Efficiency evaluation of county-level public hospitals in Hainan, China: a four-stage data envelope analysis model based on panel data

Yi Yang, Wen-Jing Xue, Jing Liu

Department of Health Management, School of Management, Hainan Medical University, Haikou, Hainan 571199, China.

To the Editor: Hainan is located in the southernmost of China, which has attracted increasing international attention. Although it is continuously developing its health services in recent years, there are still significant differences between hospitals. To continue to formulate the reform measures and reduce the gap, it is essential to understand whether there are differences in efficiency between different types of hospitals and what factors influence them.[1] This study was to evaluate the efficiency scientifically, observe the efficiency changes from 2015 to 2017, and analyze the factors that caused these changes.

We implemented a stratified sampling design to obtain a representative sample of 88 hospitals from 12 counties on the premise of balancing the geographical, economic, and service population characteristics. The sample size was determined by the data envelope analysis (DEA) method (The minimum sample capacity of the DEA model is $2 \times N \times M$, where N and M represent the number of input and output indicators, respectively.).[2] Finally, 264 observations were obtained. There were 66 general hospitals (GHs) and 22 traditional Chinese medicine hospitals (TCMHs). Patient information was not included in the study, so that ethics statement or informed consent was not needed.

We used the Stata v.14.0 software (Stata Corp., College Station, TX, USA) to perform Tobit regression analysis and random effects to analyze the data according to a Hausman test.[3] A four-stage DEA model was used to analyze the efficiency of county-level public hospitals in Hainan from 2015 to 2017.

Stage 1: Super-efficiency DEA model. The model can analyze whether the hospital achieves both technical effectiveness and effective scale, find the influencing factors of hospital benefits, optimize the allocation of hospital resources, and improve efficiency by reducing the amount of input without changing the output quantity.

Stage 2: Tobit regression for slack. The Tobit regression method is used to analyze the effect of external influence factors on the slack of the decision unit. The value of the slack variable refers to the difference between the actual input and the input of the most effective scheme. In this study, the dependent variable in the Tobit is the calculated total amount of relaxation (the sum of the amount of ray relaxation and the amount of non-radiative relaxation). The independent variable is the environmental influence factor.

Stage 3: Adjusting the original input factors. The results of the Tobit regression model are used to further adjust the input of the decision making unit (DMU), increase the input of the DMU with a better environment, and eliminate the external environmental impact.

Stage 4: Using the adjusted input factors and original output data, the ultra-efficient DEA is performed again to obtain new efficiency values.

The descriptive statistical results show that there was a large gap between the input and output for 88 hospitals. DEA results show that 13 hospitals had a comprehensive technical efficiency, 29 hospitals had a pure technical efficiency, and 13 hospitals had a scaling efficiency. Tobit regression analysis results [Table 1] show that the disposable income of urban residents, financial subsidy income, and the number of visits per doctor per day were significant factors affecting the efficiency. The degree of influence for each variable on the 88 hospitals was different. Therefore, the initial input factors were adjusted using the regression results of this stage to

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Correspondence to: Prof. Jing Liu, Department of Health Management, School of Management, Hainan Medical University, 3 Xueyuan Road, Haikou, Hainan 571199, China
E-Mail: 478047206@qq.com

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Table 1: Regression analysis of environmental factors and input slack variables for stage 2 from 2015 to 2017.

Explained Variables	Coefficient	Standard error	*Z*	*P*
Model 1: Number of practicing (assistant) physicians				
GDP	−0.02	0.01	1.67	0.094
Disposable income of urban residents	0.02	0.00	2.74	0.006
Hospital grade	−10.82	7.67	−1.41	0.158
Hospital type	−14.68	7.89	−1.86	0.063
Actual number of open beds	0.03	0.03	0.93	0.351
Financial subsidy (RMB, Yuan)	0.00	0.00	2.25	0.025
The number of health technicians	−0.02	0.02	−0.71	0.477
Number of visits per doctor per day	−2.37	0.86	−2.77	0.006
Model 2: Actual number of open beds				
GDP	0.01	0.03	0.28	0.780
Disposable income of urban residents	0.00	0.00	2.01	0.044
Hospital grade	−14.38	17.32	−0.83	0.406
Hospital type	−6.81	18.01	−0.38	0.705
Actual number of open beds	0.40	0.07	5.58	0.000
Financial subsidy (RMB, Yuan)	0.00	0.00	2.07	0.039
The number of health technicians	−0.25	0.06	−4.47	0.000
Number of visits per doctor per day	−5.42	1.98	−2.73	0.006
Model 3: Fixed assets				
GDP	−3.59	18.81	−0.19	0.849
Disposable income of urban residents	2.74	1.69	1.62	0.105
Hospital grade	−16,813.46	10,114.05	−1.66	0.096
Hospital type	−7117.27	10,664.12	−0.67	0.505
Actual number of open beds	14.34	48.66	0.29	0.768
Financial subsidy (RMB, Yuan)	0.33	0.19	1.69	0.091
The number of health technicians	16.03	37.35	0.43	0.668
Number of visits per doctor per day	−3166.67	1258.03	−2.52	0.012
Model 4: Number of equipment above 10,000 Yuan				
GDP	−0.16	−0.15	−1.05	0.294
Disposable income of urban residents	0.03	0.01	2.72	0.007
Hospital grade	−120.31	83.24	−1.45	0.148
Hospital type	−120.43	86.61	−1.39	0.164
Actual number of open beds	0.44	0.33	1.33	0.184
Financial subsidy (RMB, Yuan)	0.00	0.00	2.35	0.019
The number of health technicians	−0.06	−0.26	−0.24	0.810
Number of visits per doctor per day	−14.82	8.56	−1.73	0.083

GDP: Gross domestic product.

place the hospitals in the same external environment as much as possible before performing the adjusted DEA. Adjusted DEA results show that there were 49 hospitals with increased scale benefits in 2015, 46 hospitals in 2016, and 36 hospitals in 2017. Jiang *et al*[4] found the total health expenditure, the medical business income, the doctors' daily burden of diagnosis and treatment, the number of hospital beds, and the total number of outpatients and treatments affected the efficiency, this differs from our findings. Adding environmental variables to the analysis can help to control and diminish the impact of environmental factors on the evaluation results. After the adjustment, the overall efficiency value had decreased, indicating that directly measuring the efficiency value of the hospital will overestimate the efficiency level of the hospital before the adjustment of the external environmental variables.

The uniqueness of this study is that we added a super-efficiency DEA to the traditional DEA model. We have seen the changes in the efficiency of each hospital more intuitively. However, due to insufficient data, we could only observe the efficiency across 3 years and could not conduct an in-depth, dynamic evaluation of the overall efficiency of each hospital. Future research should focus on what are the factors that lead to the difference in efficiency among different county hospitals. A dynamic evaluation assessment may be necessary.

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Conflicts of interest

None.

References

1. Wu SW, Chen T, Pan Q, Wei LY, Wang Q, Li C, *et al*. Establishment of a quantitative medical technology evaluation system and indicators within medical institutions. *Chin Med J* 2018; 131:1327–1332. doi: 10.4103/0366-6999.232804.
2. Li XW, Gao YM, Zhang YL. Indicator selection for healthcare organization data envelopment analysis. *Health Econ Res* 2009; 2:12–14. doi: 10.14055/j.cnki.33-1056/f.2009.02.002.
3. Hahn J, Hausman J. A new specification test for the validity of instrumental variables. *Econometrica* 2002; 70:163–189. doi: 10.2139/ssrn.195729.
4. Jiang MM, Gao K, Guo PP, Lu YY, Luo J. Evaluation of the efficiency of medical service in China and its influencing factors. *Med Soc* 2020; 3:32–36. doi: 10.13723/j.yxysh.2020.03.007.

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