Efficiency and Productivity of County-level Public Hospitals Based on the Data Envelopment Analysis Model and Malmquist Index in Anhui, China

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Abstract

Background: China began to implement the national medical and health system and public hospital reforms in 2009 and 2012, respectively. Anhui Province is one of the four pilot provinces, and the medical reform measures received wide attention nationwide. The effectiveness of the above reform needs to get attention. This study aimed to master the efficiency and productivity of county-level public hospitals based on the data envelopment analysis (DEA) model and Malmquist index in Anhui, China, and then provide improvement measures for the future hospital development.

Methods: We chose 12 country-level hospitals based on geographical distribution and the economic development level in Anhui Province. Relevant data that were collected in the field and then sorted were provided by the administrative departments of the hospitals. DEA models were used to calculate the dynamic efficiency and Malmquist index factors for the 12 institutions.

Results: During 2010–2015, the overall average relative service efficiency of 12 county-level public hospitals was 0.926, and the number of hospitals achieved an effective DEA for each year from 2010 to 2015 was 4, 6, 7, 7, 6, and 8, respectively, as measured using DEA. During this same period, the average overall production efficiency was 0.983, and the total productivity factor had declined. The overall production efficiency of five hospitals was >1, and the rest are <1 between 2010 and 2015.

Conclusions: In 2010–2015, the relative service efficiency of 12 county-level public hospitals in Anhui Province showed a decreasing trend, and the service efficiency of each hospital changed. In the past 6 years, although some hospitals have been effective, the efficiency of the county-level public hospitals in Anhui Province has not improved significantly, and the total factor productivity has not been effectively improved. County-level public hospitals need to combine their own reality to find their own deficiencies.

Key words: China; County Level Public Hospital; Data Envelopment Analysis; Malmquist Index; Service Efficiency

Introduction

As the leading part of the county medical service system in China, county hospitals play an important role in the national health network, they are links between primary health-care institutions and urban tertiary hospitals in health services structure.¹ However, the problems of county-level public hospitals are the most prominent and in need of reform. In comparison with the community health service agencies, township hospitals and other primary health institutions, the internal management model, external policy environment, commitment to medical tasks, and personnel structure of county-level hospital are more complex and changeable.

Meanwhile, compared with the top level hospitals, the number of county-level public hospitals is large, but they are facing backward technology, poor medical equipment, an unreasonable medical care ratio, weak scientific
research, and other disadvantages. Therefore, it is of great practical significance to understand the current situation of county-level public hospitals, to understand their own deficiencies and to promote their own benign development. How to choose the appropriate data analysis method is a key to the correct analysis.

Data envelopment analysis (DEA) is a new performance evaluation method developed in 1978 by well-known American operational scientists, based on the relative concept.[2] It is a new method of performance evaluation that includes mathematical planning (including linear programming and multi-planning) models to evaluate the relative effectiveness of the department or unit under study using multiple input and output indicators, called the decision-making unit (DMU).[3,4] This method was first used to evaluate the efficiency of nonprofit institutions and the public sector, and it was then gradually extended to finance, economy, project evaluation, and other fields. This method has been widely used worldwide for health service efficiency evaluation currently.[5] Based on the data measured by each DMU, it is determined whether the DMU is valid for DEA. It is necessary to determine whether the DMU is located on the “production frontier” of the production set. The “production frontier” is a promotion of the production function to multiple outputs in economics.[6]

Based on two basic assumptions, constant returns to scale and variable returns to scale, two basic DEA models are proposed: Charnes, Cooper, Rhodes (CCR) and Banker, Charnes, Cooper (BCC).[3] The CCR-DEA model assumes that the returns to scale remain constant, assuming that the DMU being studied can be scaled up by investing in an equal scale. The BCC-DEA model assumes the scale output of the DMU being studied is disproportionately expanded in relation to the invested scale.[7] Both the CCR-DEA and the BCC-DEA model can be divided into two types: input oriented and output oriented. In studying the effectiveness of the DMU, the input-oriented model is based on constant output related to minimum inputs, and the output orientation is based on constant input related to maximum outputs.

The Malmquist index was first introduced by Malmquist for use in consumption analysis using indifference curves and input distance functions to compare consumption bundles.[9] Caves et al. introduced the idea to production analysis, through the calculation of the ratio between the distance function to the productivity index, and named it the Malmquist index.[9,10] It was widely used after Fare used DEA to calculate the distance function.[11] Caves et al. also further subdivided the index into technological change (TC) and technical efficiency (TE) technical efficiency change (TEC), and Fare further subdivided TEC into pure TEC (PTEC) and scale efficiency change (SEC). TEC reflects the improvement of production and operation behavior of DMUs, such as the improvement of management level. TC mainly reflects the production of technological progress on the impact of changes in productivity. PTEC can be reflected in the variable-scale remuneration assumptions under the DMUs technical level and can play an important role. SEC reflects the different stages of the DMUs economies of scale changes. The Malmquist index is defined according to the proposed distance function, which is used to reflect the efficiency index of the efficiency change of t to s (usually t + 1), and the catching up effect in a period of time.[10] It is a reflection of the total factor productivity (TFP) of the nonparametric method of dynamic change. The TFP changes (TFPC) in different periods of a Markov DMU can be used to measure the TFP index of multiple inputs and multiple outputs.[12] If the Malmquist index is >1, it shows that the TFP levels as well as the productivity have improved during this period. If it is <1, TFP levels have declined, and productivity has regressed.

Anhui province, with a middle economic development level, is located in central China. In 2014, its gross domestic product per capita was 20,848 Yuan, ranking it in the fourteenth place among administrative districts in China (there are 34 provincial administrative districts in China). Its population in 2015 was 61.44 million. In 2009, China started the new round of medical reforms and in 2012 the reforms of county-level public hospitals started. Anhui, Jiangsu, Qinghai, and Fujian provinces together were the four pilot provinces of the reform. Therefore, the author has selected Anhui Province as the focal point, using the collation and analysis of data of 12 county hospitals in Anhui province to evaluate the efficiency of the development of county hospitals and to provide the evidence for future development.

According to DEA models and theories, this article will consider each county-level public hospital service as a DMU and the hospital service system as the economic system of human and financial resources producing service outputs. Using input and output data collected from statistical reports, we carried out an empirical study on the Service efficiency of 12 county-level public hospitals using DEA.

Methods

Ethics
This study was not a study on human beings and the data collected has no relationship with patients’ medical records data, therefore, ethics statement was not needed.

Study design and data collection
We divided Anhui Province into three districts (Southern Anhui, Central Anhui, and Northern Anhui) based on economic development and regional differences. And in each district, we used simple random sampling method to choose four county-level public hospitals as our study site. The 12 hospitals were designated by letters, the Southern Anhui hospitals (A, B, C, and D), the Central Anhui hospitals, (E, F, G, and H), and the Northern Anhui hospitals (I, J, K, and L). The sample data were collected by a unified training investigator at the site from June to August.
in 2016 and completed by the hospital. A total of 6 years of data were collected for the years 2010–2015.

**Measures**

**Input and output indicators**

Based on the evaluation of Chinese hospitals and references to previous studies such as Flokou and Dimas and fully considering the requirements of representation, availability, stability, and independence, the experts chose input indicators for the number of actual doctors (I1), the number of actual nurses (I2), the actual number of beds (I3) and the total expenditure (I4) and output indicators for the number of emergency visits (O1), the number of discharged (O2), and the number of hospitalized patients (O3). Among the indicators, the number of doctors and nurses was considered the hospital’s human capital, and the actual number of open beds supplied by the hospital and the total cost expenditure were considered the hospital’s economic investment. The number of outpatient and emergency visits, the number of discharged, and the number of hospitalized patients relating to the hospital’s service capacity were used as the output indicators.

**Statistical analysis**

Microsoft Excel 2007 was used for data entry, while SPSS 16.0 software (SPSS Inc., Chicago, IL, USA) was used for the median and variance calculation of input and output indicators. And, DEAP 2.1 software was used for analyzing the integrated efficiency, including TE, pure technology efficiency (PTE), and scale efficiency (SE). TE is the production efficiency of the DMU based on a certain input factor. It is a comprehensive evaluation of the resource allocation capacity and resource utilization efficiency of each DMU. The TE of each DMU was calculated based on the CCR model under the scale pay fixed hypothesis and it represents a hospital that is in the forefront of current production conditions when the hospital technology is effective. The TE of each DMU was subdivided into PTE and SE using the BCC model, and $TE = PTE \times SE$. PTE is the efficiency of hospital systems and management which is affected by factors such as management and the technology of DMUs. A $PTE = 1$ indicates that the use of resources at the current level of technology is effective. SE is the difference between the existing scale and the optimal size under the premise of the existing system and management level which is affected by the size of the hospital.

The DEA-based Malmquist index method was used to analyze the dynamic efficiency of total factors productivity. If TFP is $>1$, it shows that the TFP levels have improved during this period, that is to say the cost has declined and the productivity has been increased. If it is $<1$, TFP levels have declined, and productivity has regressed. TEC reflects the improvement of production and operation behavior of DMUs, such as the improvement of management level. If it is $>1$, it reflects the efficiency improvement. TC mainly reflects the production of technological progress on the impact of changes in productivity. If it is $>1$, it means that the cost economy or productivity improvement is caused by technical innovation. If it is $<1$, it reminds that technical innovation is needed.

PETC can be reflected in the variable-scale remuneration assumptions under the DMUs technical level and can play an important role. If it is $>1$, it means that the performance is better than average level. If it is $<1$, it reminds the urgent of management improvement. SEC reflects the different stages of the DMUs economies of scale changes. If it is $<1$, it reflects the scale down and adjustment is needed.

As input indicators are more easily controlled and the output of health services is achieved in terms of reducing health inputs and achieving health services, we choose the input-oriented DEA method.

**Results**

Descriptive input and output from 2010 to 2015 is shown in Table 1.

**Table 1: Descriptive input and output from 2010 to 2015**

| Year | Items   | Input | O1   | O2 | O3   |
|------|---------|-------|------|----|------|
|      |         | I1 (person, $n$) | I2 (person, $n$) | I3 (Bed) | I4 (Yuan) | Output (person-time) |
| 2010 | Median  | 123.5 | 205.5 | 370.0 | 7692.5 | 160,234.0 |
|      | SD      | 47.923 | 58.898 | 119.786 | 2935.159 | 68,854.553 |
| 2011 | Median  | 136.5 | 233.5 | 370.0 | 9833.0 | 183,279.0 |
|      | SD      | 51.490 | 54.948 | 151.084 | 3632.074 | 79,043.829 |
| 2012 | Median  | 145.5 | 233.5 | 393.0 | 12,002.5 | 210,867.5 |
|      | SD      | 53.323 | 52.429 | 223.334 | 5354.589 | 86,754.229 |
| 2013 | Median  | 178.0 | 244.5 | 450.5 | 13,109.5 | 246,285.0 |
|      | SD      | 59.278 | 75.418 | 253.811 | 6735.380 | 86,235.592 |
| 2014 | Median  | 185.0 | 257.5 | 477.5 | 14,513.0 | 293,540.0 |
|      | SD      | 59.860 | 77.431 | 291.428 | 7829.730 | 110,032.431 |
| 2015 | Median  | 188.5 | 260.5 | 477.0 | 15,660.5 | 301,521.0 |
|      | SD      | 63.043 | 95.549 | 280.206 | 9406.540 | 122,256.676 |

SD: Standard deviation; I1: Input indicators for the number of actual doctors; I2: Number of actual nurses; I3: Actual number of beds; I4: Total expenditure; O1: Output indicators for the number of emergency visits; O2: Number of discharged; O3: Number of hospitalized patients.
Technical efficiency results for data envelopment analysis of sample hospitals
As shown in Table 2, in 2010–2015, the comprehensive efficiency of the 12 county-level public hospitals showed an upward trend, and hospitals B, G, I, J, and C were valid for DEA (TE = 1). Hospital C, before 2012, showed an upward trend and then showed a downward trend. In the past 6 years, a total of nine hospitals (75%) have reached a TE of 1, while the other three hospitals (hospitals C, F, and H) have never reached 1. From 2010 to 2015, there are 4, 6, 7, 7, 6, and 8 hospitals, respectively, each year that were valid for DEA. From the regional point of view, the Northern Anhui had the highest efficiency, followed by Southern Anhui while the Central Anhui had the lowest efficiency. In 2012 and 2013, Northern Anhui had a TE average of 1.

Pure technology efficiency results for data envelopment analysis of sample hospitals
As shown in Table 3, in the period 2010–2015, hospitals A, B, G, I, J, K, and L have been active in maintaining PTE = 1 for the use of resources. Hospital C has never reached 1, and after 2013, its PTE value has declined. During the period 2010 to 2015, there were 8, 7, 10, 10, 11, and 11 hospitals, respectively, each year that achieved an effective DEA. The average PTE in Northern Anhui is 1, higher than that in Southern and Central Anhui.

Scale efficiency results for data envelopment analysis of sample hospitals
As shown in Table 4, generally, a total of nine hospitals (75%) have reached a SE of 1, while the other three hospitals (hospitals C, F, and H) have never reached 1 in the past 6 years. During this same period, the number of hospitals achieved an effective DEA for each year from 2010 to 2015 was 4, 6, 7, 7, 6, and 8 respectively. The average SE in Northern Anhui is the highest, 0.979, followed by Southern Anhui, and the last was in Central Anhui.

Compare pure technology efficiency and scale efficiency
From Figure 1, the PTE was always greater than SE during 2010–2015, it can be concluded that PTE, and not SE, was the main factor affecting TE.

REDUNDANT INPUTS AND INADEQUATE OUTPUT
Through the study of the service efficiency of five county hospitals with poor efficiency based on PTE, it was found that some of the input factors were relatively redundant while the output was relatively insufficient. As shown in Table 5, in five hospitals, the actual number of doctors, nurses, beds, and the total cost of expenditure were redundant, while the output was mainly reflected in the number of emergency visits, especially in the years 2010–2013. During the period from 2014 to 2015, the situation had improved, except for hospital C, which showed input redundancy and inadequate production during 2010–2015, especially in the number of registered nurses, the actual number of beds and the total cost. Redundant inputs and inadequate output were also found in the hospital D and E in 2011, hospitals F in 2012 and hospital H in 2010, 2011, and 2013. Take the 2010 result of

![Figure 1: Comparison of PTE and SE of the sample hospitals.](image)
hospital C, for example, the I1, I2, I3, and I4 can be reduced by 37.423, 63.070, 40.512, and 1316.922, respectively, in the current output. Or otherwise, the O1 should increase by 1663.014 in the current input.

**Productivity change for Malmquist index in the 6 years-period (2010–2015)**

As shown in Table 6, the average TFPC was 0.983, a decline of 1.7%. The average TEC was 1.018, and the average TC was 0.965. The decrease in the average productivity is due to the decrease in TC, and the effect of the rise in TEC is less than that of TC.

On a year-to-year basis, the Malmquist index was 0.957, 0.991, 0.973, and 0.931 in the periods of 2010–2011, 2011–2012, 2012–2013, and 2014–2015, respectively, and the service efficiency decreased in years 2014–2015, down by 6.9%. The decline in service efficiency in 2010–2011, 2011–2012, 2012–2013, and 2014–2015 is due to a decline in the efficiency of technological progress. A drop of 4.1% in TE in 2012–2013 led to a decline in service efficiency. In the period of 2013–2014, the Malmquist index was up to 1.061, with a relative increase in service efficiency of 6.1%, due to rising TEC and TC, up 2.4% and 4.2%, respectively, with the rise in TEC due to rising PECT and SEC, up 1.2%.

### Table 4: Scale efficiency of sample hospitals in 2010–2015

| Hospital | A | B | C | D | E | F | G | H | I | J | K | L | Southern | Central | Northern | Mean |
|----------|---|---|---|---|---|---|---|---|---|---|---|---|---------|---------|---------|------|
|          | 0.985 | 1 | 1 | 1 | 1 | 1 | 1 | 0.998 | 1 | 1 | 1 | 1 | 0.986 | 0.926 | 0.949 | 0.926 |

### Table 5: Slack values and redundant values of the sample hospitals

| Hospitals | Years | Input | Output |
|-----------|-------|-------|--------|
|           |       |       | 01     | 02     | 03     |
| C         | 2010  | −37.423 | −63.070 | −40.512 | −3116.922 | 1663.014 | 0.000 | 0.000 |
|           | 2011  | −25.197 | −72.090 | −23.665 | −1070.882 | 44,856.151 | 0.000 | 0.000 |
|           | 2012  | −43.423 | −14.754 | −10.594 | −401,169 | 0.000 | 0.000 | 0.000 |
|           | 2013  | −39.645 | −60.115 | −272.470 | −7490.805 | 51,285.297 | 0.000 | 1031.887 |
|           | 2014  | −28.365 | −42.697 | −180.772 | −7250.156 | 48,688.659 | 0.000 | 0.000 |
|           | 2015  | −36.276 | −57.169 | −219.332 | −6125.106 | 44,938.874 | 0.000 | 290.630 |
| D         | 2010  | −1.889 | −34.121 | −80.625 | −131.209 | 53,906.493 | 0.000 | 406.045 |
|           | 2011  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2012  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2013  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2014  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2015  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| E         | 2010  | −78.918 | −59.704 | −98.074 | −3199.561 | 0.000 | 0.000 | 0.000 |
|           | 2011  | −87.835 | −66.312 | −91.679 | −3017.607 | 0.000 | 0.000 | 279.015 |
|           | 2012  | −61.325 | −39.075 | −27.425 | −3410.554 | 0.000 | 0.000 | 0.000 |
|           | 2013  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2014  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2015  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| F         | 2010  | −68.912 | −117.878 | −243.263 | −2288.110 | 0.000 | 0.000 | 0.000 |
|           | 2011  | −40.816 | −102.000 | −225.068 | −3068.297 | 0.000 | 0.000 | 1433.327 |
|           | 2012  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2013  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2014  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2015  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| H         | 2010  | −9.911 | −13.270 | −55.998 | −654.875 | 35,837.464 | 3252.490 | 0.000 |
|           | 2011  | −0.936 | −1.319 | −50.332 | −56.218 | 42,123.855 | 4041.131 | 0.000 |
|           | 2012  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2013  | −8.125 | −12.044 | −55.998 | −1199.906 | 128,307.081 | 0.000 | 0.000 |
|           | 2014  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
|           | 2015  | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

I1: Input indicators for the number of actual doctors; I2: Number of actual nurses; I3: Actual number of beds; I4: Total expenditure; O1: Output indicators for the number of emergency visits; O2: Number of discharged; O3: Number of hospitalized patients.
As seen in Figure 2, the whole factor of production has two peaks and one trough, showing “M” change. The two peaks are in the periods of 2011–2012 and 2013–2014, with the growth rate in the latter period higher than the former. In the period of 2012–2013, the total factor of production was 0.973, and in the period of 2014–2015, it was 0.931, the lowest level. The TEC volatility and TFPC were consistent but also showing “M,” and in contrast to TFPC, the 2011–2012 growth rate was less than the 2013–2014 growth rate.

Productivity change for Malmquist index by hospital
As we can see from Table 7, for the 12 county-level public hospitals, the Malmquist index of hospitals A, B, E, F and G was >1, at 1.011, 1.004, 1.069, 1.002, and 1.035, respectively, as Factor productivity at the five hospitals increased in varying degrees. The remaining seven hospitals had a Malmquist index of <1, and the last three hospitals D, L, and J had reductions of 5.8%, 7.3%, and 7.7%, respectively.

**Table 6: Malmquist index for public hospitals**

| Years    | TEC   | TC    | PTEC  | SEC   | TFPC  |
|----------|-------|-------|-------|-------|-------|
| 2010–2011| 1.016 | 0.942 | 1.011 | 1.005 | 0.957 |
| 2011–2012| 1.087 | 0.912 | 1.041 | 1.045 | 0.991 |
| 2012–2013| 0.959 | 1.015 | 0.983 | 0.975 | 0.973 |
| 2013–2014| 1.024 | 1.042 | 1.012 | 1.012 | 1.061 |
| 2014-2015 | 1.010 | 0.922 | 0.996 | 1.015 | 0.931 |
| Mean     | 1.018 | 0.965 | 1.008 | 1.010 | 0.983 |

TEC: Technical efficiency change; TC: Technological change; PTEC: Pure technical efficiency change; SEC: Scale efficiency change; TFPC: Total factor productivity changes.

**Table 7: Malmquist index for public hospitals**

| Hospitals | TEC   | TC    | PTEC  | SEC   | TFPC  |
|-----------|-------|-------|-------|-------|-------|
| A         | 1.003 | 1.008 | 1.000 | 1.003 | 1.011 |
| B         | 1.000 | 1.004 | 1.000 | 1.000 | 1.004 |
| C         | 0.998 | 0.958 | 0.983 | 1.015 | 0.956 |
| D         | 1.020 | 0.924 | 1.020 | 1.020 | 0.942 |
| E         | 1.072 | 0.997 | 1.058 | 1.013 | 1.069 |
| F         | 1.043 | 0.960 | 1.044 | 0.999 | 1.002 |
| G         | 1.000 | 1.035 | 1.000 | 1.000 | 1.035 |
| H         | 1.034 | 0.956 | 1.018 | 1.016 | 0.988 |
| I         | 1.000 | 0.950 | 1.000 | 1.000 | 0.950 |
| J         | 1.000 | 0.923 | 1.000 | 1.000 | 0.923 |
| K         | 1.050 | 0.952 | 1.000 | 1.050 | 0.999 |
| L         | 1.005 | 0.922 | 1.000 | 1.005 | 0.927 |
| Mean      | 1.018 | 0.965 | 1.008 | 1.010 | 0.983 |

TEC: Technical efficiency change; TC: Technological change; PTEC: Pure technical efficiency change; SEC: Scale efficiency change; TFPC: Total factor productivity changes.

**Discussion**

The efficiency of county level public hospitals shows an increasing trend, but the SE still needs to be strengthened. From the static analysis results, the average comprehensive TE of 12 hospitals in 2010–2015 was 0.956, and the average PTE and SE were 0.976 and 0.980, respectively. The comprehensive efficiency was higher than the PTE and SE, although not reaching 1. In the 2010–2015 periods, the average comprehensive TE showed an overall upward trend. Compared with PTE, SE is always lower, and the problem of scale is related to the ability of the organization personnel to overcome the decline in the returns of scale by optimizing the organizational structure through the allocation of decision power, the use of performance evaluation, and promotion methods. From the dynamic analysis results, the total change of TFP in the hospitals from 2010 to 2015 showed “M.” The average Malmquist index of service efficiency of county-level public hospitals in Anhui Province in 2010–2015 was 0.983, down by 1.7%. The efficiency of technological progress decreased by 3.5%, and the influence of organizational management level was less than that of technological progress and innovation.

Regional differences exist in the service efficiency of county-level public hospitals. As shown in Tables 2–4, whether in terms of comprehensive TE, PTE, or SE, Northern Anhui is higher than Southern and Central Anhui regions. This is in contrast to the traditional relationship between hospital service efficiency and the level of economic development seen in the past. This result also provides another way for future researchers to consider aspects other than the level of regional economic development in an area. We speculate on these two possibilities: first, the level of economic development of the hospital is not the only factor affecting its operational efficiency, as long as there is rational and scientific management and a reasonable optimization of the hospital operating environment. Second, hospital’s operating efficiency may be related to the demographics of the local population base. For the Northern Anhui has a much larger population base than Southern and Central Anhui.

Reasonable reduction of resource investment, effective allocation, and use of resources are needed for hospital development. The main ways to reduce the cost of hospitals are to improve the efficiency, the rational allocation of resources, and achieve the effective application of limited health resources for hospitals. Through the analysis of the input and output factors of five hospitals, it was found that there were insufficient investment and insufficient output in these hospitals. It is clear that the situation was improving.
in the period of 2014–2015 due to the implementation of relevant health-care reform policies. For example, reforms were made in terms of personnel distribution, innovation, and job management related to the county hospital functions. The amount of work and the use of existing systems and other factors, both scientific and reasonable, were used to determine the staffing, general job categories, job scale, and grade and structure ratios at county-level hospitals. Implementing a unified management system will help identify management positions. A series of reform measures, to a certain extent, improves the problem of investment redundancy for hospitals.

County hospital reform has a certain effect, and there is a delay effect. On June 7, 2012, the comprehensive reform policy for county-level public hospital was announced, and by the end of 2012, the county-level public hospitals began to formally implement the reforms. In the period of 2013–2014, the Malmquist index was significantly higher than in the periods of 2010–2011, 2011–2012, and 2012–2013 showing that the reforms had some effect. In addition, although the reform policy implemented at the end of 2012, the 2012–2013 index did not rise, and compared with 2011–2012, the decline in 2013–2014 points to a delay effect of the policy.

Although the TE is growing, the efficiency of technological progress is declining and is not conducive to the development of the hospital. We can see the following from Tables 1-7: TE showed a growth trend, but the efficiency of technological progress showed a low level of development. Although TE has grown due to the growth of PTEC and SEC, along with the growth of hospital technology and size, the efficiency of technological progress in the hospitals has been ignored, so in the development process, the hospital has not achieved service improvement. This is not the same as the long-term development of the hospital. It is a reminder that we should pay attention to hospital management improvements but not just the impact of technological advances on productivity. The hospital management degree plays an important role in the sustainable development of the hospital.

The reform experience of some hospitals is worth learning. From Table 7, we can conclude that the Malmquist index of hospitals A, B, E, F, and G has reached 1 and increased by 1.1%, 0.4%, 6.9%, and 0.2%, respectively. The improvement in hospital E is the most noticeable. Hospital E had not exhibited redundancy inputs and insufficient outputs. In the actual survey of hospital E, we found active implementation of relevant policies after the reform. In hospital A, where TE, PTE, and SE performed very well, that performance may have been due to the hospital’s own management and scale.

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Conflicts of interest
There are no conflicts of interest.

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