The Technical Efficiency of Essential Public Health Services Provision in China: Based on a Panel Data Analysis

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The technical efficiency of essential public health services provision in China: based on a panel data analysis

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Declarations

- Ethics approval and consent to participate

  Not applicable.

- Consent for publication

  Not applicable.

- Availability of data and materials

  The datasets generated and/or analysed during the current study are not publicly available due [REASON WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.

- Competing interests

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- Authors' contributions

  Fankun Cao's work included conceptualization, data curation, formal analysis, methodology, resources, software, validation, visualization, writing-original draft, writing-review & editing.

  Yan Xi's work included conceptualization, project administration, supervision, writing-review & editing.

  Tongyu Bai's work included data curation, investigation.

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  Qiang Sun's work included conceptualization, data curation, project administration, supervision, visualization, writing-review & editing.

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Abstract

Background

Providing essential public health services equally to all Chinese is one of the objectives of health system reform since 2009. Essential public health service program is to provide a package of public health services for all Chinese freely by the primary health institutions. Since the implementation of the national essential public health service program, the level of funding and the intensity of input have been continuously increasing. However, in the context of China's economic development entering a new normal phase, the growth rate of funding for essential public health services has far exceeded the growth rate of GDP and central fiscal revenue, and the sustainability of the development of national essential public health service programs has been seriously challenged. Improving the efficiency of resource use may be an effective way to ensure the continuation of the national essential public health service program. But little evidence was available about technical efficiency in essential public health services provision. Therefore, the aim of this study was to assess the technical efficiency of essential public health services in Shandong province.

Methods

This study was a retrospective study based on the historical panel data of Shandong Province, East China. The data came from the Shandong Provincial Essential public health Service Program Database of the Medical Management Center of Shandong

Provincial Health Commission, which covered all 137 counties and districts in 16 cities of Shandong Province from 2014 to 2019. The principal component analysis method was used to classify multiple output indicators of essential public health service programs, so as to achieve the purpose of generic index extraction. The efficiency coefficient transformation analysis method was used to transform the data of each principal component score after the principal component analysis of the input index of essential public health service programs. The CCR model and BBC model in the Data Envelopment Analysis（DEA）method were used to calculate the comprehensive technical efficiency, pure technical efficiency and scale efficiency of essential public health services.

Results

The average comprehensive technical efficiency of essential public health services in Shandong Province showed a slight downward trend from 0.8896 in 2014 to 0.8753 in 2019. The average pure technical efficiency of essential public health services was kept at 0.99. The average scale efficiency of essential public health services showed a slight downward trend from 0.8871 in 2014 to 0.8744 in 2019. The proportion of counties and districts with the comprehensive technical efficiency of essential public health services in Shandong Province was increased from 15.3% in 2014 to 21.9% in 2019. But the proportion of counties with the pure technical efficiency decreased from 38.0% in 2014 to 35.9% in 2019. The proportion of counties with scale efficiency of essential public health services showed an upward trend, rising from 14.8% in 2014 to 22.6% in 2019, increasing by 7.8%.

The ratio of effective comprehensive technical efficiency of essential public health services in Shandong Province to all counties and districts has shown a upward trend. Among them, the proportion of counties with effective pure technical efficiency was higher than the proportion of counties with efficient scale efficiency each year. At the same time, the increase in the proportion of counties with effective scale efficiency was higher than the increase in the proportion of counties with effective pure technical efficiency. The increasing proportion of effective counties in the comprehensive technical efficiency of essential public health services in Shandong Province was mainly due to the increasing proportion of effective counties in the scale efficiency and the good performance of effective counties in the pure technical efficiency. This showed that, although the investment scale of Shandong Province in the counties was gradually sufficient, there was still a phenomenon of insufficient resource investment in most counties. That would ultimately affect the sustainability of the implementation of essential public health services.

Conclusion

The research have demonstrated that the technical efficiency of essential public health services in Shandong Province has shown a slight downward trend, and the main reason for its downward trend was the decline in scale efficiency. The scale efficiency in essential public health services affected the technical efficiency and would ultimately threaten the sustainable development of essential public health services. It is recommended that future research directions should focus on the influencing factors and improvement measures of the scale efficiency of essential public health services.

1 Introduction

The essential public health services (abbreviated as EPHS in the following) are public service products determined by the government based on the priority of the main health problems that endanger the country and citizens in a specific period, as well as the country's available funding and service capacity [1]. EPHS are of great significance to improving the health of residents and narrowing the gap of residents' health status [2-3]. The national essential public health service program is one of the five major contents of deepening medical reform and a major measure to implement the strategy of "Healthy China" in the new era [4]. Essential public health service program is a non-profit health service program freely provided by the government and implemented by the primary health care institutions to children, pregnant women, the elderly and patients with chronic diseases as the key groups

[5]. The program is a national public health intervention program with the broadest coverage, the largest service population and the highest investment since the founding of the People's Republic of China [6-8].

Since the implementation of the national essential public health service program, the service funds have been provided in the form of fully public financing by governments at all level, and the funding and the intensity of input have been continuously increasing. The ever-increasing investment of public health funds showed that the government attached great importance to public health undertakings, and also provided financial guarantee for the promotion of essential public health service programs [9]. The level of funding has increased from 15 Yuan per capita in 2009 to 74 Yuan per capita in 2020, and funding has increased nearly five times in ten years. Over the past 11 years since the implementation of the national essential public health service program, the accumulated financial investment was over 300 billion Yuan by governments at all levels [10]. The central government has subsidized a total of 169.2 billion Yuan in subsidies, accounting for 55% of the all levels governments' financial investment [11]. In 2020, the COVID-19 epidemic occurred with the fastest transmission rate, the widest scope of infection and the most difficulty in prevention and control since the founding of the People's Republic of China. The state has paid more attention to EPHS, raised funding standards, and released nearly 85% of the subsidy funds in advance. The central budget for EPHS totaled 60.33 billion Yuan in 2020, an increase of 79.4% compared to 33.63 billion Yuan in 2016 and an increase of 61.1% compared to 37.45 billion Yuan in 2017.

However, on the basis of scientific analysis of domestic and foreign economic development situation, the Party Central Committee elaborated on China's entry into the "new normal of economic development" stage [12-14]. The sustainability of the development of national essential public health service programs has become an issue worthy of consideration [15-16]. Improving the efficiency of allocation and utilization of essential public health service input resources has become the focus of the country's future work in this field [17]. According to the National Bureau of Statistics report, the GDP growth rate in 2020 was 2.3% year on year, which was 5 percentage points lower than the 7.3% in 2014, showing a downward trend. The growth rate of central fiscal revenue in 2020 was -3.9% year on year, which was a decrease of 12.5 percentage points from 8.6% in 2014, showing an obvious downward trend.

The sustainability of national EPHS will be seriously challenged if the previous investment trend is unrealistic after the national economic development has entered the new normal [18]. Therefore improving the efficiency of health resource utilization have become possible effective ways to ensure the sustainable development of national essential public health service programs [19-23].

What is the current situation of technical efficiency of EPHS provision? This question is an important issue that policy makers, practitioners and academic researchers pay close attention to, and it has become an important problem that needs to be solved in theory and practice in the implementation of national essential public health service program [24-25].

It is necessary and urgent to study the efficiency of national essential public health service in theory and practice [26-29]. From the perspective of health economics, this study used metrological methods, taking Shandong Province as an example, to study the status quo of essential public health service technical efficiency. Our research provided objective basis and theoretical guidance for the adjustment of relevant policies and work practices of the national essential public health service projects in the next step.

2 Methods

This study was conducted in Shandong Province, East China. There are 16 cities, 137 counties (districts) in Shandong Province. The permanent residents was 100 million (7.2% of the total population in the Chinese mainland), the proportion of urban population and rural population in the province was comparable, and the population ranked second in the country by 2020. Shandong's gross domestic product (GDP) was 7.31 trillion Yuan (about $1.12 trillion). Shandong was a microcosm of China in terms of population and economic development. (China National Bureau of Statistics, 2020) .

2.1 Data source

The Shandong Provincial Essential Public Health Service Program Database covered all 137 counties and districts in 16 cities of Shandong Province from 2014 to 2019. The database was filled in and reported by the primary medical institutions in 16 cities of Shandong Province on an annual basis, reflecting the essential public health service programs in the district county-level in accordance with the annual county level. The database is reviewed by the health administrative departments at all levels and finally summarized and reported.

The key indicators of essential public health service program database were shown in Table 1. It included 24 indicators of 13 types of service contents.

Table 1 The key indicators of essential public health service program

Types of Service Contents	**Key Indicator**	**Connotation of Key Indicators**
Health records management services for residents	Filing rate of health records (%)	Number of registered persons/number of permanent residents in the jurisdiction *100%
	Filing rate of electronic health records (%)	Number of residents with electronic health records/number of permanent residents in the jurisdiction *100%
	Utilization rate of health records (%)	Number of files with dynamic records in the files/the total number of files *100%
Health Education Services	Number of Health Education Talks (Number)	Number of Health Education Talks
	Number of Health Lectures Attended (Person)	Number of Health Lectures Attended
Vaccination Services	Certificate issuance rate (%)	Number of people who have established vaccination certificate in the annual jurisdiction/number of

		people who should have established vaccination certificate in the annual jurisdiction *100%
Health management services for children aged 0 to 6 years	Neonatal visit rate (%)	Number of newborns received once and visited by petition/number of live births in the jurisdiction in the year*100%
	Child health management rate (%)	Number of children aged 0 to 6 years old who received 1 or more follow-up visits in the annual jurisdiction/number of children aged 0 to 6 years old in the annual jurisdiction *100%
Maternal health management services	Early pregnancy enrollment rate (%)	Number of women registered before 13 weeks of gestation and having their first prenatal check-up in the area/number of live births in the area during that period *100%
	Postpartum visit rate (%)	Number of maternal people who have received postpartum visits 28 days after the birth of women in the jurisdiction / number of live births in the area during that time period *100%
Health management services for the elderly	Health management rate for the elderly (%)	Number of persons aged 65 or above receiving health management/number of permanent residents aged 65 or above in the jurisdiction within the year *100%
Health management services for hypertensive patients	Standard management rate of Hypertensive Patients (%)	Number of hypertension patients under health management according to the standard

		requirements/number of hypertension patients under management within the year *100%
	Blood pressure control rate of management population (%)	Number of patients whose blood pressure reached the target in the last follow-up within the year/number of patients with hypertension under management within the year *100%
Health management services for patients with type 2 diabetes	Standard management rate of patients with type 2 diabetes (%)	Number of patients with type 2 diabetes under health management according to the specification/number of patients with type 2 diabetes under management within the year *100%
	Glucose control rate of management population (%)	Number of patients with fasting blood glucose meeting the criteria in the last follow-up within the year/number of patients with type 2 diabetes under management within the year *100%
Management services for people with severe mental disorders	Standard management rate of patients with severe semen concentration (%)	Number of patients with severe mental disorders managed according to the standard requirements/number of patients with confirmed severe mental disorders registered in the jurisdiction within the year *100%
Tuberculosis patient health management services	Tuberculosis patient management rate (%)	Number of tuberculosis patients under management/number of tuberculosis patients confirmed by the medical institutions appointed by

		the superior and informed by the basic medical institutions for management in the same period in the jurisdiction *100%
	Regular drug taking rate in patients with tuberculosis (%)	Number of tuberculosis patients who took their medication as required/number of tuberculosis patients who completed treatment in the same period in the jurisdiction *100%
Traditional Chinese Medicine health management services	Traditional Chinese Medicine health management rate for the elderly (%)	Number of residents aged 65 and above receiving Traditional Chinese Medicine health management services/number of permanent residents aged 65 and above within the jurisdiction within the year *100%
	Traditional Chinese Medicine health management rate of children aged 0 to 36 months (%)	Number of children from 0 to 36 months who receive Traditional Chinese Medicine health management services in accordance with the monthly age in the jurisdiction / number of children from 0 to 36 months who should be managed in the jurisdiction *100%
Services for reporting and handling infectious diseases and public health emergencies	Reporting rate of infectious diseases (%)	Number of infectious disease cases reported online/number of registered infectious disease cases *100%
	Timely reporting rate of	Number of timely cases reported/number of

	infectious diseases (%)	infectious disease cases reported *100%
	Public health emergency information reporting rate (%)	Number of information related to public health emergencies reported in time/number of information related to public health emergencies reported *100%
Health and family planning supervision and coordination services	Health and Family Planning Supervision and Co-management Information Reporting Rate (%)	Number of incidents or clues reported/Number of incidents or clues found *100%

2.2 Data analysis

2.2.1 Selection and analysis methods of input and output indicators

There were certain basis for choosing the above input and output indexes in this study. Based on the relevant systems of EPHS and the actual implementation of EPHS, our research finally formulated the input and output indicators for measuring the technical efficiency of EPHS.

The input of EPHS mainly included three aspects, namely financial input （essential public health service subsidy funds）, human input （public health staff） and material input（material expenditure）. The output of EPHS included 24 indicators of 13 types of service contents（The 24 indicators was shown in Table 1）.

In order to make full and effective use of data, we conducted principal component analysis on the output indicators of EPHS. Through principal component analysis, a small number of principal components are summarized from the original variables of many basic public health service output indicators, so as to retain as much information of the original variables as possible to explain the internal structure of multiple variables [30-31]. Principal component analysis could simplify and reduce the dimensionality of basic public health service output indicators, revealing the profound internal laws of things more simply and intuitively [32-34].

Assuming that there are n cases of the original data collected, each case has the value of m indicators, and the original variables are denoted as x_1, x_2, …, x_m, then the specific steps of extracting principal components by using principal component analysis are as follows,

(1) Standardize the original index data

$$X_{ij} = \frac{x_{ij} - \overline{x_j}}{S_j}, \quad j=1,2,3,\cdots,m \tag{1-1}$$

X_{ij} is the data index after standardization, and X is the data matrix after standardization, then

$$X = \begin{pmatrix} X_{11} & X_{12} & \cdots & X_{1m} \\ X_{21} & X_{22} & \cdots & X_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ X_{n1} & X_{n2} & & X_{nm} \end{pmatrix} \tag{1-2}$$

(2) Calculate the correlation matrix R of X

The normalized covariance matrix of X, Cov (X) is

$$R = Cov(X) = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & & r_{nm} \end{pmatrix} = \begin{pmatrix} 1 & r_{12} & \cdots & r_{1m} \\ r_{21} & 1 & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & & 1 \end{pmatrix} \quad (1\text{-}3)$$

(3) Calculate the eigenvalues and eigenvectors of the matrix

From the characteristic equation of R

$$|R - \lambda I| = 0 \quad (1\text{-}4)$$

M non-negative eigenvalues are obtained, and they are arranged in order from the largest to the smallest

$$\lambda_1 \geqslant \lambda_2 \geqslant \lambda_3 \cdots \geqslant \lambda_m \geqslant 0 \quad (1\text{-}5)$$

According to

$$\begin{cases} (R - \lambda I)\alpha i = 0 \\ \alpha i \ \ \alpha i = 1 \end{cases} \qquad i=1,2,3,\cdots,m \quad (1\text{-}6)$$

Each eigenvalue λ_i corresponds to a unit eigenvector

$$\alpha_i = (\alpha_{i1}, \ \alpha_{i2}, \ \cdots, \ \alpha_{im}) \quad (1\text{-}7)$$

Thus the principal component can be obtained

$$Z_i = \alpha_i X = a_{il} X_1 + a_{12} X_2 + \cdots + a_{im} X_m \quad (1\text{-}8)$$

The principal component of the calculated result can describe the percentage of information carried by the original variable. When the extraction cumulative variance contribution rate is more than 80%, it is considered that the original information is basically retained, and it can be extracted as the main component [35-36].

The data operation of this method is realized by SPSS 20.0 software and Excel software.

2.2.2 Analysis methods for technical efficiency of EPHS

Under the guidance of Data Envelopment Analysis （DEA） that is the best constructed non-parametric efficiency measurement method so far. The efficiency of EPHS is measured, that is, based on multiple input indicators and multiple output indicators of EPHS, linear programming was used to evaluate the implementation of essential public health service programs. Through DEA, the technical efficiency of EPHS in all 137 counties and districts in Shandong Province from 2014 to 2019 can be obtained.

DEA requires that the total number of evaluation indexes should be less than half of the number of decision-making units [37]. In the production process of economic units, decision-making units usually have constant returns to scale and variable returns to scale. Therefore, these two situations should all be taken into consideration when studying the efficiency of decision-making units. The measurement models of efficiency of decision-making units are correspondently divided into two situations, namely CCR model and BBC model [38-39].

CCR model assumes Constant Returns to Scale (CRS), and the technical efficiency obtained by CCR model contains the components of scale efficiency, so it is often referred to as comprehensive technical efficiency. The nonlinear programming model of the CCR model is expressed as

$$\max \frac{\sum_{r=1}^{q} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$\text{s. t.} \quad \frac{\sum_{r=1}^{q} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leqslant 1$$

$$v \geqslant 0;\ u \geqslant 0$$

$$i=1,2,\cdots,m;\ r=1,2,\cdots,q;\ j=1,2,\cdots,n \qquad (1\text{-}9)$$

Then let u= tu and v= tv, so the nonlinear model (1-9) is transformed into an equivalent linear programming model

$$\max \frac{\sum_{r=1}^{q} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}}$$

$$\text{s. t.} \quad \sum_{r=1}^{q} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leqslant 0$$

$$\sum_{i=1}^{m} v_i x_{ik} = 1$$

$$v \geqslant 0;\ u \geqslant 0$$

$$i=1,2,\cdots,m;\ r=1,2,\cdots,q;\ j=1,2,\cdots,n \qquad (1\text{-}10)$$

The dual model of model (1-10) is

$$\min \ \theta$$

$$\text{s. t.} \quad \sum_{j=1}^{n} \lambda_j x_{ij} \leqslant \theta x_{ik}$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geqslant y_{rk}$$

$$\lambda \geqslant 0$$

$$i=1, 2, \cdots, m; \ r=1,2, \cdots, q; \ j=1,2, \qquad (1\text{-}11)$$

In the dual model (1-11), λ represents the linear combination coefficient of DMU, and the optimal solution θ of the model represents the efficiency value. The range of θ is (0,1].

The CCR dual model (1-11) measures the inefficiency to the extent that each input can be reduced in proportion to the given output, so it is called the input-oriented CCR model.

In actual production, many production units are not in the optimal scale production state, so the technical efficiency derived from the CCR model includes the scale efficiency component. In 1984, Banke, Charnes and Cooper proposed a DEA model for estimating scale efficiency, which was referred to as BCC model in subsequent literature [40]. The BCC model is based on Variable Returns to Scale (VRS), and the technical efficiency obtained excludes the influence of scale, so it is called "Pure Technical Efficiency" (PTE) [41-42].

The BCC model is based on the CCR dual model with additional constraints $\sum_{j=1}^{n}\lambda_j$ =1（λ≥0）, which can make the production scale of projection point in the same level as that of DMU evaluated [43].

$$\min\ \theta$$

$$\text{s. t.}\quad \sum_{j=1}^{n}\lambda_j x_{ij} \leqslant \theta x_{ik}$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} \geqslant y_{rk}$$

$$\sum_{j=1}^{n}\lambda_j = 1$$

$$\lambda \geqslant 0$$

$$i=1,2,\cdots,m;\ r=1,2,\cdots,q;\ j=1,2,\cdots,n \qquad (1\text{-}12)$$

The dual programming formula of BCC model (1-12) is as follows,

$$\max \sum_{r=1}^{s}u_r y_{rk} - u_0$$

$$\text{s. t.}\quad \sum_{r=1}^{q}u_r y_{rj} - \sum_{i=1}^{m}v_i x_{ij} - u_0 \leqslant 0$$

$$\sum_{i=1}^{m}v_i x_{ik} = 1$$

$$v \geqslant 0;\ u \geqslant 0;\ u_0 \text{ free}$$

$$i=1,2,\cdots,m;\ r=1,2,\cdots,q;\ j=1,2,\cdots,n \qquad (1\text{-}13)$$

This part of operation was realized by Max DEA 8 software and Excel software.

The DEA model requires that all data entering the model must be positive. This study adopted the method of power coefficient transformation analysis to transform the scores of each principal component of the output indicators to ensure that the values of subsequent DEA were positive.

If the principal component score was recorded as Z and the principal component score transformed by the efficiency coefficient method was recorded as X, then the conversion formula of the efficiency coefficient method is

$$X = 0.1 + 0.9\,\frac{(Z-\min Z)}{\max Z-\min Z} \qquad (1\text{-}14)$$

Min Z represents the minimum value of the principal component score, Max Z represents the maximum value of the principal component score, and X is within the interval of [0.1,1] [44-47].

The data operation of this method was realized by SPSS 20.0 software and Excel software.

2.2.3 Analysis method for technical efficiency trend of EPHS

After obtaining the efficiency (comprehensive technical efficiency, pure technical efficiency, and scale efficiency) of the EPHS in all 137 counties and districts in Shandong Province from 2014 to 2019, this study analyzed the efficiency trend over the six years. The analysis of the efficiency trend includes two parts, namely the trend analysis of the efficiency (comprehensive technical efficiency, pure technical efficiency, scale efficiency) and the trend analysis of the proportion of comprehensive technical efficiency effective counties.

The analysis method of the efficiency trend was to average the annual efficiency of 137 counties and districts to obtain the average annual efficiency of the province, and then analyze the trend of the efficiency of EPHS in Shandong Province from 2014 to 2019.

The analysis method for the trend of the proportion of counties with effective comprehensive technical efficiency was to calculate the proportion of counties with effective comprehensive technical efficiency in all 137 counties. After obtaining the annual proportion, the trend analysis of the proportion of counties and districts with effective technical efficiency of EPHS in Shandong Province from 2014 to 2019 was carried out.

2.3 Data quality control

Shandong Province summarized the statistical survey report of essential public health service programs with districts and counties as the main body, and the data reported by districts and counties were reviewed by users at provincial and municipal levels. City-level users review county-level users within their jurisdiction, and provincial-level users review city-level users within their jurisdiction. Provincial users would report to the National Health and Family Planning Commission after review.

A variety of assessment methods can ensure the quality of data submission, such as self-examination by grass-roots institutions, comprehensive assessment at the county level, random inspection and review at the city level and above, etc. Provincial and prefecture-level assessments are carried out at least once a year. The annual assessment of provincial-level, prefecture-level, county-level and county-level grassroots medical and health institutions covered 100% of their jurisdictions. Reward and punishment mechanisms were implemented in the assessment of the quality of data filling.

3. Empirical results

3.1 Results of output indicators classification

Through the correlation matrix analysis of 24 output indicators of EPHS, we found that the correlation coefficients of most of the correlation matrices are greater than 0.3. All the KMO values were greater than 0.80, indicating good applicability. The results of Bartlett's sphericity test were all $P < 0.05$, and the original variables were not independent of each other. The results showed that the output indicators had a good correlation and are suitable for principal component analysis.

Based on the principal component extraction of 24 output indicators, the obtained principal component variance contribution rate showed that the characteristic roots of the first seven principal components of output indicators were all greater than 1（Table 2）.

Table 2 showed that the cumulative total variance contribution rate was 87.09%, meaning that the seven principal components extracted could better summarize the main information of output index.

Table 2 The variance contribution rate of the principal component of the output index

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	Composition of variance (%)	The cumulative constitute (%)	Total	Composition of variance (%)	The cumulative constitute (%)
1	4.667	19.444	19.444	4.667	19.444	19.444
2	3.202	13.340	32.784	3.202	13.340	32.784
3	2.089	8.705	41.489	2.089	8.705	41.489
4	1.851	7.711	49.199	1.851	7.711	59.199
5	1.375	5.728	54.927	1.375	5.728	69.927
6	1.139	4.745	59.672	1.139	4.745	79.672
7	1.060	4.415	64.088	1.060	4.415	87.088
8	1.000	4.167	68.254	–	–	–
9	1.000	4.167	72.421	–	–	–

10	1.000	4.167	76.588	–	–	–
11	1.000	4.167	80.754	–	–	–
12	1.000	4.167	84.921	–	–	–
13	0.961	4.003	88.924	–	–	–
14	0.633	2.639	91.563	–	–	–
15	0.464	1.933	93.495	–	–	–
16	0.452	1.885	95.380	–	–	–
17	0.287	1.196	96.577	–	–	–
18	0.245	1.019	97.596	–	–	–
19	0.197	0.822	98.418	–	–	–
20	0.163	0.677	99.096	–	–	–
21	0.127	0.527	99.623	–	–	–
22	0.055	0.231	99.854	–	–	–
23	0.029	0.119	99.973	–	–	–
24	0.006	0.027	100.000	–	–	–

1= Filing rate of health records，2= Filing rate of electronic health records，3= Utilization rate of health records，4= Number of Health Education Talks，5= Number of Health Lectures Attended，6= Certificate issuance rate，7= Neonatal visit rate，8= Child health management rate，9= Early pregnancy enrollment rate，10= Postpartum visit rate，11= Health management rate for the elderly，12= Standard management rate of Hypertensive Patients，13= Blood pressure control rate of management population，14= Standard management rate of patients with type 2 diabetes，15= Glucose control rate of management population，16= Standard management rate of patients with severe semen concentration，17= Tuberculosis patient management rate，18= Regular drug taking rate in patients with tuberculosis，19= Traditional Chinese Medicine health management rate for the elderly，20= Traditional Chinese Medicine health management rate of children aged 0 to 36 months，21= Reporting rate of infectious diseases，22= Timely reporting rate of infectious diseases，23= Public health emergency information reporting rate，24= Health and Family Planning Supervision and Co-management Information Reporting Rate。

Orthogonal rotation of the extracted principal components was carried out to form the rotation component matrix of the output index after rotation. Finally, after dimensionality reduction and classification of 24 output indicators, 7 principal components were formed.

As shown in the Table 3, the seven newly extracted principal component output indicators were named as health management services for women, children and the elderly, health management services for traditional Chinese medicine, health management services for patients with chronic diseases, health education services, residents' health records management services, health management services for patients with severe mental disorders, and health management services for tuberculosis patients.

Table 3 Principal component naming of output index

The principal components	Indicators significantly related to principal components and their loads	named

F1	Neonatal visit rate（0.588）、Child health management rate（0.569）、Early pregnancy enrollment rate（0.283）、Postpartum visit rate（0.642）、Health management rate for the elderly（0.615）	health management services for women, children and the elderly
F2	Traditional Chinese Medicine health management rate of children aged 0 to 36 months（0.369）、Traditional Chinese Medicine health management rate for the elderly（0.602）	health management services for traditional Chinese medicine
F3	Standard management rate of Hypertensive Patients（0.761）、Blood pressure control rate of management population（0.581）、Standard management rate of patients with type 2 diabetes（0.748）、Glucose control rate of management population（0.616）	health management services for patients with chronic diseases
F4	Number of Health Education Talks（0.840）、Number of Health Lectures Attended（0.780）	health education services
F5	Filing rate of electronic health records（0.646）、Filing rate of health records（0.588）、Utilization rate of health records（0.843）	residents' health records management services
F6	Standard management rate of patients with severe semen concentration（0.523）	health management services for patients with severe mental disorders
F7	Tuberculosis patient management rate（0.263）、Regular drug taking rate in patients with tuberculosis（0.491）	health management services for tuberculosis patients

Finally, the newly extracted 7 principal components that processed by the efficiency coefficient method represented 24 original output indicators, and entered the DEA for calculation, completing the process of simplifying the 24 redundant output indicators into 7 principal component indicators.

3.2 DEA analysis result

Based on the above-mentioned principal component analysis and efficiency coefficient analysis results, further EPHS efficiency analysis was carried out.

We eliminated decision-making units with incomplete indicators in the database, and no longer analyzed their results. Thence 124 decision-making units were included in the analysis in 2014, 132 in 2015, 137 in 2016, 132 in 2017, 137 in 2018 and 137 in 2019.

3.2.1 Results of comprehensive technical efficiency score

As shown in the Figure 1, the average comprehensive technical efficiency of EPHS in Shandong Province showed a slight downward trend from 2014 to 2019. Comprehensive technical efficiency decreased from 0.8896 in 2014 to 0.8753 in 2019.

From 2014 to 2019, the average pure technical efficiency of EPHS in Shandong Province was kept at 0.99 （Figure 2）.

The average scale efficiency of EPHS in Shandong Province showed a slight downward trend from 0.8871 in 2014 to 0.8744 in 2019 (Figure 3).

It can be explained by the above result that the main reason for the decline in the technical efficiency of EPHS in Shandong Province was the decline in scale efficiency.

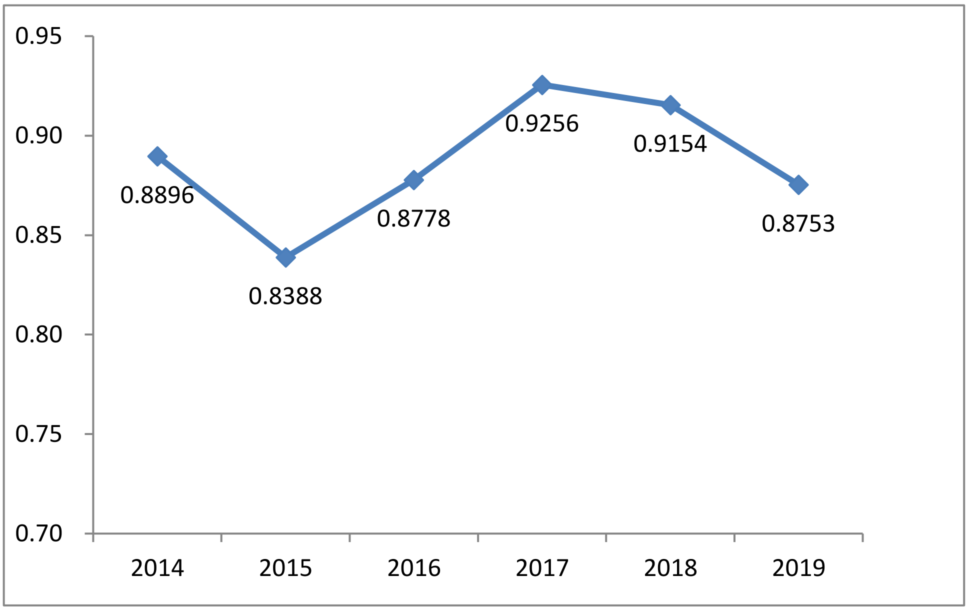

Figure 1 The average comprehensive technical efficiency of EPHS in Shandong Province from 2014 to 2019

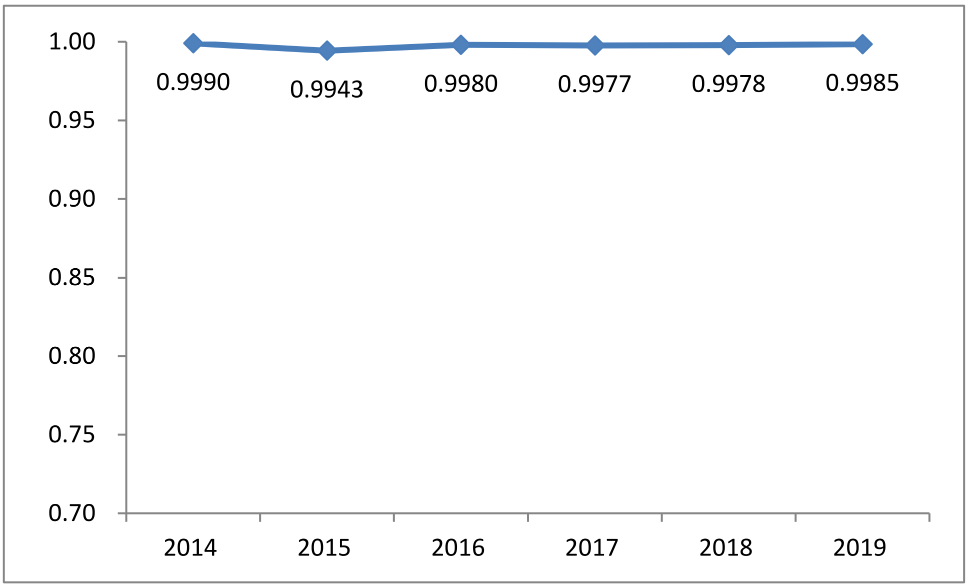

Figure 2 The average pure technical efficiency of EPHS in Shandong Province from 2014 to 2019

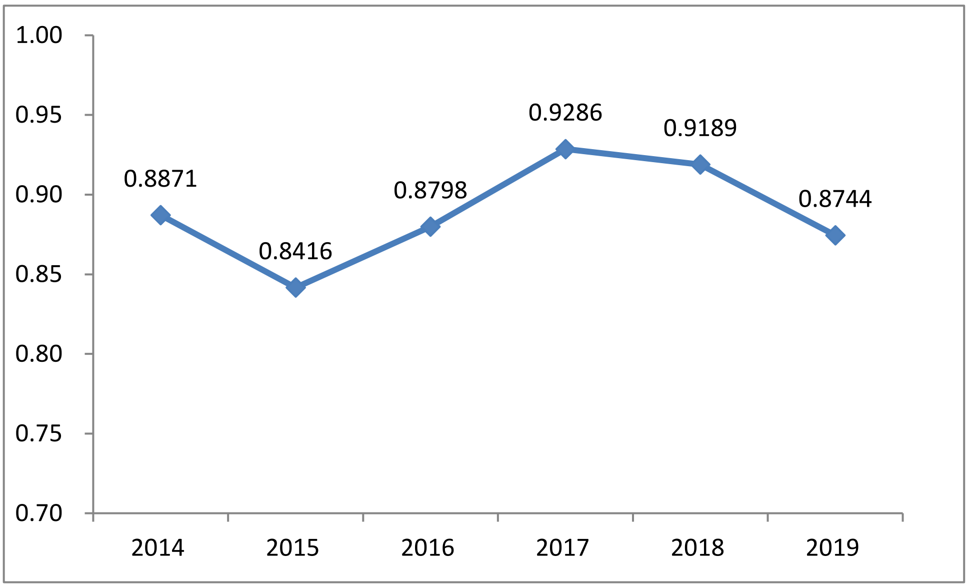

Figure 3 The average scale efficiency of EPHS in Shandong Province from 2014 to 2019

3.2.2 Results of the proportion of counties with effective technical efficiency

The proportion of counties and districts with the comprehensive technical efficiency of EPHS in Shandong Province was increased from 15.3% in 2014 to 21.9% in 2019 (Figure 4).

But the proportion of counties with the pure technical efficiency decreased from 38.0% in 2014 to 35.9% in 2019 (Figure 5).

Figure 6 showed the proportion of counties with scale efficiency of EPHS in Shandong Province from 2014 to 2019. The proportion of counties and districts showed an upward trend, rising from 14.8% in 2014 to 22.6% in 2019, increasing by 7.8%.

The increasing proportion of effective counties and districts in the comprehensive technical efficiency of EPHS in Shandong Province was mainly due to the increasing proportion of effective counties and districts in the scale efficiency and the good performance of effective counties and districts in the pure technical efficiency.

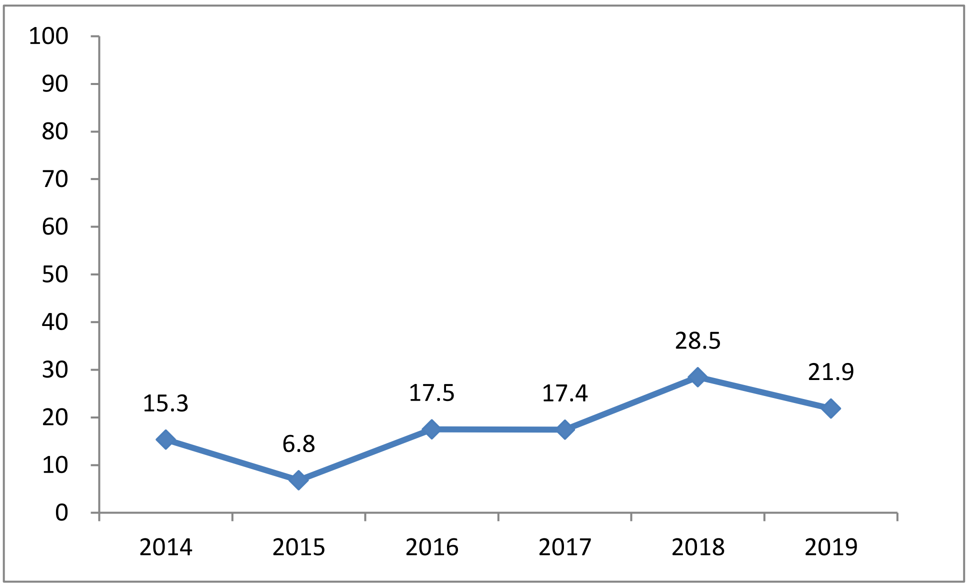

Figure 4 The proportion of counties and districts with effective comprehensive technical efficiency of EPHS in Shandong Province from 2014 to 2019

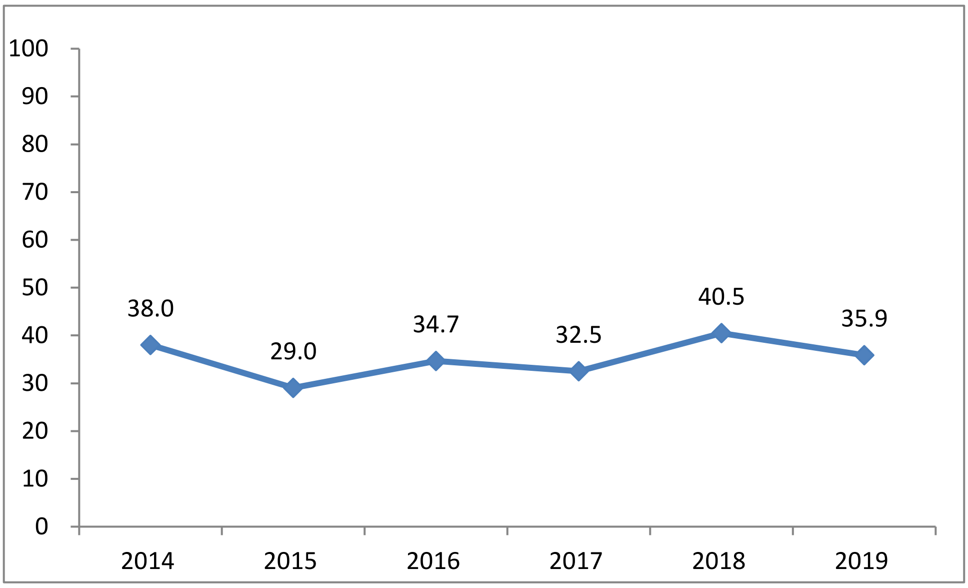

Figure 5 The proportion of counties and districts with effective pure technical efficiency of EPHS in Shandong Province from 2014 to 2019

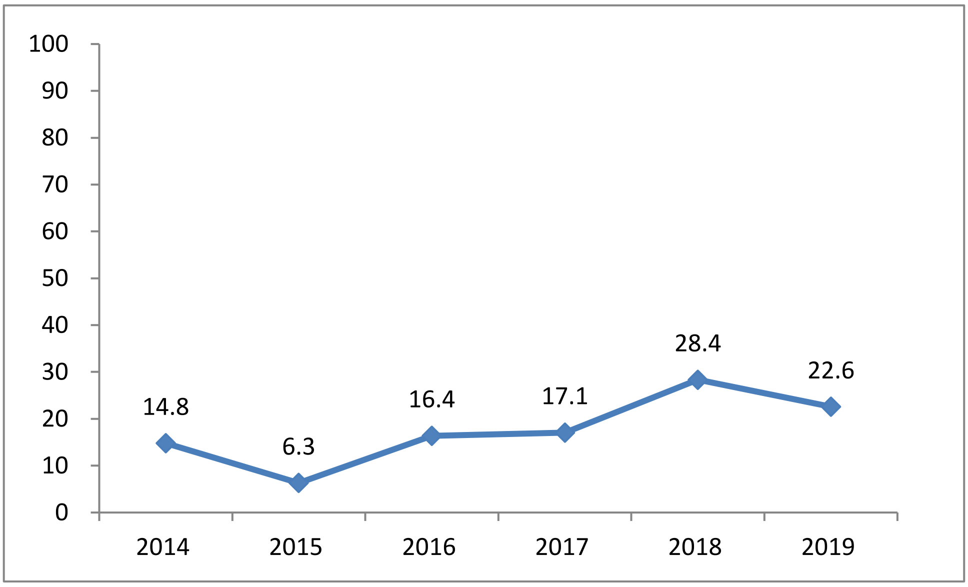

Figure 6 The proportion of counties and districts with effective scale efficiency of EPHS in Shandong Province from 2014 to 2019

4. Discussion

In the context of the new normal of economic development, subsidies for EPHS were still increasing year by year, and the investment was huge [48]. If this trend continued, the sustainability of EPHS would be challenged. Under the current level of investment and funding, full and effective use of resources was a powerful way to resolve this contradiction. Increasing the ratio of input to output was the essence of improving resource utilization efficiency. The prerequisite for studying the efficiency of EPHS was to understand the current efficiency status, and to analyze whether the technical efficiency was effective or ineffective through scientific measurement. Therefore, the purpose of this study was to fully understand the status quo of the technical efficiency of EPHS and provide a basis for the next step of analyzing efficiency influencing factors and efficiency improvement strategies.

There were a few studies on the technical efficiency of EPHS, and the existing research results shown that the technical efficiency of EPHS was not fully effective [49-50]. The reasons for the inefficiency of the technical efficiency of EPHS were concentrated in the efficiency of scale, which was mainly reflected in insufficient investment, which required further increase in capital and manpower investment [51]. At the same time, the input-output indicators of some studies only considered available data, rather than selecting indicators based on the relevance of service program activities [52]. This has led to the phenomenon of incomplete inclusion of input-output indicators. The scientific and accuracy of the research would be deeply affected [53].

Our research found that the average comprehensive technical efficiency of EPHS in Shandong Province from 2014 to 2019 showed a downward trend, but the decline was small. Among them, the average value of pure technical efficiency hardly changed, while the average value of scale efficiency showed a downward trend. Therefore, the main reason for the decline in the technical efficiency of EPHS in Shandong Province was the decline in scale efficiency. The decline in scale efficiency indicated that the scale and total amount of resource inputs such as program funds and personnel in EPHS were insufficient in the actual reality [54].

From 2014 to 2019, the ratio of effective comprehensive technical efficiency of EPHS in Shandong Province to all counties and districts has shown a upward trend. Among them, the proportion of counties with effective pure technical efficiency was higher than the proportion of counties with efficient scale each year. At the same time, the increase in the proportion of counties with effective scale efficiency was higher than the increase in the proportion of counties with effective pure technical efficiency. Therefore, the increasing proportion of effective counties and districts in the comprehensive technical efficiency of EPHS in Shandong Province was mainly due to the increasing proportion of effective counties and districts in the scale efficiency and the good performance of effective counties and districts in the pure technical efficiency. In the implementation of EPHS, counties with effective pure technical efficiency could have standardized program management, perfect personnel training and good service quality [55-56]. And the counties with effective scale efficiency could guarantee sufficient investment scale in the implementation of EPHS, that was the investment of capital and personnel could fully meet the operation of EPHS [57].

At the same time, although the proportion of counties with effective scale efficiency was on the rise, the proportion of counties with effective scale efficiency was lower than the proportion of counties with effective pure technical efficiency each year. This showed that although the investment scale of Shandong Province in the counties was gradually sufficient, there was still a phenomenon of insufficient resource investment in most counties. Insufficient investment in basic public health service resources affected the proportion of counties with effective scale efficiency in EPHS in Shandong Province, which in turn lead to a lower proportion of counties with effective comprehensive technical efficiency.

The results showed that the low proportion of the county ratio of the effective comprehensive technical efficiency of EPHS in Shandong Province was due to the low proportion of the county ratio of the effective scale efficiency and the problem of insufficient resource input, which would ultimately affect the sustainability of the implementation of EPHS. Therefore, scale efficiency was the key to further improve the comprehensive technical efficiency of EPHS and ensure the sustainability of programs. Further increase in resource input would have important implications for the sustainable development of EPHS.

In summary, the technical efficiency of EPHS in Shandong Province showed an upward trend on the whole, but there was still room for improvement. Among them, scale efficiency was the key to further improve the comprehensive technical efficiency. The study found that scale efficiency is the reason for lowering the comprehensive technical efficiency of EPHS in Shandong Province. In other words, the scale efficiency in EPHS in Shandong Province needs to be increased. At the same time, it is also necessary to continue to maintain a good state of pure technical efficiency of EPHS.

Future research should focus on the influencing factors and improvement measures of the scale efficiency of EPHS. At present, there are many gaps in the study of technical efficiency of EPHS. This study explores the status quo and factors of technical efficiency of EPHS. The results showed that the scale efficiency of EPHS was an important factor affecting technical efficiency. Therefore, it is suggested that future research should focus on the influencing factors and improvement measures of the scale efficiency of EPHS.

5. Conclusions

This study provides an empirical picture of the technical efficiency of EPHS in Shandong Province from 2014 to 2019. The research has demonstrated that the technical efficiency of EPHS in Shandong Province has shown a slight downward trend, and the main reason for its downward trend was the decline in scale efficiency. The scale efficiency in EPHS affected the technical efficiency and would ultimately threaten the sustainable development of EPHS. It is recommended that future research directions focus on the influencing factors and improvement measures of the scale efficiency of EPHS.

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