of the primary CDC laboratories in the three provinces of China is at the upper-middle level, but the overall trend is a slight downward trend, with slight decreases in TE, PTE and SE. In terms of Returns to scale (RS), from 2017 to 2019, the number of units with constant returns to scale in grassroots CDC laboratories are 11, 8, and 7, the number of units with Increasing Returns to scale (INS) are 3, 3, and 4, and the number of units with Decreasing Returns to scale (DRS) is 5. 8. 8, More and more grassroots CDC laboratories began to show a downward trend in their returns to scale. (Table 5, Table 6, Table 7)

Table 5 Operational efficiency results of China's grassroots CDC laboratories in 2017

Province	DMU	TE	PTE	SE	RS	Province	DMU	TE	PTE	SE	RS
A	A1	1	1	1	-		G6	1	1	1	-
	A2	1	1	1	-	S	S1	1	1	1	-
	A3	1	1	1	-		S2	0.572	0.962	0.595	DRS
	A4	1	1	1	-		S3	0.655	1	0.655	DRS
	A5	0.767	1	0.767	IRS		S4	0.818	0.832	0.983	IRS

G	G1	0.962	1	0.962	IRS		S5	1	1	1	-
	G2	1	1	1	-		S6	0.307	0.821	0.374	DRS
	G3	1	1	1	-		S7	0.256	0.869	0.294	DRS
	G4	0.554	1	0.554	DRS		S8	1	1	1	-
	G5	1	1	1	-		Mean	0.836	0.973	0.852	

Table 6 Operational efficiency results of China's grassroots CDC laboratories in 2018

Province	DMU	TE	PTE	SE	RS	Province	DMU	TE	PTE	SE	RS
A	A1	1	1	1	-		G6	0.684	1	0.984	IRS
	A2	1	1	1	-	S	S1	1	1	1	-
	A3	1	1	1	-		S2	0.620	1	0.620	DRS
	A4	1	1	1	-		S3	0.713	1	0.713	DRS
	A5	0.748	1	0.748	IRS		S4	0.374	0.375	0.998	DRS
G	G1	0.963	1	0.963	IRS		S5	0.377	0.426	0.885	DRS
	G2	0.953	1	0.953	DRS		S6	0.321	0.783	0.411	DRS
	G3	1	1	1	-		S7	0.262	0.901	0.291	DRS
	G4	0.554	1	0.554	DRS		S8	1	1	1	-
	G5	1	1	1	-		Mean	0.766	0.920	0.832	

Table 7 Operational efficiency results of China's grassroots CDC laboratories in 2019

Province	DMU	TE	PTE	SE	RS	Province	DMU	TE	PTE	SE	RS
A	A1	1	1	1	-		G6	1	1	1	-
	A2	1	1	1	-	S	S1	0.791	0.991	0.798	drs
	A3	1	1	1	-		S2	0.706	1	0.706	DRS

	A4	1	1	1	-	S3	0.665	0.985	0.676	DRS
	A5	0.858	1	0.858	IRS	S4	0.449	0.451	0.994	IRS
G	G1	0.909	1	0.909	IRS	S5	0.386	0.449	0.859	DRS
	G2	0.859	1	0.859	DRS	S6	0.325	0.887	0.367	DRS
	G3	0.813	0.818	0.994	IRS	S7	0.255	0.905	0.282	DRS
	G4	0.533	1	0.533	DRS	S8	1	1	1	-
	G5	1	1	1	-	Mean	0.765	0.920	0.833	

From a regional perspective, from 2017 to 2019, the operating efficiency of grassroots CDC laboratories in different regions is quite different. The operating efficiency of grassroots CDC laboratories in Anhui Province is the best, followed by Guangdong Province, and the operating efficiency of grassroots CDC laboratories in Sichuan Province is the most efficient. The data shows that from 2017 to 2019, the TE, PTE and SE of the grassroots CDC in Guangdong Province have always been the highest among the three provinces, and the technical efficiency value of Anhui Province has always been 1 in the past three years. The overall efficiency of the grassroots CDC in Sichuan has been showing a clear downward trend. And it is always the lowest among the three provinces. By 2019, the TE of the grassroots CDC in Sichuan Province will reach the lowest point at 0.572, which is only slightly higher than 0.5. In terms of PTE and SE, it is also at the lowest level. This shows that geographical location and economic level will still cause differences in the efficiency of grassroots CDC operations. See Table 8.

Table 8 Average efficiency of primary CDC laboratories in 3 provinces in China (2017-2019)

Age	Province	TE	PTE	SE
2017	A	0.953	1	0..953

	G	0.919	1	0.919
	S	0.701	0.934	0.738
2018	A	0.945	1	0.945
	G	0.919	1	0.919
	S	0.583	0.811	0.740
2019	A	0.972	1	0.972
	G	0.852	0.967	0.883
	S	0.572	0.834	0.710

Projection analysis

A projection analysis of ineffective grassroots CDC laboratories found that, as a whole, in 2017-2019, although China's grassroots CDC laboratories have a good overall utilization of input resources, there are still mild resource surplus problems, mainly concentrated. Mainly the number of inspectors with intermediate and senior professional titles and the fixed assets of the laboratory. The output indicator projection results show that there is a serious output shortage in the output of grassroots CDC laboratories from 2017 to 2019. Among them, the output of Y3 (Completion of public function projects) is relatively good, but the output of Y4 Number of laboratory test samples) and Y5 (Number of test reports issued) has serious shortcomings. The data shows that the difference ratios of Y3, Y4, and Y5 in my country's grassroots CDC laboratories in 2017 were 1.1, 6.8, and 2.1; in 2018, they were 1.0, 9.4, and 3.3; in 2019, they were 0.9, 3.9, and 2.7. (Table 9)

Table 9 Overall projection analysis of China's ineffective grassroots CDC laboratories (2017-2019)

Category	X3	X4	X7	X10	X13	X16	Y3	Y4	Y5
2017									

Actual value	113.0	65.0	17226.0	24444.4	15409.0	1466.9	4.8	80965.0	13007.4
Target value	98.4	36.2	7833.8	11513.6	11349.6	1322.9	10.3	632530.9	40809.2
Difference	-14.6	-28.8	-9392.2	-12930.8	-4059.4	-144.0	5.5	551565.9	27801.8
Average difference	-1.8	-3.6	-1174.0	-1616.4	-507.4	-18.0	0.7	68945.7	3475.2
Difference ratio	0.1	0.4	0.5	0.5	0.3	0.1	1.1	6.8	2.1
2018									
Actual value	164.9	188.0	23915.0	51785.4	21716.3	1797.0	6.4	118845.3	17564.0
Target value	118.6	47.9	11387.9	16624.7	14029.2	1578.2	12.7	1231715.3	75552.1
Difference	-46.3	-140.1	-12527.1	-35160.7	-7687.1	-218.8	6.3	1112870.0	57988.1
Average difference	-4.2	-12.7	-1138.8	-3196.4	-698.8	-19.9	0.6	101170.0	5271.6
Difference ratio	0.3	0.7	0.5	0.7	0.4	0.1	1.0	9.4	3.3
2019									
Actual value	184.0	88.0	22413.1	64128.7	22238.2	1918.0	7.3	107765.0	20355.0
Target value	121.9	40.6	10266.8	21135.8	17955.1	1624.3	13.8	531917.6	75949.3
Difference	-62.1	-47.4	-12146.3	-42992.9	-4283.1	-293.7	6.5	424152.6	55594.3
Average difference	-5.2	-3.9	-1012.2	-3582.7	-356.9	-24.5	0.5	35346.0	4632.9
Difference ratio	0.3	0.5	0.5	0.7	0.2	0.2	0.9	3.9	2.7

Note: Difference ratio = difference /actual value

In terms of different regions, comparing the input and output resource utilization of non-effective grassroots CDC laboratories, it is found that from 2017 to 2019, the grassroots CDC laboratories in Guangdong Province are located at X7 (Total fixed assets of the institution) and X10 (Laboratory investment). Has a more serious over-resource situation. The X13 (Laboratory building area) in Anhui and Sichuan provinces have a higher over-resource situation than Guangdong Province; in terms of output, the under-output of non-effective grassroots CDC laboratories in Guangdong Province is much smaller than that in Anhui Province. The ineffective grassroots CDC laboratories in Sichuan Province and Sichuan Province, especially Y3 (Completion of public function projects) and Y4 (Number of laboratory test samples), have the most serious output shortages. From the data point of view, 2017-2019, In Anhui, the difference ratios of Y3 and Y4 of the grassroots CDC laboratories in the province are 20.7 and 10.9, 24.6 and 20.2, 11.1 and 189.7. The difference ratios of the grassroots CDC laboratories in Sichuan Province in Y3 and Y4 are 12.1 and 1.6, 17.4 and 189.7, respectively. 4.5, 7.9, and 2.9, while the difference ratio of Y3 and Y4 of Guangdong's grass-roots CDC laboratory is only less than 3.0. The overall description is that Guangdong's grass-roots CDC resources have excessive input and the output is relatively good, and the grass-roots CDC input resources in Anhui Province are relatively Reasonable, but the amount of output is insufficient. The grassroots CDC in Sichuan has a slight surplus of input resources and insufficient output. (Table 10)

Table 10 Segmented projection analysis of China's ineffective grassroots CDC laboratory (2017-2019)

Category		X3	X4	X7	X10	X13	X16	Y3	Y4	Y5
2017										
A	Average difference	-1.0	0.0	-146.4	-392.8	-721.9	0.0	0.1	24567.0	960.7
	Difference ratio	0.3	0.0	0.5	0.6	0.7	0.0	0.3	20.7	10.9
G	Average difference	0.0	-4.3	-2148.1	-3404.4	-198.1	0.0	0.3	36093.8	1659.0
	Difference ratio	0.0	0.5	0.6	0.7	0.2	0.0	0.5	1.7	1.9

S	Average difference	-2.7	-4.0	-990.0	-1145.8	-588.3	-28.8	0.9	90962.3	4704.6
	Difference ratio	0.2	0.4	0.5	0.4	0.2	0.1	1.4	12.1	1.6
2018										
A	Average difference	-0.7	0.0	-11.6	-35.0	-287.7	0.0	0.1	23701.9	1230.6
	Difference ratio	0.2	0.0	0.0	0.1	0.3	0.0	0.3	24.6	20.2
G	Average difference	-5.9	-30.9	-2357.8	-6230.6	-323.7	-6.0	0.2	46281.4	2599.5
	Difference ratio	0.4	0.9	0.6	0.8	0.2	0.1	0.4	2.8	1.3
S	Average difference	-3.7	-2.8	-514.1	-1700.5	-1017.4	-32.5	0.9	150673.8	7726.6
	Difference ratio	0.2	0.3	0.4	0.5	0.4	0.1	1.4	17.4	4.5
2019										
A	Average difference	-0.5	0.0	-307.5	0.0	-291.9	-0.6	0.0	8057.6	6450.9
	Difference ratio	0.1	0.0	0.5	0.0	0.3	0.0	0.0	11.1	189.7
G	Average difference	-9.5	-6.5	-564.9	-8911.5	-9.9	-0.7	0.3	20171.5	1940.5
	Difference ratio	0.6	0.7	0.5	0.9	0.0	0.0	0.4	1.2	1.3
S	Average difference	-3.3	-3.1	-1100.0	-1049.6	-564.5	-48.3	0.7	42915.6	5911.6
	Difference ratio	0.2	0.4	0.5	0.3	0.2	0.2	1.2	7.9	2.9

Note: Difference ratio = difference /actual value

Malmquist index analysis

Through Malmquist index analysis, it is found that from 2017 to 2019, the Total Factor Productivity (TFP) of China's grassroots CDC laboratories has gradually declined, and the technical level and management efficiency have declined, and the work capabilities of grassroots CDC laboratories have not been effectively improved. The data shows that the total factor productivity index of the grassroots CDC central laboratory in 2019 was 0.905, a decrease of 9.5 percentage points compared to 2017. At the same time, Technical Change (TC) and Technical Efficiency Change (TEC) also showed a downward trend, falling by 4.8 % and 5.0% respectively.

Looking at it in stages, between 2017 and 2019, the TFP of China's grassroots CDC laboratories declined first and then increased, but the increase was not as fast as the decrease. The data shows that from 2017 to 2018, the TFP of 19 grassroots CDC laboratories was 0.800, a decrease of 20 percentage points. At the same time, the TC and TEC indexes also dropped by 9.5% and 11.6%, respectively. From 2018 to 2019, The TEP of CDC laboratories at the grass-roots level is on the rise, and the technical level and management efficiency have been improved. The TEP of the year was 1.024, an increase of 2.4 percentage points, and TC and TEC increased by 0.2% and 2.2%, respectively. But the degree of increase is still not as good as the degree of decline, and the overall numbers of TFP, TC and TEC are still decreasing. (Table 11)

Table 11 Malmquist index results of China's grassroots CDC laboratories (2017-2019)

Age	TFP	TC	TEC	PEC	SEC
2017-2018	0.800	0.905	0.884	0.994	0.889
2018-2019	1.024	1.002	1.022	1.037	0.985
2017-2019	0.905	0.952	0.950	1.016	0.936

Discussion

The overall operating efficiency of CDC laboratories at the grassroots level has declined, and the problem of uneven regional development is serious

We found that from 2017 to 2019, the operating efficiency of grassroots CDC laboratories was at a medium-to-high level, but from the perspective of development trends, the overall decline. This shows that the effective utilization of input resources in grassroots CDC laboratories has been declining during the past three years, and the working capacity of grassroots CDC laboratories has not been effectively improved. In addition, we also found that there is a serious regional development imbalance in the development of grassroots CDC laboratory operating efficiency. The operating efficiency value of grassroots CDC laboratories in the western region is only slightly higher than 0.5, and the laboratory operating efficiency is relatively not high. It is much lower than the grassroots CDC laboratories in the central and eastern regions. Western China is at a disadvantage in terms of economic level and geographic location. Differences in economic level and regional geographic location will affect the operating efficiency of grassroots CDC laboratories[32]， Problems such as economic backwardness, wide jurisdiction and inconvenient transportation will all cause western regions. The basic-level CDC laboratories are difficult to work, and the actual output is difficult to compare with the central and eastern regions, and it is difficult to effectively use the input resources. This reminds us that when improving the operating efficiency of a country's grassroots CDC laboratories, we should comprehensively consider the economic development level and geographical conditions of the region where the grassroots CDC laboratories are located, and provide appropriate policy and economic support for these poorly located grassroots CDC laboratories.

The grassroots CDC laboratory has the problem of unreasonable resource utilization and serious shortage of actual output

Through further analysis, we found that among the output results of grassroots CDC laboratories, the output of Completion of public function projects is the best, indicating that China's grassroots CDC laboratories already have sufficient laboratory testing capabilities and can complete the corresponding testing. Ability to perform inspection tasks[33]， but China’s grassroots CDC laboratories have not reached the maximum output without increasing input without increasing input, and there is a serious shortage of output, especially in the number of samples tested in the laboratory. On the one hand, the difference ratio is as high as 9.4. If the actual output can reach the target value, the operating efficiency of China's grassroots CDC laboratories can be further improved and play a greater role. According to the analysis results, most of the grassroots CDC institution laboratories are ineffective, which indicates that the resource utilization of most basic-level CDC institution laboratories is unreasonable and the resource utilization conversion rate is low. This reminds us that when improving the operating efficiency of grassroots CDC laboratories, we should rationally allocate and use input resources, give full play to the capabilities of a country's grassroots CDC laboratories, comprehensively improve the effective work output of grassroots CDC laboratories, and improve grassroots CDC laboratory operation efficiency.

Laboratory technical level and management efficiency need to continue to improve

Technical level and management efficiency are two key factors in the process of improving laboratory operation efficiency[34, 35]， The study found that China's grassroots CDC laboratories had insufficient development of laboratory technology and management efficiency during 2017-2019. To a certain extent, it has affected the improvement of the operation efficiency of the grassroots CDC laboratory. Improving the technical level and improving the management efficiency is very important for the operation efficiency of the grassroots CDC laboratory. Through the introduction of highly educated professional talents, increase opportunities for personnel to go out for training, etc., through the improvement of personnel technical and management capabilities, the laboratory technology level and management efficiency can be promoted.

Conclusion

Based on the DEA method, this study accurately evaluated the operating efficiency of China's grassroots CDC laboratories from 2017 to 2019 through rigorous concept definition and evaluation index screening, and learned about the development of operating efficiency of China's grassroots CDC laboratories in recent years. And it was found that there were in sufficient development of operational efficiency, unbalanced regional development, unreasonable use of resources, insufficient actual output, and the need to improve laboratory technology and management efficiency in the development of grassroots CDC laboratories. This may also be the present There are important problems in the development of CDC laboratories in various countries around the world, which help us understand the current development status of grassroots CDC laboratories, underdevelopment issues, and help decision makers to more clearly improve the operating efficiency of grassroots CDC laboratories, so as to further improve the grassroots CDC Level of public health security assurance capabilities.

Limitation

First of all, this is only a preliminary study on the evaluation of the operation efficiency of China's grassroots CDC laboratories. Taking China as an example, a small-scale evaluation has been carried out using the DEA method. Future research can expand the scope of research and increase the grassroots CDC laboratories in other provinces in China. To increase the representativeness of the research. Secondly, the definition of the concept of operating efficiency and the evaluation indicators determined around this concept have yet to be improved by researchers in the future to better and more accurately evaluate the efficiency of laboratory operations.

Abbreviations

BBC: R.D.Banker、A.Charnes、W.W.Cooper; **CCR：** A.Charnes、W.W.Cooper、E.Rhodes; **CDC：** Center for Disease Control and Prevention; **DEA：** Data envelopment analysis; **DMU:** Decision making units; **DNS:** decreasing returns to scale; **INS:** increasing returns to scale; **PEC:** Pure technical efficiency change; **PTE:** Pure Technical Efficiency Score；**RS:** Returns to scale; **SE**: Scale efficiency; **SEC:** Scale efficiency change; **TE:** Technical Efficiency Score; **TFP：** Total factor productivity; **TC:** Technology Change; **TEC：** Efficiency Change.

Declarations

Ethics approval and consent to participate

Ethics approval for the study protocol was obtained from the Ethics Committee of Harbin Medical University. Informed consent was obtained from all participants before the start of the survey. The Ethics Committee of Harbin Medical University approved the procedure for obtaining informed consent. All methods were carried out in accordance with relevant guidelines and regulations.

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Authors' contributions

ZK and XNH contributed to the research and design. ZL, YHZ and SMZ led the research data. YLL, GMT and BKZ completed research, data interpretation and writing manuscripts. YZ and HXW assists in research design, acquisition, and analysis. TZ and HYZ helps in data interpretation and manuscript writing. All authors critically reviewed and revised the manuscript, and approved the final manuscript.

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Availability of data and materials

The data that support the findings of this study are available from China National Health Development Research Center, managed by China National Health Development Research Center, but the availability of these data is managed. According to management requirements, the research data contains detailed data of each CDC. Can't be made public. The corresponding author can generate data that meets the requirements according to reasonable requirements and with the permission of China National Health Development Research Center, and provide it to qualified researchers, China National Health Development Research Center.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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Figures

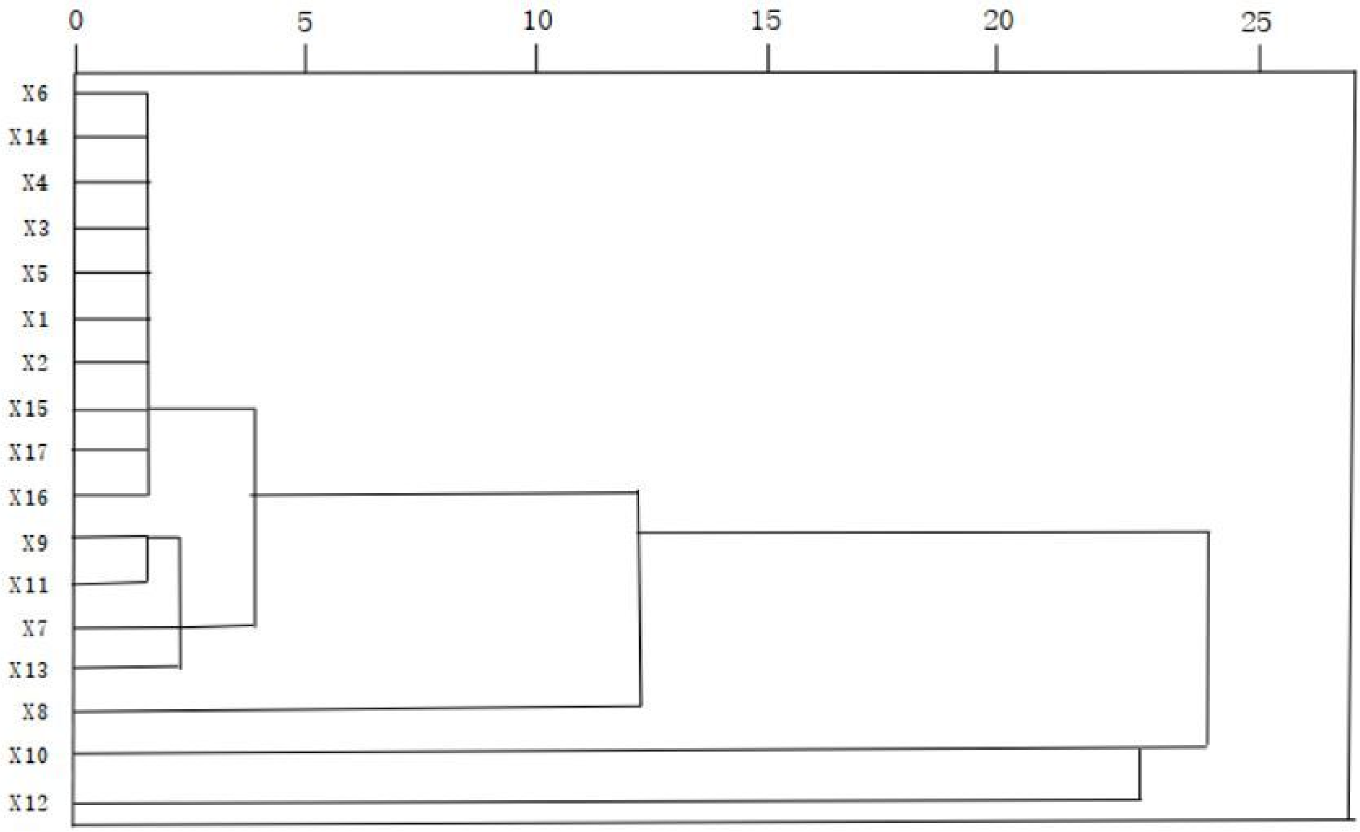

Figure 1

Cluster tree diagram of input indicators

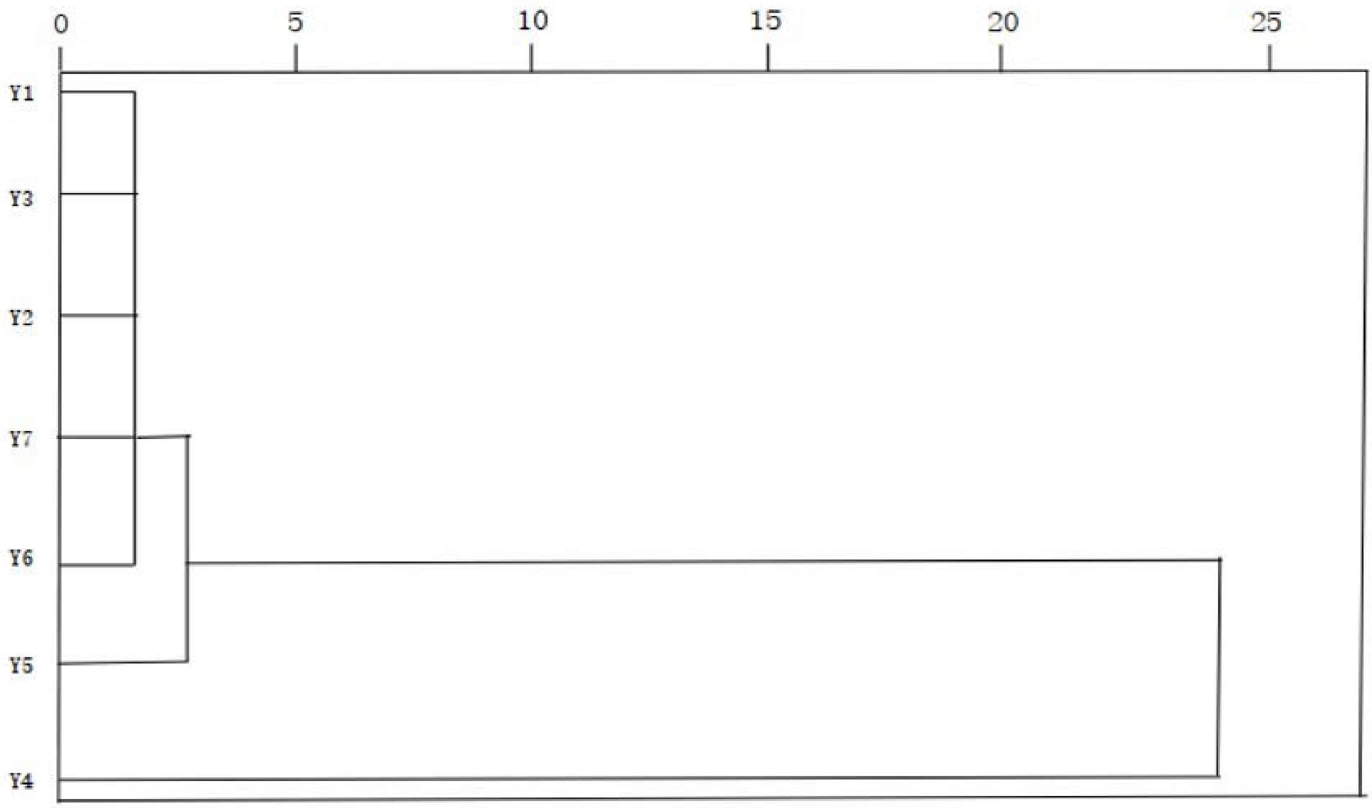

Figure 2

Cluster tree diagram of output indicators