sustainability

MDPI

Article

Performance Measurement of Healthcare Service and Association Discussion between Quality and Efficiency: Evidence from 31 Provinces of Mainland China

Tao Du [1,2]

[1] School of Management and Economics, Beijing Institute of Technology, Beijing 100081, China; dutao0608@163.com

[2] School of Economics and Management, Yan'an University, Yan'an 71600, China

Received: 20 November 2017; Accepted: 27 December 2017; Published: 30 December 2017

Abstract: Performance of healthcare service includes quality and efficiency, so there is inevitably an association between them. In general, it is believed that there is a trade-off between quality and efficiency; however, we prove that it is not completely accurate. We take the quality as an additional output to measure the healthcare service efficiency creatively, and discuss the association between quality and efficiency based on the effect of quality on relative efficiency. Firstly, we use TOPSIS method to calculate relative quality index values of healthcare service of 31 provinces of mainland China. This practice ensures the consistent comparison of 31 provinces' qualities. Subsequently, we measure the 31 provinces' relative performances and efficiencies of healthcare service with consideration of quality or not, by constructing DEA models. Then, we analyze the association between quality and efficiency from each group of the national, east, central and west, and conclude that the association between them is different along with their advantage degrees of quality and efficiency. Finally, we use the Tobit regression method to test 12 environment variables' net impacts on efficiency values both with consideration of quality or not. The results indicate that the main drivers of healthcare service efficiency are different when we take quality as an additional output or not. This article contributes to the field of performance measurement of healthcare service, puts forward a new method to integrate quality and efficiency and provides management guidelines.

Keywords: healthcare service; performance measurement; relative quality index; data envelopment analysis; Tobit regression

1. Introduction

Healthcare has widespread influences on all aspects of society. In the national conference on health and wellness, which had been held in Beijing from 19–20 August 2016, China's President Xi Jinping stressed that "health is a necessary requirement of promoting the people's all-round development, the basic condition for economic and social development, an important symbol of prosperity of the nation and country, and the common pursuit of the people". As a fundamental guarantee of health, efficiency and quality of healthcare service determine the level of health development directly. Besides, with the increasing of medical expenditure and demand constantly, it is urgent to improve the performance of healthcare service [1].

All over the world, Healthcare System Reform (referred to as healthcare reform), which aims to improve the performance of healthcare service, has become one of the key issues in government reforms. The Chinese government has been promoting healthcare reforms according to social development, and attaching great importance to people's health since the reform and opening up in 1978. The main target of China's new healthcare reform, which has been implemented in January 2009, is to solve the issue of "medical treatment is difficult and expensive" [2]. This issue is mainly caused by the problem existed in medical resources allocation and operation management of hospitals [3]. Improving healthcare system's efficiency, service level and quality are the main principles and objectives in each stage of the implementations and advices of deepening the healthcare reform in China.

Improving healthcare service level and quality is also one of the core elements of the strategy for health development in the "healthy China 2030 program" issued by the State Council of China on 25 October 2016. As an important part and foundation of the reform and development of health service, healthcare quality directly concerns the rights and interests of people's health and personal experience on healthcare services. So healthcare service quality should be considered during the process of measuring the healthcare service efficiency. High efficiency means that institutions use minimum inputs to meet a certain quality and quantity outputs of healthcare service [4]. Efficiency and quality constitute the performance, so performance measurement of healthcare service not only can reveal the organizations' exact status of unsatisfactory performance areas, but also can provide the improvement strategies both for efficiency and quality [5].

Data envelopment analysis (DEA) method is a non-parametric method for evaluating the relative efficiency of the similar units which have multiple inputs and multiple outputs. DEA is widely applied to efficiency measurement of decision making units (DMUs) in various industries, including agriculture [6,7], industry [8,9] and service industry-such as finance [10,11], education [12,13], retail [14,15], healthcare service and so on. Thereby, in the field of healthcare service, the applications of DEA method mainly focus on the simple efficiency measurement of medical and healthcare institutions or organizations.

Rollins et al. [16] evaluated the efficiency of the United States' 36 Health Organization during 1933∼1997, basing on the study [17]. Using Malmquist-DEA method, Sulku [18] studied the efficiencies of provincial public hospitals in Turkey, including before and after the implementation of the healthcare reform. Kawaguchi et al. [19] measured the efficiency of Japan's 112 municipal hospitals after implementing the healthcare reform in 2007∼2009. This study applied a dynamic network DEA (DNDEA) model. Tigga and Mishra [20] applied the traditional DEA model to evaluate the healthcare systems' efficiency, and they took India's 27 states as DMUs. Samut and Cafrı [21] measured hospitals' efficiencies in 29 OECD countries by using DEA method and analyzed environment factors' influences on efficiency scores by using Panel Tobit Analysis. All above researches did not take into account the level of healthcare service quality in the efficiency measurement process, and assumed that the quality levels of all DMUs were the same. However, the quality levels of different DMUs are often significantly different in practice.

The existing researches, which focused on the association analysis between efficiency and quality of healthcare service, mainly applied regression analysis. Laine et al. [22] studied the association between productive efficiency and clinical quality of institutional long-term care for the elderly by applying stochastic production frontier approach. Their results revealed that there was no system relationship between productive efficiency and quality, but lower quality might have an impact on the productivity efficiency from a long-term point of view. Laine et al. [23] calculated the technical efficiency of institutional long-term care for the elderly by DEA method. Meantime, they discussed the relationship between quality and technical efficiency by Mann-Whitney test and correlation coefficients analysis. This study found a significant correlation between the technical efficiency and "unwanted dimensions of Quality". Gok and Sezen [24] measured the efficiency of 348 public hospitals in Turkey utilizing DEA method and analyzed the trade-off between quality and efficiency of healthcare service by multiple regression analysis. In the process of analysis, they took the efficiency values as explained variables and regarded healthcare service quality as explanatory variables. The results manifested that the hospital size could affect the trade-off between quality and efficiency. It can be seen that these researches did not integrate the quality and efficiency to discuss their association, and they took quality as an influence factor of efficiency. In addition, the trade-off between efficiency and quality of healthcare has not got a qualitative or quantitative conclusion form the aspect of united efficiency and quality.

In the healthcare service field, Nayar and Ozcan [25] first used quality-adjusted DEA model to measure and compare hospitals' comprehensive performance in terms of technical efficiency and quality. They concluded the hospitals were with higher efficiency also with higher quality services, and there was no evidence to prove the existence of a trade-off between quality and efficiency. This study directly puts 3 quality indicators as outputs to measure efficiency by DEA model. Quality-adjusted DEA model was developed by Sherman and Zhu [26], and it viewed quality as the output for efficiency measurement. DEA measures the efficiency through the ratio of inputs and outputs, so only taking quality as the output(s) may not lead to efficiency assessment fully. Moreover, each DMU will choose the most favorable own weights of inputs and outputs when we use DEA method to evaluate the efficiency, so it could result in the DMUs' quality levels incomparable by taking the quality indicators viewed as outputs to replace the comprehensive quality level. Consequently, it is essential for efficiency measurement more accurately and systematically to calculate the DMUs' relative quality index value and then put it as an additional output to indicate the quality level in DEA model.

Based on the analysis above, we calculate the relative quality index value Q of healthcare service of 31 provinces of mainland China by using technique for order preference by similarity to an ideal solution (TOPSIS) method, and then treat Q as the comprehensive quality level during efficiency measurement by DEA model. TOPSIS method calculates DMUs' relative index values by building ideal and negative ideal solutions, so its basic idea is similar to DEA method. Accordingly, we can calculate the Q and ensure the comparability, then evaluate DMUs' efficiency more fully by taking the Q as an additive output of comprehensive quality. In addition, we measure 31 provinces' relative performance and efficiency values Q-E and E, considering Q as an output or not, by using DEA method. Furthermore, we test the significant difference of Q among the east, central and the west by Kruskal Wallis test, and the significant difference between Q-E and E by Paired-Samples T test in order to discuss the association between quality and efficiency of healthcare service. In addition, the trade-off between efficiency and quality of healthcare is described qualitatively. For analyzing drivers of the performance and efficiency, we regard the E values and Q-E values as explanatory variables respectively, and apply Tobit regression method to analyze the influences of 12 environmental variables.

The remainder of the paper is organized as follows. In Section 2, we calculate the healthcare service quality index value Q by using TOPSIS method. Section 3 applies DEA model to measure the efficiency value E and performance value Q-E of 31 provinces of mainland China. Basing on the results of Sections 2 and 3, we analyze the association between quality and efficiency of healthcare service in Section 4. In Section 5, the effect of environment variables for E and Q-E, respectively, are inspected by Tobit regression. Section 6 concludes the study.

2. Calculation of Healthcare Service Quality Index Value Q

2.1. Measurement of Healthcare Service Quality

Healthcare service quality represents the ability to achieve the attainable health by using reasonable methods [27]. It also can be said as a way to improve the health status of "consumer" [28]. For the perspective of the ability of providing healthcare service, it is defined as the coherence degree between the individual's expectation of the healthcare service' outputs and the expertise levels of the existing healthcare service [29]. For the healthcare service organization, high healthcare service quality is one of important keys to improve patient satisfaction, maintain long-term competitive advantage and obtain profits [30,31]. Li and Bento [32] made a point that the necessary conditions for ensuring high quality of healthcare were appropriate technology, timely treatment, adequate demand-based service supply, and acceptable standards of healthcare practice. Healthcare service as a cornerstone of society, its impact is throughout the aspects of pharmaceutical, social, political, moral, commercial and economic [33]. Therefore, the healthcare service quality is a multi-dimensional complex system with multi-factor interaction influence. It will be affected together by the state policies and systems, the development of located region, and the front-line agencies and personnel providing healthcare service.

There are many researches that have studied the system of healthcare service quality from different perspectives. Giarelli [34] discussed the healthcare service quality from three main dimensions: management quality, stakeholder perceived quality and professional quality, and he depicted the multi-dimensional association in Figure 1. The management quality measures the efficiency and effectiveness of resource utilizing in the process of organization provide services for meeting the needs of all stakeholders. The stakeholder perceived quality includes people or patients' perception on healthcare service accessibility, responsiveness, doctor-patient association, attitudes of healthcare staff, etc. Professional quality refers to professional knowledge and treatment of healthcare experts.

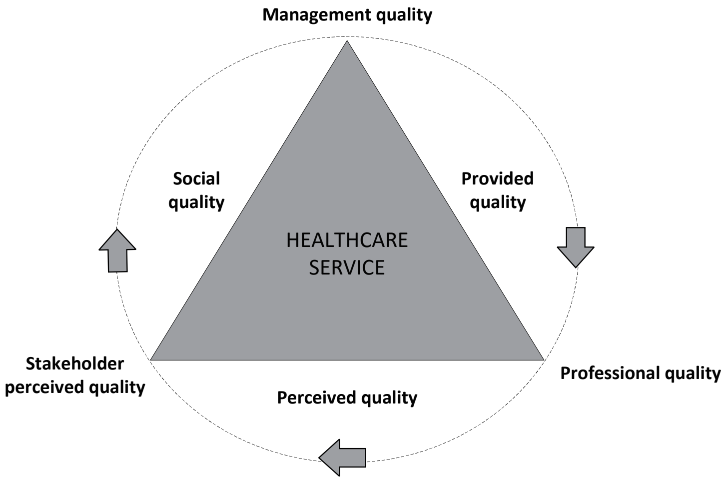


Figure 1. Multi-dimensional relationships of healthcare quality.

We take 31 provinces in mainland China as the research objects for measuring the healthcare service quality. Basing on the system of healthcare service quality proposed by Giarelli [34], and combining with the purpose of the study, we choose some certain indexes from the angle of output to measure the quality of the three dimensions with a microscopic perspective. Table 1 shows the specific indicators of healthcare quality and their descriptions.

(1) Management quality. Hospital beds as one of the key facilities in healthcare service, their management and operation would directly affect the allocation and management of other resources (e.g., personnel, large-scale inspection equipment, operating room, etc.). Therefore, it has a strong representation by using the efficiency and effectiveness of hospital beds management to measure the management quality. We utilize the indicators, utilization rate of hospital beds and working day of hospital beds, weigh the efficiency and effectiveness of hospital beds management, respectively.

(2) Professional quality. Mortality in emergency room and mortality in observation room, which are the negative indicators for measuring the effectiveness of healthcare services, together with the positive indicator—average length of stay are used to make an assessment to the professional quality of healthcare service from outpatient and inpatient. As the main healthcare service institution in China, the hospital professional quality is the core of professional quality of healthcare service. Hence, the three indicators can reflect the professional quality dimension in an all-round way.

(3) Stakeholder perceived quality. As the key stakeholders in healthcare services, society and patient perceptions on healthcare services are major for stakeholder perceived quality. We select the life

expectancy to express the society perceived quality, and select the average outpatient expenses and per capita hospitalization costs to express patient perceived.

Table 1. Indicators of healthcare service quality.

Dimensions	Indicators	Indicators Description
Management quality	Utilization rate of hospital beds (%)	Actually using bed days/actual opening total bed days × 100%, the key indicator for efficiency evaluation of beds efficiency
	Working day of hospital beds (day)	Actually using bed days/average opening bed days, evaluating the effectiveness of beds management
Professional quality	Mortality in emergency (%)	Emergency room death toll/emergency visits number × 100%, a negative indicator for measuring the effectiveness
	Mortality in observation room (%)	Observation room death toll/observing room people number × 100%, a negative indicator for measuring the effectiveness
	Average length of stay (day)	Actually using bed days of discharges/discharges number, shorten average length of stay is the healthcare reform's requirement, and it is the main objective of general hospitals
Stakeholder perceived quality	Life expectancy (year)	Average years expected to survive for newborn, one of the most important indicators to evaluate the quality of life and health of a country's population
	Average outpatient expenses (yuan)	Medical outpatient revenue/total number of medical treatment, an indicator of healthcare service expenses of individuals
	Per capita hospitalization costs	Medical inpatient revenue/discharges number, an indicator of healthcare service expenses of individuals

2.2. TOPSIS Method

TOPSIS method was proposed by Hwang and Yoon in 1981 [35]. By constructing the ideal solution and negative ideal solution of multi-index problem, TOPSIS takes two benchmarks (near the ideal solution and away from the negative ideal solution) as the basis for evaluating finite set of alternatives.

For a multi-attribute decision-making problem, there are k alternatives, and t attributes are for each alternative. Let $\mathbf{A} = \{a_k\}$ $(k = 1, 2, \ldots, p)$ be as the alternative set, and $\mathbf{\Phi} = \{\varphi_t\}$ $(t = 1, 2, \ldots, q)$ be as the attribute vector, then the calculation process of the TOPSIS method is as follows.

(1) Normalizing the attribute values of alternatives

Let $\mathbf{Z} = \{z_{kt}\}$ be the normalized vector of attribute value $\mathbf{\Phi} = \{\varphi_{kt}\}$. Then,

$$z_{kt} = \begin{cases} \frac{\varphi_{kt} - \varphi_t^{\min}}{\varphi_t^{\max} - \varphi_t^{\min}} & \text{if } t \text{ is a benifit attribute} \\ \frac{\varphi_t^{\max} - \varphi_{kt}}{\varphi_t^{\max} - \varphi_t^{\min}} & \text{for } t \text{ is a cost attribute} \end{cases}.$$

(2) Constructing the weighted norm matrix $\gamma = \{\gamma_{kt}\}$

Let $\mathbf{w} = (w_1, w_2, \ldots, w_t)^T$ be known as weight vector of attribute. Thus,

$$\gamma_{kt} = w_t \times z_{kt}.$$

(3) Determining the ideal solution γ^* and negative ideal solution γ^0

Let γ_t^* and γ_t^0 be the tth attribute value of ideal solution and negative ideal solution, respectively. Then,

$$\gamma_t^* = \begin{cases} \max\limits_k \gamma_{kt} & \text{if } t \text{ is a benifit attribute} \\ \min\limits_k \gamma_{kt} & \text{for } t \text{ is a cost attribute} \end{cases}$$

$$\gamma_t^0 = \begin{cases} \min\limits_k \gamma_{kt} & \text{if } t \text{ is a benifit attribute} \\ \max\limits_k \gamma_{kt} & \text{for } t \text{ is a cost attribute} \end{cases}.$$

(4) Calculating the distances from a_k to γ^* and γ^0, respectively denoted as d_k^* and d_k^0. Then,

$$d_k^* = \sqrt{\sum_{t=1}^{n} (\gamma_{kt} - \gamma_t^*)^2}$$

$$d_k^0 = \sqrt{\sum_{t=1}^{n} (\gamma_{kt} - \gamma_t^0)^2}.$$

(5) Calculating the ranking index C_k^* of each alternative,

$$C_k^* = d_k^0 / (d_k^0 + d_k^*).$$

(6) Ranking the alternatives on the C_k^* in descending order.

2.3. Results of Quality Index Value Q

We take the healthcare service quality of 31 provinces as alternatives, and take the 8 indicators shown in Table 1 as their attributes. We choose 2014 as the observation year, and collect data from China Healthcare and Family Planning Statistics Yearbook 2015. Thereby, the indicator of life expectancy calculated every 10 years uses the 2010 data. We calculate and rank the healthcare service quality value Q of 31 provinces by using TOPSIS method, and the results are shown in the column of quality index in Table 2. When constructing the weighted norm matrix, we apply entropy method to determine the weight of each indicator. According to the order of indicators in Table 1, the calculated weights are 0.137, 0.064, 0.075, 0.180, 0.180, 0.087, 0.044, 0.233. Based on the entropy theory [36], quantity and quality of information obtained by human being is one of key factors to the accuracy and reliability of decision-making. Accordingly, entropy method is more objective, more accurate, and can better explain the results obtained than subjective weighting method.

From the Q value column in Table 2, we can see that, in 31 provinces, Shanghai's Q is the largest, and Guizhou's is the smallest. In addition, their values are, respectively, 0.857 and 0.223. Divided 31 provinces by regions, the east's mean value of Q is maximum (0.573), the central's take the second place (0.5), and the west's is minimum (0.388). In the east region, 6 provinces' Q value are more than 0.5 within 11 provinces, including Beijing (0.611), Tianjin (0.595), Liaoning (0.659), Shanghai (0.857), Jiangsu (0.588) and Zhejiang (0.617). In the central region, 5/8 provinces' Q value are more than 0.5, including Shanxi (0.506), Heilongjiang (0.557), Jiangxi (0.502), Henan (0.555), and Hubei (0.603). In the western region, only Guangxi (0.512) and Sichuan's (0.582) Q values are more than 0.5 within 12 provinces. Applying Kruskal-Walliis test the Q values in different regions, we can see that the $p = 0.017$ from the test result in Table 3. The p value demonstrates that the healthcare service quality in east, central and west are significant difference in 95% confidence level.

Table 2. Efficiency, performance and quality index value.

Regions	Provinces	Quality Index		Efficiency		Performance	
		Q Values	Ranks	E Values	Ranks	Q-E Values	Ranks
the East	Beijing	0.611	4	1	1	1	1
	Tianjin	0.595	6	0.884	17	1	1
	Hebei	0.399	20	1	1	1	1
	Liaoning	0.659	2	0.546	28	0.424	25
	shanghai	0.857	1	1	1	1	1
	Jiangsu	0.588	7	0.818	18	0.534	21
	Zhejiang	0.617	3	1	1	1	1
	Fujian	0.366	24	1	1	1	1
	Shandong	0.475	16	0.973	12	0.604	19
	Guangdong	0.374	22	1	1	1	1
	Hainan	0.367	23	0.696	22	0.956	14
Mean		0.537	-	0.902	-	0.865	-
the Central	Shanxi	0.506	12	0.457	31	0.36	29
	Jilin	0.384	21	0.684	23	0.466	22
	Heilongjiang	0.557	9	0.49	30	0.455	23
	Anhui	0.423	19	1	1	1	1
	Jiangxi	0.502	13	0.771	20	0.665	18
	Henan	0.555	10	1	1	1	1
	Hubei	0.603	5	0.897	16	0.769	15
	Hunan	0.47	17	0.621	25	0.255	30
Mean		0.5	-	0.74	-	0.621	-
the West	Inner Mongolia	0.329	28	0.547	27	0.379	28
	Guangxi	0.512	11	0.918	13	0.746	16
	Chongqing	0.479	15	0.914	14	0.699	17
	Sichuan	0.582	8	0.913	15	0.431	24
	Guizhou	0.223	31	0.614	26	0.247	31
	Yunnan	0.305	29	0.814	19	0.561	20
	Tibet	0.247	30	1	1	1	1
	Shaanxi	0.447	18	0.753	21	0.42	26
	Gansu	0.344	27	1	1	1	1
	Qinghai	0.351	26	1	1	1	1
	Ningxia	0.485	14	0.64	24	1	1
	Xinjiang	0.353	25	0.543	29	0.41	27
Mean		0.388	-	0.805	-	0.627	-

Table 3. Test statistics [a,b].

	Q
Chi-Square	8.205
df	2
Asymp. Sig.	0.017

Note. [a] Kruskal Wallis Test; [b] Grouping Variable: region.

3. Measurement of Healthcare Service Performance

3.1. DEA Method

The basic idea of the DEA method is to construct the production frontier composed of Pareto optimal solution with minimum inputs and maximum outputs. This method calculates the DMUs' relative efficiency by measuring the distances between each DMU and production frontier [37]. Charnes et al. [38] proposed the first DEA model called CCR model, as well as the BCC model proposed by Banker et al. [39], are called the traditional DEA model. CCR model assumes scale returns of DMUs are constant (e.g., CRS) and measures the technology efficiency, which includes the scale efficiency. BCC model assumes the scale returns are variable (e.g., VRS), and the efficiency is called pure technical efficiency, which excludes the scale efficiency. DEA method is divided into input-oriented model and output-oriented model according to its different purpose of measuring efficiency. Input-oriented (Out-oriented) refers to the situation in which the outputs (inputs) are not decreased (increased), and inputs (outputs) values should be reduced (increased) to achieve relative efficiency [38]. In practice, managers want to improve efficiency from the both points of view of reducing inputs and increasing outputs, so some scholars put forward the non-oriented model. Tone [40] proposed the non-oriented slacks-based model (SBM) from the angle of slacks improvements. Taking the SBM-CRS model as an example, we can get its mathematical form as below.

$$\min \quad \theta_o = \frac{1-(1/m)\sum_{i=1}^{m} s_i^- / x_{io}}{1+(1/s)\sum_{r=1}^{s} s_r^+ / y_{ro}} \tag{1}$$

$$s.t. \quad \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro} \tag{2}$$

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io} \tag{3}$$

$$\lambda_j \geq 0, \;\; s_i^- \geq 0, \;\; s_r^+ \geq 0, \;\; j = 1,2,\ldots,n, \;\; i = 1,2,\ldots,m, \;\; r = 1,2,\ldots,s$$

where θ_o is the efficiency value of DMU*o*. $\{x_{ij}\}$ and $\{y_{rj}\}$ are the observed values of DMUs' inputs and outputs respectively. $\{s_i^-\}$ and $\{s_r^+\}$ are, respectively, slacks improvement of inputs and outputs. λ_j is the weight coefficient of the reference DMU*j*. When we add the constraint $\sum_{j=1}^{n} \lambda_j = 1$, the above model represents the SBM-VRS model. When the efficiency value $\theta_o = 1$, DMU*o* is called DEA efficient, otherwise called DEA inefficiency.

3.2. Data and Indicators

The purpose of this study is to measure the performances of healthcare service of 31 provinces, and analysis the association between quality and efficiency based on the quality effect on efficiency. Therefore, we both assess the 31 provinces' relative efficiency value E and the performance value Q-E, which consider the quality by taking the healthcare service quality index value Q (calculated in Section 2.3) as an additional output in the efficiency measurement process. We take provinces as DMUs, and measure their healthcare service efficiencies and performances from macroscopic level. Meanwhile referring to the relevant literatures, and from the aspects of human, financial and material, we select number of healthcare service institution, number of healthcare service personnel, total healthcare expenditure and number of bed as inputs. In addition to Q, we select number of treatment and total healthcare income, which are the most direct healthcare service output indicators, as outputs. According to the latest statistical data released by the relevant departments of the state, we choose 2014 as the observation year, and all data are derived from China Health and Family Planning Statistical Yearbook 2015 compiled by the National Health and Family Planning Commission of the People's Republic of China.

3.3. Results and Discussion

We choose SBM-CRS model to measure the technical efficiency and consider both input and output slacks, then apply the DEA SOLVER PRO 5.0 software to solve the model. The results of 31 provinces' efficiency value E and performance value Q-E are shown in Table 2. Figure 2 shows the relationships of Q, E and Q-E values among 31 provinces by the form of series chart.

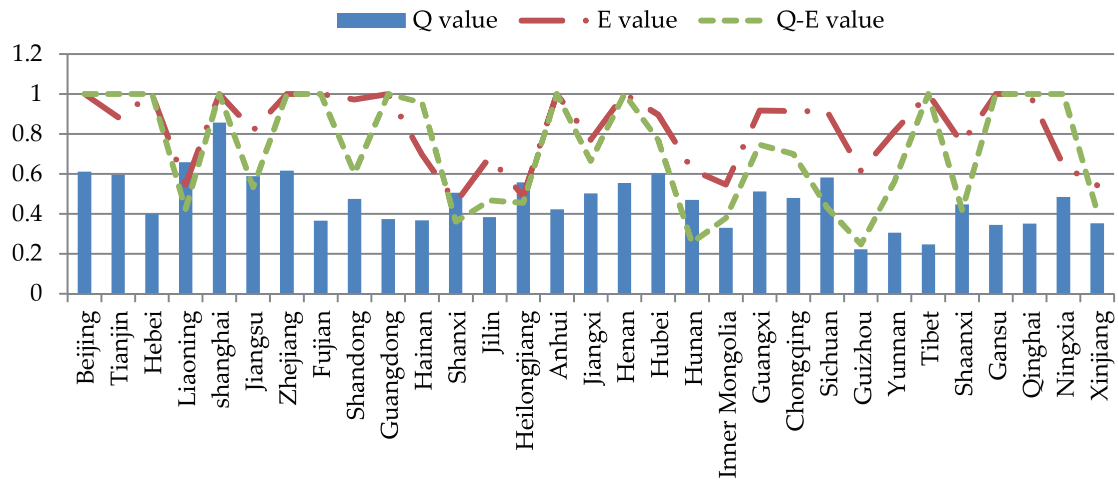


Figure 2. Relationships of 31 provinces of Q, E and Q-E value.

From column E in Table 2, we can see that 11 provinces are DEA efficient (i.e., efficiency value E is 1). In the east, central and west, the proportions of efficiency provinces are 6/11, 2/8 and 3/12 respectively. The mean efficiency of the east is maximum (0.902), the west's is the second (0.805), and the central's is minimum (0.74). From the column Q-E, 13 provinces, including the 11 provinces that DEA efficient without quality, are DEA efficient (i.e., performance value Q-E is 1) with consideration of quality. Therefore, Tianjin and Ningxia achieve DEA efficient by considering the quality as an additional output in efficiency measurement DEA model. The east's Q-E mean value is also the largest (0.865), the central's is the second (0.627), which is slightly more than the west's (0.621). From Table 2 and Figure 2, we can clearly see that the remaining 28 provinces' Q-E values are not more than their E values, except Tianjin, Ningxia and Hainan.

4. Association between Quality and Efficiency

4.1. Effect of Quality on Relative Efficiency Values

In order to verify the difference between E and Q-E values, we use paired-samples t test to test their difference significance from the nation, the east, the central and the west respectively, and the test results are shown in Table 4. The column p in Table 4 indicates that there are significant differences between E values and Q-E values except the east region, and the difference is statistically significant at 99% confidence level in the nation.

Table 4. Paired samples statistics of E and Q-E.

			df	std. Error Mean	t	p
the Nation	E	Q-E	30	0.033	3.034	0.005 ***
the East	E	Q-E	10	0.052	0.691	0.505
the Central	E	Q-E	7	0.044	2.715	0.030 **
the West	E	Q-E	11	0.064	2.308	0.041 **

Note. ***, **, * denote, respectively, significance at the 1%, 5% and 10% levels.

From the results in Section 3.3, we can obtain the effect of healthcare service quality on relative efficiency that the relative performance value of healthcare service is less when taking quality index as an additional output in efficiency measurement. Specifically, there are three cases: (1) For DEA efficient DMUs. The 11 provinces, of which DEA efficient is without consideration of quality, are still DEA efficient with consideration of quality. In addition, the scope of quality index value Q are larger within the 11 provinces, such as Shanghai's Q value (0.857) which is the largest one in 31 provinces, and Tibet's

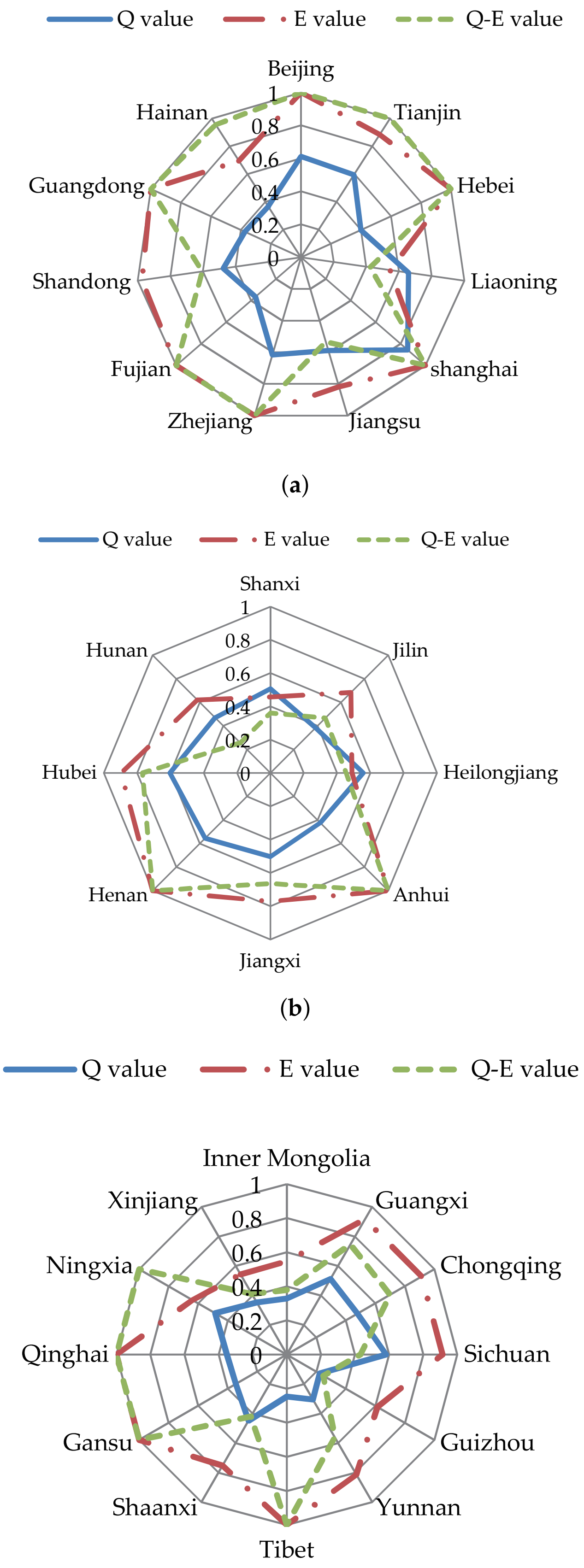
Q value is 0.247, which is the second smallest. Thus, it is clear that the quality does not have effect on DEA efficient DMUs' relative efficiency when taking the relative quality index Q as an additional output. (2) For DEA inefficient DMUs. In the 20 DEA inefficient provinces, excluding Tianjin, Ningxia and Hainan, the remaining 17 provinces' performance values that are with consideration of quality are decreasing. Therefore, for the DEA inefficient DMUs, the quality has a negative effect on their relative efficiency values when taking the relative quality index Q as an additional output. (3) For special DMUs. The special DEA inefficient provinces–Tianjin, Ningxia and Hainan's relative efficiencies are increasing when taking the relative quality index Q as an additional output. Tianjin and Ningxia become DEA efficient, and Hainan's relative efficiency value are increasing from 0.696 to 0.956. These three provinces' relative quality index values Q are 0.595, 0.485 and 0.367, respectively, and their ranks are the 6th, 14th and 23rd. Therefore, the relative quality is not the main reason of their efficiency increasing. From the analysis above and with the ranks' change of Q, E and Q-E values in Table 2 and Figure 2, we can conclude that there is an effect of quality on relative efficiency value, but the influence is not clear. From the perspective of the whole nation, the influence could be positive, negative or not obvious.

4.2. Association between Quality and Relative Efficiency

From a regional point of view, the relative efficiency values E and Q-E in Table 2 reveal that the east's mean value is maximum, followed by the west's, and the central's is the smallest. However, we can see clearly that the mean efficiency values gap between the central and the west is significantly narrowed when take into consideration of quality. The two regions' mean efficiency values are changed from 0.805 and 0.74 to 0.627 and 0.621. Combining with the mean values of regional quality index Q of Table 2, in which the quality index value Q of the central is greater than that in the west, we can conclude that the high quality helps to increase the efficiency's relative advantage as a whole. The association between quality and efficiency is analyzed in each region, the results are shown in Figure 3, which express the associations among Q value, E value and Q-E value in each region, separately, by the form of radar chart.

Figure 3a indicates the association among Q value, E value and Q-E value of 11 provinces in the east. Combining with Table 2, We can find that the east is with high relative quality and high relative efficiency. In this region, the province's Q-E value may be bigger than its E value (e.g., Tianjin and Hainan), or smaller (e.g., Liaoning, Jiangsu and Shandong), or equal (e.g., the provinces which E = 1). Moreover, the trend of Q change is not the same as the E and Q-E according to the curve in Figure 3a. For example, the Q of Hebei and Fujian are the two smallest in the 11 provinces (only 0.399 and 0.366), but both their E values and the Q-E values reach the maximum value 1. However, from Table 2, we can see that the rank of the Q-E value is not lower than that of the E value in the east provinces except Jiangsu and Shandong. Therefore, the high quality taken as an additional output, can increase the ranks of relative efficiency of the DMUs, even if it could decrease values of relative efficiency.

Figure 3b indicates the association among Q value, E value and Q-E value of 8 provinces in the central. It can be seen that the all province's Q-E value is not larger than its E value in the central. From the curves, we can get that the trend of Q change is in accord with that of E and Q-E, and there is a positive correlation between them. Combining with the ranks of E values and Q-E values in Table 2, we can see that the provinces' relative rank of Q-E value is not lower than that of E value in the central except Hunan. In particular, excluding the two DEA efficient provinces (Anhui and Henan), the other 5 provinces' ranks are increased. To summarize, we can conclude that the higher relative quality could help to promote the relative advantages of efficiency of DMUs whose relative efficiencies are lower.



(**c**)

Figure 3. Association among Q value, E value and Q-E value. (**a**) In the east; (**b**) In the central; (**c**) In the west.

Figure 3c shows the association among Q value, E value and Q-E value of 12 provinces in the west. The figure indicates that there are 9 of the 11 provinces' Q-E values are smaller than their E values, and only Ningxia's Q-E value is bigger than its E value. From the curves, we also can obtain that the ranks change trends of Q value, E value and Q-E value are not perfectly consistent. For example, Sichuan's higher relative quality, whose rank is the 8th in 31 provinces, pushes down its relative efficiency rank. From Table 2, we can see that rank of Sichuan's relative efficiency changes from the 15th to the 24th when we take the quality as an additional output in the efficiency measurement process. In addition, it can be seen that 10 provinces' ranks of relative efficiency are decreased when we take the quality as an additional output in the 12 provinces of the west. Meanwhile, we know that the west's mean E value 0.805 is less than that of the east 0.902, and the west's mean Q value is the smallest, which is only 0.338 and much lower than the east and the central's mean Q values 0.537 and 0.5. Therefore, it can be concluded that when the relative efficiency of DMUs does not have an absolute advantage, their lower quality would also significantly reduce the rank of relative efficiency.

In summary, there is a certain association between quality and efficiency in healthcare service and the association can be classified into three cases. (1) If DMU's relative efficiency has an absolute advantage (e.g., the east's mean E value is the largest), the quality, as an additional output, could cut down the sheer value of relative efficiency, but the highest relative quality (e.g., the east's mean Q value is the largest) could not lead to the rank of DMU's relative efficiency decrease. (2) When the relative efficiency is the lowest (e.g., the central's mean E value is the smallest), although the relative performance value with consideration of quality is still reduced, the higher relative quality (e.g., the central's mean Q value is much bigger than the west's) can make a significant increase to rank of relative efficiency and greatly enhance the comparative advantage of relative efficiency. (3) When there is no absolute advantage in the relative efficiency (e.g., the west's mean E value is smaller than the east's), the lowest quality (e.g., the west's mean Q value is the smallest, and much smaller than the central's) not only leads to a decrease of relative efficiency value, but also reduces the rank of relative efficiency for reducing the advantage of relative efficiency. These three conclusions also demonstrate that high quality of healthcare service do not lead to a decrease in relative efficiency, whereas higher quality could lead to a promotion for the relative efficiency (e.g., provinces in the east and central) and the lowest quality could lead to the decline of relative efficiency (e.g., provinces in the west).

5. Performance Drivers

5.1. Tobit Regression

In order to analyze the net influences of some relevant factors on the relative efficiency value E and performance value Q-E of healthcare service further, we take the E value and Q-E value, respectively, as the explained variables for regression analysis. The interval of relative efficiency or performance value, measured by DEA method, is [0, 1], so the general least squares (OLS) could cause estimation bias because of the truncation of the explained variables [41]. Tobit model is a regression model based on the maximum likelihood estimation method in which the explained variable is limited. Tobit regression model can be estimated by the below expression.

$$\delta_{it} = \begin{cases} \mathbf{z'}_{it}\boldsymbol{\beta} + \varepsilon_{it} & \text{if } 0 < \delta_{it} < 1 \\ 0 & \text{for other values of } \delta_{it} \end{cases}$$

where δ_{it} is observed value of E or Q-E. $\mathbf{z}_{it}$ is a vector of environmental variables. $\boldsymbol{\beta}$ is a vector of parameters of coefficients to be estimated. ε_{it} is statistical noise, and $\varepsilon_{it} \sim N(0, \sigma^2)$.

Although the Tobit model is widely used in the truncated regression problem, it has some constraints in practical application. Simar and Wilson [42,43] pointed out that the correlation between the environmental variables and the efficiency value, measured by DEA method, might lead to inconsistency of estimate in Tobit model. Perez-Reyes and Tovar [44] also proposed that the sample representative might have some limitations in the estimation process. In this study, we choose the external environmental factors, which are not related to the E and Q-E values as much as possible, to ensure the consistency of estimation. We also use the scatter plot to verify that there is no obvious correlation between the selected environment variables and E or Q-E. The scatter plots can be seen in Appendix A, and Z1∼Z12 depicted in Section 5.2 in detail are the 12 environment variables. At the same time, we choose all 31 provinces of mainland China as the sample, so there is no sample representative problem. Therefore, Tobit model can be used to analyze the influence of the selected 12 environmental factors on the relative efficiency or performance.

5.2. Environment Variables

We study the performance of healthcare service of 31 provinces from a macro perspective, so 12 environment variables are chosen from the angle of the horizontal comparability of each variable to analysis the performance and efficiency drivers. The 12 environment variables are focused on the three aspects of the people's living standard, the degree of government attention and the level of healthcare development, which are depicted in Table 5. We take 2014 as the observation year, and data come from China Statistics Yearbook 2015 and China Healthcare and Family Planning Statistics Yearbook 2015. Due to the data of Z5∼Z6 that were counted in the yearbook 2015 is the data of 2013, so we use the 2013 data for analysis, and we can believe that it could not affect the results directly.

Table 5. Environment variables

Variables	Variables Name	Variables Description
Z1	per capita GDP (ten thousand yuan)	GDP/population, it is not only used to measure a region's economic development, but also used to a measurement of the people living standard.
Z2	per capita disposable income (ten thousand yuan)	It is the average of personal disposable income, which is used to measure the changes of people's living standards, and it is proportional to living standards.
Z3	natural population growth rate (%)	(number of births per year-number of deaths per year)/average number of people × 100% = birth rate − population mortality rate, it is an important indicator of population growth and population planning, and it is used to indicate the extent and trend of natural population growth.
Z4	percentage of medical income (%)	medical income/total health income × 100%, it represents income generated by the medical and healthcare institutions to carry out medical service activities in the total income of medical institutions.
Z5	percentage of total healthcare expenditure to GDP (%)	total health expenditure/GDP × 100%, it is used to measure the importance of health in a region, the World Health Organization (WHO) stipulates that a country of this indicator value should not less than 5% (China was 5.55% in 2014).
Z6	percentage of government healthcare expenditure (%)	government health expenditure/total health expenditure × 100%, it is used to measure the degree of government's emphasis on health and its fiscal functions.
Z7	per capita healthcare expenditure (ten thousand yuan)	total health expenditure/population, it is used to measure the level of resource utilization and fairness in a region.
Z8	percentage of healthcare technical personnel (%)	healthcare technical staff/total healthcare staff × 100%, it is used to measure the level of public health and the development of healthcare service in a country or region.
Z9	number of healthcare technical personnel per 1000 population (ren)	healthcare technical personnel/(population × 1000), it is used to measure the level of human resource investment and the fairness of the distribution of medical and health service.
Z10	number of inpatients per 100 outpatients (ren)	inpatients/outpatients × 100%, it is used to measure the level of medical care.
Z11	number of outpatient per doctor per day (ren)	number of clinics/number of average physicians/251, it is also used to measure the level of medical care.
Z12	actual using bed per doctor per day (day)	total days of actual bed occupancy/average number of physicians/365, it is used to measure the quality and efficiency of medical service, and reflects the workload of doctors.

5.3. Results and Discussion

We test the net effects of 12 environment variables on the efficiency value E and performance value Q-E, respectively, by using Tobit regression. Table 6 presents the results of their coefficient estimates and t values, from which we can draw that there are 5 environment variables statistically significant to E at 1%, 5% or 10% levels, including Z1, Z3, Z5, Z8 and Z11. Meanwhile, there are 6 variables statistically significant to Q-E at 1%, 5% or 10% levels, including Z1, Z3, Z7, Z8, Z9 and Z10, and neither of the other variables of Z2, Z4, Z6 and Z12 are statistically significant to E nor Q-E.

Variable Z1 is statistically significant to E at 5% level and to Q-E at 10% level, but it has different coefficient for them. The coefficient is positive (0.075) for E and negative (−0.308) for Q-E. These coefficients denote that environment variable Z1 has a positive effect on efficiency of healthcare service without considering the quality, but it has a negative effect on the performance when we take the quality as an additional output. Therefore, as a measurement of the people living standard, Z1 would help to improve efficiency of healthcare service. However, with the improvement of people's living standards, people's attention to health is also increasing, and the requirement for healthcare service's quality is increasing. In turn, the increase of per capita GDP would limit the performance of healthcare service with consideration the quality.

Z3 is also both statistically significant to E and Q-E, respectively at 5% level and at 1% level, with the coefficients are 0.026 and 0.053. The positive coefficients denote that one unit increase in Z3 can augment 0.026 and 0.053 units in E and Q-E, respectively. Natural population growth rate (Z3) is directly related to the population of one region, so it can be seen that the increase of population is conducive to improving the efficiency of healthcare service whether with consideration of quality or not.

Z5 is statistically significant to E at 10% level, but not statistically significant to Q-E. The coefficient to E is 0.09, so it has a positive effect to E value, but it has a negative effect to Q-E value with coefficient −0.201. As we known, in one region, the higher percentage of total healthcare expenditure to GDP (Z5) achieved, the greater people's emphasis on health, but the higher the efficiency of healthcare service has, the lower the performance of healthcare service with consideration of quality has.

Z7, in contrast to Z5, is statistically significant to Q-E at 5% level, but not statistically significant to E. It indicates that the utilization level and fairness of medical resources in one region has no significant effect on the efficiency of healthcare service, but there is a significantly positive effect on the performance of healthcare service with consideration of quality. Therefore, the higher and fairer the utilization of medical resources achieved, the higher the performance of healthcare service has.

Z8 is both statistically significant to E at 1% level and to Q-E at 5% level, and it has negative effects to them. So we can conclude that the increase of healthcare technical personnel in China at present not only cannot promote the improvement of efficiency of healthcare service but also would restrict it, whether considering the quality or not. Therefore, it makes clear that China's healthcare service needs to be further developed from improving outputs and quality, and should not be from the aspect of increasing investments only.

Z9 and Z10 are both statistically significant to Q-E at 5% level and 1% level, and they both have a negative effect to it. Number of healthcare technical personnel per 1000 population and number of inpatients per 100 outpatients (Z9 and Z10) indicate the level of medical service by the development level and equality of professional human resource. Therefore, it can be concluded that the improvement of the medical service's level in one region does not mean the improvement of the efficiency of the healthcare service. Conversely, the performance of the healthcare service would decrease significantly with the improvement of the medical service's level.

Z11 is statistically significant to E at 5% level, but not statistically significant to Q-E, and the coefficient to E is 0.072. Number of outpatient per doctor per day (Z11) reflects, to a certain extent, the output indicator number of treatment, so the increase plays a positive role for the efficiency promoting. However, it has no significant effect on the performance with quality considering, which reveals that the increasing of number of outpatient per doctor per day does not have a significant effect on the improvement of healthcare service quality.

Table 6. Results of Tobit regression.

Variables	E Values		Q-E Values	
	Coefficient	t-Ratio	Coefficient	t-Ratio
Z1	0.075 (0.030)	2.58 **	−0.308 (0.159)	−1.93 *
Z2	0.093 (0.203)	0.46	0.294 (0.367)	0.8
Z3	0.026 (0.012)	2.22 **	0.053 (0.018)	2.91 ***
Z4	0.810 (1.000)	0.81	−0.413 (1.689)	−0.24
Z5	0.090 (0.049)	1.85 *	−0.201 (0.152)	−1.32
Z6	0.001 (0.005)	0.12	0.006 (0.009)	0.7
Z7	0.359 (0.966)	0.37	9.155 (3.482)	2.63 **
Z8	−7.528 (1.554)	−4.84 ***	−5.547 (2.233)	−2.48 **
Z9	−0.034 (0.062)	−0.54	−0.241 (0.098)	−2.47 **
Z10	−0.058 (0.036)	−1.64	−0.164 (0.053)	−3.07 ***
Z11	0.072 (0.033)	2.18 **	0.037 (0.052)	0.72
Z12	0.063 (0.136)	0.46	0.110 (0.222)	0.49
-cons.	4.319 (1.387)	3.11	6.270 (2.517)	2.49

Note. (1) Std.Err. are given in parentheses. (2) ***, **, * denote, respectively, significant at the 1%, 5%, 10% levels.

In summary, the effects of environment variables on the efficiency of healthcare service are varied and even have exact opposite effects under the condition of consideration of quality or not in the measurement process. Such as Z1 and Z5, which are variables reflecting social or people's attention to health, have significant positive impacts on the efficiency of healthcare service without consideration of quality, but have negative effects on the performance with consideration of quality. It shows that China's healthcare service's quality development level lags behind the level of its technical efficiency, and it also confirms the previous result that performance Q-E value with consideration of quality is less than the efficiency E value without consideration of quality. At the same time, the variables Z8, Z9 and Z10, which reflect the healthcare service's level and development status, have a negative effect on efficiency of healthcare service whether they are with considering the quality or not. Consequently, we can see that while China is improving the level and promoting the development of healthcare service, the quality and efficiency of healthcare service have not kept pace with its development, and may even develop at an expense of quality and efficiency to achieve the extensive development. Especially, the 3 variables Z8, Z9 and Z10 all have a significant negative impact on the performance with consideration of quality. Therefore, we should both focus on improving the quality and efficiency of healthcare service with the development of healthcare service.

6. Conclusions

Performance includes quality and efficiency, and there is obviously an association between quality and efficiency. As a special product, the quality of healthcare service is directly related to the final utility of the service. We take the quality as an additional output in the process of using DEA model to measure the performance of healthcare service of 31 provinces of mainland China. In order to ensure the comparability of the quality and the validity of efficiency measurement, we use TOPSIS method to rank the quality of healthcare service of 31 provinces. At the same time, we take the ranking index Q as the quality index value to measure the quality level and an additional output in performance measurement process by DEA model. Results show that the quality index value Q of Shanghai is the highest (0.857), and Guizhou's is the lowest (0.223). While divided by regions, the east's mean quality index value is the highest (0.537), the second is the central's (0.5), and the west's is the lowest (0.223). The Kruskal-Walliis test shows that there are significant differences between the mean quality index values of healthcare service in the different regions.

In order to measure the association between the efficiency and quality of healthcare service, we use the SBM-CRS model to measure the 31 provinces' relative efficiency value E and performance value Q-E respectively. Value E is the relative efficiency without consideration of quality, and value Q-E is the performance in which efficiency measurement process takes the quality as an additional output. Results show that the east's E and Q-E values are both the largest (0.902, 0.865), followed by the west's (0.805, 0.627), the central's are minimum (0.74, 0.621). Except Liaoning, Hainan and Ningxia, the others DEA inefficient provinces' Q-E values are all less than their E values. We also validate that between the E and Q-E values of the nation, the central and the west are significant difference by paired-samples t test.

Then we analyze the association between efficiency and quality of healthcare service from the perspective of the east, the central and the west regions. The results show that there is a certain association between relative efficiency and quality. The effect of quality on relative efficiency is related to the DMU's relative quality and efficiency's advantage. The association can be summed into the following 3 cases: (1) When relative efficiency has the absolute superiority, higher quality would not lead to the decrease of its relative efficiency advantage, such as the east. (2) When the relative efficiency does not have the absolute advantage, the lower quality would not enhance its relative efficiency advantage, but even weaken it, such as the west. (3) When the relative efficiency is the lowest, the higher quality would greatly enhance the relative advantages of its efficiency, such as the central.

We take the E and Q-E values, respectively, as explained variables, and analyzes the net influences of 12 environment variables by Tobit regression. The results show that the impacts of environment variables on the efficiency of healthcare service would vary, or even have an opposite effect, depending on whether we consider the quality as an additional output or not. Such as per capita GDP and percentage of total healthcare expenditure to GDP both have significant different effects on the efficiency and performance whether we consider the quality or not. In general, the results of Tobit regression show that the development of the quality and efficiency of healthcare service in China has lagged far behind the development of healthcare service.

In addition to the above empirical results and recommendations, this research also has the three contributions as follows: (1) Combining with the characteristics of DEA method, we present a more scientific and reasonable idea of taking quality indicator as an output. We use the multi-attribute decision-making method TOPSIS to achieve the ranking and measurement of DMUs' relative quality, and make them more comparable; (2) We analyze the quality and efficiency of healthcare service from a macro perspective, and measure the overall performance of healthcare services of 31 provinces of mainland China; (3) We get the association between quality and efficiency of healthcare service, and complement existing research on trade-off issues between efficiency and quality of healthcare service.

Conflicts of Interest: The author declare no conflict of interest.

Appendix A

Appendix A.1

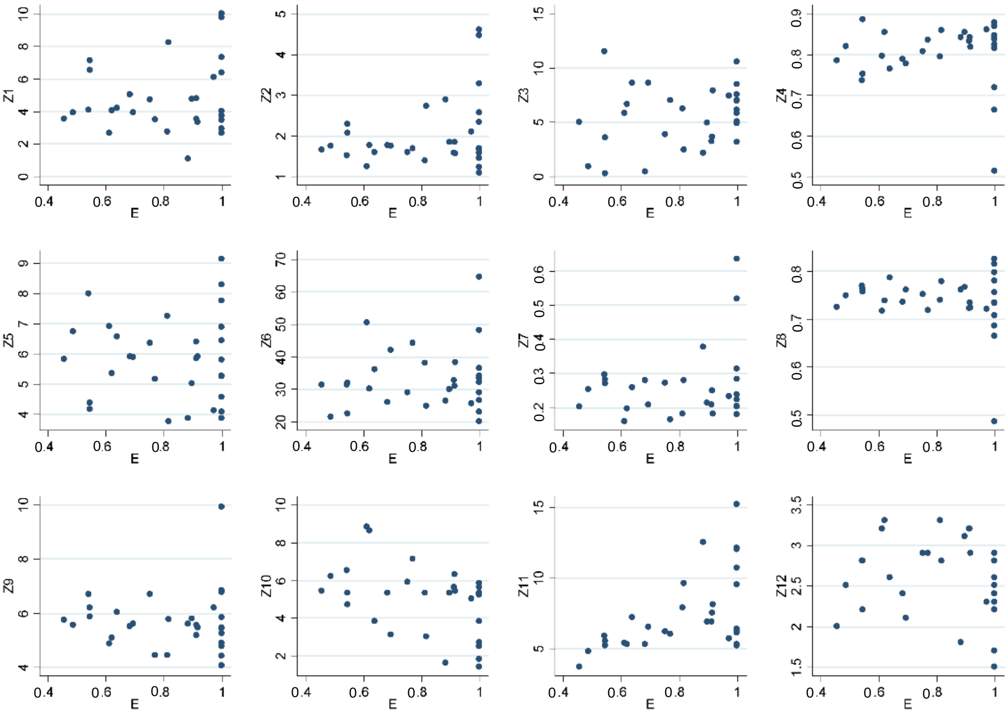


Figure A1. Scatter plots between E and Z1∼Z12.

Appendix A.2

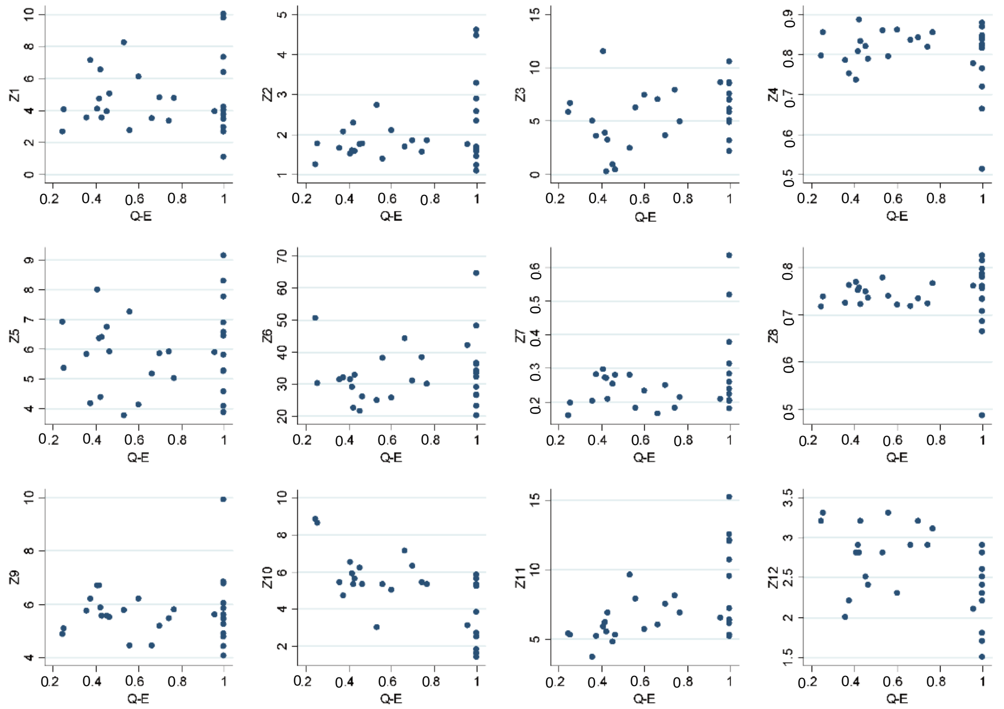


Figure A2. Scatter plots between Q-E and Z1∼Z12.

References

1. Chang, S.J.; Hsiao, H.C.; Huang, L.H.; Chang, H. Taiwan quality indicator project and hospital productivity growth. *Omega* **2011**, *39*, 14–22.
2. Li, C. Influence of previous healthcare reforms on evolution of medical service in China. *Med. Philos.* **2015**, *2015*, 38–41.
3. Ji, N.; Li, J.J.; Huang, M.Y. Survey analysis of the status and role of urban community health service system in mitigating the "difficult and expensive". *J. Med. Theory Pract.* **2012**, *25*, 2560–2570.
4. Ozcan, B. *Health Care Benchmarking and Performance Evaluation*; Springer: New York, NY, USA, 2008.
5. Bhagwat, R.; Sharma, M.K. Performance measurement of supply chain management: A balanced scorecard approach. *Comput. Ind. Eng.* **2007**, *53*, 43–62.
6. Atici, K.B.; Podinovski, V.V. Using data envelopment analysis for the assessment of technical efficiency of units with different specialisations: An application to agriculture. *Omega* **2015**, *54*, 72–83.
7. Skevas, T.; Serra, T. The role of pest pressure in technical and environmental inefficiency analysis of dutch arable farms: An event-specific data envelopment approach. *J. Product. Anal.* **2016**, *46*, 1–15.
8. Christopoulos, A.G.; Dokas, I.G.; Katsimardou, S.; Vlachogiannatos, K. Investigation of the relative efficiency for the greek listed firms of the construction sector based on two dea approaches for the period 2006–2012. *Oper. Res.* **2016**, *16*, 423–444.
9. Wu, J.; Yin, P.; Sun, J.; Chu, J.; Liang, L. Evaluating the environmental efficiency of a two-stage system with undesired outputs by a dea approach: An interest preference perspective. *Eur. J. Oper. Res.* **2016**, *254*, 1047–1062.
10. Tsolas, I.E.; Charles, V. Incorporating risk into bank efficiency: A satisficing dea approach to assess the greek banking crisis. *Expert Syst. Appl.* **2015**, *42*, 3491–3500.
11. Amin, G.R.; Hajjami, M. Application of optimistic and pessimistic owa and dea methods in stock selection. *Int. J. Intell. Syst.* **2016**, *31*, 1220–1233.
12. Nazarko, J.; Šaparauskas, J. Application of dea method in efficiency evaluation of public higher education institutions. *Technol. Econ. Dev. Econ.* **2014**, *20*, 25–44.
13. Lee, B.L.; Worthington, A.C. A network dea quantity and quality-orientated production model: An application to australian university research services. *Omega* **2015**, *60*, 26–33.
14. González, E.; Cárcaba, A.; Ventura, J. How car dealers adjust prices to reach the product efficiency frontier in the spanish automobile market. *Omega* **2014**, *51*, 38–48.
15. Zervopoulos, P.D.; Brisimi, T.S.; Emrouznejad, A.; Cheng, G. Performance measurement with multiple interrelated variables and threshold target levels: Evidence from retail firms in the US. *Eur. J. Oper. Res.* **2016**, *250*, 262–272.
16. Rollins, J.; Lee, K.; Xu, Y.; Ozcan, Y.A. Longitudinal study of health maintenance organization efficiency. *Health Serv. Manag. Res.* **2001**, *14*, 249–262.
17. Draper, D.A.; Solti, I.; Ozcan, Y.A. Characteristics of health maintenance organizations and their influence on efficiency. *Health Serv. Manag. Res.* **2000**, *13*, 40–56.
18. Sulku, S.N. The health sector reforms and the efficiency of public hospitals in turkey: Provincial markets. *Eur. J. Public Health* **2012**, *22*, 634–638.
19. Kawaguchi, H.; Tone, K.; Tsutsui, M. Estimation of the efficiency of japanese hospitals using a dynamic and network data envelopment analysis model. *Health Care Manag. Sci.* **2014**, *17*, 101–112.
20. Tigga, N.S.; Mishra, U.S. On measuring technical efficiency of the health system in india: An application of data envelopment analysis. *J. Health Manag.* **2015**, *17*, 285–298.
21. Samut, P.K.; Cafrı, R. Analysis of the efficiency determinants of health systems in oecd countries by dea and panel tobit. *Soc. Indic. Res.* **2016**, *129*, 1–20.
22. Laine, J.; Finnesoveri, U.H.; Bjorkgren, M.; Linna, M.; Noro, A.; Hakkinen, U. The association between quality of care and technical efficiency in long-term care. *Int. J. Qual. Health Care* **2005**, *17*, 259–267.
23. Laine, J.; Linna, M.; Hakkinen, U.; Noro, A. Measuring the productive efficiency and clinical quality of institutional long-term care for the elderly. *Health Care Manag. Sci.* **2005**, *14*, 245–256.
24. Gok, M.S.; Sezen, B. Analyzing the ambiguous relationship between efficiency, quality and patient satisfaction in healthcare services: The case of public hospitals in turkey. *Health Policy* **2013**, *111*, 290–300.

25. Nayar, P.; Ozcan, Y.A. Data envelopment analysis comparison of hospital efficiency and quality. *J. Med. Syst.* **2008**, *32*, 193–199.
26. Sherman, H.D.; Zhu, J. *Service Productivity Management: Improving Service Performance Using Data Envelopment Analysis (Dea)*; Springer: New York, NY, USA, 2006.
27. Donabedian, A. Quality assessment and assurance: Unity of purpose, diversity of means. *Inquiry A J. Med. Care Organ. Provis. Financ.* **1988**, *25*, 173–192.
28. Marshall, G.N.; Hays, R.D.; Mazel, R. Health status and satisfaction with health care: Results from the medical outcomes study. *J. Consult. Clin. Psychol.* **1996**, *64*, 380–390.
29. Arah, O.A.; Westert, G.P.; Hurst, J.; Klazinga, N.S. A conceptual framework for the oecd health care quality indicators project. *Int. J. Qual. Health Care* **2006**, *1*, 5–13.
30. Headley, D.E.; Miller, S.J. Measuring service quality and its relationship to future consumer behavior. *J. Health Care Mark.* **1993**, *13*, 32–41.
31. Sgroi, F.; Trapani, A.M.D.; Testa, R.; Tudisca, S. Strategy to increase the farm competitiveness. *Am. J. Agric. Biol. Sci.* **2014**, *9*, 394–400.
32. Li, L.; Bentonb, W.C. Hospital capacity management decisions: Emphasis on cost control and quality enhancement. *Eur. J. Oper. Res.* **2003**, *146*, 596–614.
33. Lupo, T. A fuzzy framework to evaluate service quality in the healthcare industry: An empirical case of public hospital service evaluation in sicily. *Appl. Soft Comput.* **2016**, *40*, 468–478.
34. Giarelli, G. *Il Malessere Della Medicina. Un Confronto Internazionale*; Franco Angeli: Milan, Italy, 2003.
35. Hwang, C.L.; Yoon, K. *Multiple Attribute Decision Making*; Springer: Berlin/Heidelberg, Germany, 1981; pp. 287–288.
36. Shannon, C.E. Communication theory of secrecy systems. *Bell Labs Tech. J.* **1949**, *28*, 656–715.
37. Wei, Q.L. *Data Envelopment Analysis Model to Evaluate the Relative Effectiveness: Dea and Network Dea*, 1st ed.; China Renmin University Press: Beijing, China, 2012; pp. 7–26.
38. Charnes, A.; Cooper, W.W.; Rhodes, E. Measuring the efficiency of decision making units. *Eur. J. Oper. Res.* **1978**, *2*, 429–444.
39. Banker, R.D.; Charnes, A.; Cooper, W.W. Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Manag. Sci.* **1984**, *30*, 1078–1092.
40. Tone, K. A slacks-based measure of efficiency in data envelopment analysis. *Eur. J. Oper. Res.* **2001**, *130*, 498–509.
41. Greene, W.H. *Econometric Analysis*; Prentice Hall: Upper Saddle River, NJ, USA, 1993.
42. Simar, L.; Wilson, P.W. A general methodology for bootstrapping in nonparametric frontier models. *J. Appl. Stat.* **1998**, *27*, 779–802.
43. Simar, L.; Wilson, P.W. Estimation and inference in two-stage, semi-parametric models of production processes. *J. Econ.* **2007**, *136*, 31–64.
44. Pérez-Reyes, R.; Tovar, B. Measuring efficiency and productivity change (ptf) in the peruvian electricity distribution companies after reforms. *Energy Policy* **2009**, *37*, 2249–2261.