The Technical Efficiency of Community Health Service Centers in Wuhan, China: Estimation and Policy Implications

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Abstract
This study seeks to measure the technical efficiency of Community Health Service Centers (CHSCs) in Wuhan City, China, to propose some policy recommendations to improve the efficiency of CHSCs. A total of 46 CHSCs in Wuhan City were included in the study as research subjects. Data of 11 selected input and output indicators were collected from Hubei Provincial Health and Family Planning Commission. R3.2.1 statistical software was used to estimate the efficiency scores of CHSCs using Bootstrap-Data Envelopment Analysis (DEA), and, on average, the bias-corrected technical efficiency score is found to be 0.7845. All the bias-corrected scores of CHSCs are lower than classical scores. At both local and regional level, large gaps exist in relative technical efficiency scores among the CHSCs, and 12 out of 46 CHSCs (26.09%) have efficiency scores at or below average levels. The results indicate big potential for the CHSCs in Wuhan to improve their technical efficiency, such as the optimization of health resources allocation, capacity building, information system strengthening, third party performance evaluation, and mechanisms design, and so on.

Keywords
community health service centers, technical efficiency, bootstrap-DEA, bias correction, performance evaluation

What do we already know about this topic?
Bootstrap-Data Envelopment Analysis (DEA) has long been applied to measure the technical efficiency of health care organizations in international literature, while in China, it is still at preliminary stage for application.

How does your research contribute to the field?
In this study, we introduce the Bootstrap-DEA approach to measure the technical efficiency of Community Health Services Centers (CHSCs) in Wuhan City, China, and propose a framework for visual reporting of efficiency scores, benchmarking, and interorganizational learning for continuous improvement.

What are your research’s implications toward theory, practice, or policy?
It is suggested to use Bootstrap-DEA to update the classical DEA models to better estimate efficiency scores of CHSCs for decision making.

Introduction
Since the second round of health system reform in China in 2009, together with the requirements set in the 13th 5-year planning of China on promoting equality in access to basic public health service, the provision of community health services has long been an important part of China’s health system reforms. Designed to function as a primary care and public health provider, the Community Health Service Centers (CHSCs) provide integrated care in 6 aspects: prevention, medical care, health care, rehabilitation, health promotion, and family planning.² Because of their convenience and basic care unit orientation, CHSCs are playing an important role to solve problems such as unreasonable...
resource allocation, insufficient resources utilization, and appropriateness of care.\(^2\) Besides, China is continuously reforming its health care system and a referral system between hospitals and CHSCs is being piloted in a number of cities and an increasing number of outpatient diagnostic services are being provided by CHSCs. However, due to limited resources of CHSCs, it is important to optimize the utilization of health resources, which can be analyzed in terms of allocative efficiency and technical efficiency. Allocative efficiency measures the success of a Decision Making Unit (DMU) in choosing an optimal set of inputs.\(^3\) It is also referred to as price efficiency.\(^3\) Therefore, price information of the inputs is needed. However, in health care, it is very hard to get all the required price information of inputs to estimate allocative efficiency. In contrast, technical efficiency measures the success of a DMU in producing maximum outputs from a given set of inputs.\(^3,4\) Only the volume number of inputs and outputs is needed, making technical efficiency measurement more feasible in practice for decision making.

In the estimation of technical efficiency, Chinese researchers have mainly applied classical models of Data Envelopment Analysis (DEA), such as Charnes, Cooper and Rhodes (CCR);\(^5\) Banker, Charnes and Cooper (BCC);\(^6\) Malmquist-DEA;\(^7\) and other derivative models.\(^5,9\) Except some application into a limited number of Chinese hospitals with Bootstrap-DEA model, few Chinese scholars have corrected the bias caused by environmental and random factors with the model to measure relative efficiency of CHSCs, while it has been used extensively since the Bootstrap method was introduced and combined with DEA.\(^9-11\) Moreover, it is suggested that the selection of input and output indicators among Chinese health care organizations needs to be standardized for more scientific estimation of efficiency scores.\(^12,13\)

The purpose of this study is to introduce Bootstrap-DEA method to estimate the technical efficiency of CHSCs in Wuhan city of China, to discuss possible policy implications for both Wuhan and other cities to further improve technical efficiency of CHSCs.

**Methods**

**Context and Sample**

Wuhan is the capital city of Hubei Province in central China, which is composed of 7 central administrative districts (Jiang’an, Jianghan, Qiaokou, Hanyang, Wuchang, Hongshan, Qingshan) and 6 new suburban districts (Dongxihu, Caidian, Jiangxia, Huangpi, Xinzhou, and Hannan). Figure 1 shows the distribution of the 13 districts and number of CHSCs (in brackets). In 2012, altogether there were 125 CHSCs in all the Wuhan districts. There were 9.028 million patient treatments,
116,900 inpatients, 5416 beds, 6768 health professionals (2369 certified doctors and 2713 enrolling nurses). Figure 2 is about the number of permanent population in districts of Wuhan in 2012.

Selection of Input and Output Indicators

It is suggested in literature that in technical efficiency measurement, some monetary indicators such as total revenue, operational revenue, total expenditure, fixed assets, and so on should not be included so as to differentiate technical efficiency from allocative efficiency. In this study, we only selected volume indicators as the input and output indicators. As CHSCs also provide public health services, some typical output indicators closely related to public health are also selected, such as number of physical examinations, number of discharged patients, number of health records, and so on. Based on further literature review combined with the availability of data, number of equipment with value greater than 10,000 RMB Yuan, number of health technical personnel (doctors, nurses, pharmacists, other health technical personnel and nonhealth technical personnel), and actual number of open beds were selected as input indicators; number of total diagnostic patients, number of physical examinations, number of discharged patients, and number of health records created for urban residents were selected as output indicators.

Bias Correction of Efficiency Scores With Bootstrap-DEA

In real context, environmental and random factors may have impact on the operations of CHSCs, which means the efficiency score of each of the DMUs is biased and shall fall to a fluctuating range. To address this issue, the Bootstrap method has been introduced by international researchers into classical DEA models to measure relative efficiency and productivity of DMUs, which has enabled the estimation of bias-corrected efficiency scores with confidential intervals and range of bias, thus contributing to the improvement of scientific estimation of efficiency scores.

In this study, Bootstrap-DEA is applied to estimate the technical efficiency of CHSCs in Wuhan based on the method proposed by Simar and Wilson. The principles of the Bootstrap-DEA method are as below: \( \Psi \) represents the set of CHSCs’ input and output indicators, that is \((x, y)\). Provided that sample \( X_n \) is produced by the data generation process, namely, \( (DGP) P, P \) is expressed as \( P = P(\Psi, f(x, y)) \).

If we postulate that \( P(X_n = P(\Psi, f(x, y))) \) stands for the estimated value of \( P \), based on the Bootstrap-DEA method, the sample \( B \) is generated by \( P(X_n) \), that is, \( X_n^* = \{(x_i^*, y_i^*) | i = 1, 2, \ldots, n\} \). Given that \( \hat{\theta}_{DEA}(x_0, y_0) \) is the real estimated value of \( \theta_{DEA}(x_0, y_0) \) on DEA efficiency score and \( \hat{\theta}_{DEA}(x_0, y_0) \) is the estimated value of \( \theta_{DEA}(x_0, y_0) \) on Bootstrap, \( \hat{\theta}_{DEA}(x_0, y_0) \) is calculated as a result of the sample produced by \( P(X_n) \).

The reliability of the estimated scores of Bootstrapping is dependent on the number of sample \( B \) and the size of capacity on \( n \). In classical BBC and CCR model, there are bias in score estimation. In fact, the average of the “real efficiency” is lower than the estimated scores generated by classical DEA models.

The estimated bias of the DEA efficiency score with the Bootstrap-DEA method is

\[
\text{BIAS}\left( \hat{\theta}_{DEA} \left( x_0, y_0 \right) \right) = B^{-1} \sum_{b=1}^{B} \hat{\theta}_{DEA,b} \left( x_0, y_0 \right) - \hat{\theta}_{DEA} \left( x_0, y_0 \right).
\]

The estimated score of \( \theta(x_0, y_0) \) after bias correction with the Bootstrap-DEA method is
\[ \bar{\theta}_{\text{DEA}}(x_0, y_0) = \hat{\theta}_{\text{DEA}}(x_0, y_0) - \text{BIAS}_\beta \left[ \hat{\theta}(x_0, y_0) \right] \]
\[ = 2\hat{\theta}_{\text{DEA}}(x_0, y_0) - B^{-1}\sum_{i=1}^{B} \hat{\theta}_{\text{DEA},\beta}(x_0, y_0). \]

The applied condition of corrected variance is
\[ \hat{\sigma}^2 < \frac{1}{3} \left( \text{BIAS} \left[ \hat{\theta}_{\text{DEA}}(x_0, y_0) \right] \right)^2. \]

Based on the Bootstrap-DEA method, the confidence interval of \( \hat{\theta}(x_0, y_0) \) at the statistically significant level of \( \alpha \) can be calculated as below:
\[ P_r\left( -\hat{a}_n \leq \hat{\theta}_{\text{DEA}}(x_0, y_0) - \hat{\theta}_{\text{DEA}}(x_0, y_0) \leq \hat{a}_n \mid P(X_n) \right) = 1 - \alpha. \]

\[ P_r\left( -\hat{a}_n \leq \hat{\theta}_{\text{DEA}}(x_0, y_0) - \hat{\theta}_{\text{DEA}}(x_0, y_0) \right) \approx 1 - \alpha. \]

\[ \hat{\theta}_{\text{DEA}}(x_0, y_0) + \hat{a}_n \leq \theta_{\text{DEA}}(x_0, y_0) \]
\[ \leq \hat{\theta}_{\text{DEA}}(x_0, y_0) + \hat{a}_n. \]

Data Collection

The statistical data came from health statistics reported from CHSCs to Hubei Provincial Health and Family Planning Commission in 2012. After eliminating CHSCs with incomplete reporting of data, only 46 of the 125 CHSCs met our study purpose.

Data Process and Analysis

R3.2.1 software and FEAR package were used to estimate the bias-corrected efficiency scores. The scores before bias correction would return to Farrell scores and the bias-corrected ones would return to scores based on Shephard’s output distance functions, bias, lower bound, and upper bound (2000 times of repeated sampling, input orientation, \( \alpha = .05 \)). The closer the score is to 1, the higher the technical efficiency is. The 46 CHSCs are labeled with C1, C2, C3, . . . C46. Based on the efficiency benchmarking principles of public hospitals by Li and Dong, the bias-corrected efficiency scores \((X)\) of the 46 CHSCs can be categorized into 5 groups with different colors. We then have following definitions: \( X \in [0.9000, 1.0000] \) represents excellent efficiency (dark green); \( X \in [0.8000 \leq X < 0.9000] \) represents good efficiency (green); \( X \in [0.7000 \leq X < 0.8000] \) represents average efficiency (yellow); \( X \in [0.6000 \leq X < 0.7000] \) represents poor efficiency (brown); \( X \in [0.0000, 0.6000] \) represents failing efficiency (red). Furthermore, stemmed from the visual presentation framework of Nuti et al on performance indicators, each of the efficiency scores will be presented into a spider diagram for further analysis.

Results

Descriptive Statistics

The 46 sample CHSCs are distributed in 9 districts in Wuhan. Table 1 demonstrates the means and standard deviations of inputs and outputs. In terms of 7 input indicators, 33 CHSCs are below average level in the number of equipment with value greater than 10 000 RMB Yuan, accounting for 71.74%; 26 CHSCs are below average level in the number of doctors, accounting for 56.52%; and 25 CHSCs are below average level in actual number of beds, accounting for 54.35% etc. In respect of 4 output indicators, 30 CHSCs are below average level in the number of total diagnostic patients, accounting for 65.22%, and 31 CHSCs are below average level in the number of physical examinations, accounting for 67.39%.

Efficiency Scores and Ranking Before and After Bias Correction

Table 2 is the estimated efficiency scores of the sample CHSCs, together with the rankings before and after bias correction. The average efficiency score of the 46 CHSCs before bias correction is 0.8980, among which 28 have efficiency scores of 1, while the average score after bias correction is 0.7845 and each of the CHSC scores is lower than 1. The highest score is 0.9225 and the lowest score is 0.4136; the gap before and after bias correction ranges from 0.0331 to 0.1892. In particular, the top no. 1 and no. 2 CHSCs are ranked at the 30th and the 28th before bias correction. Figure 3 indicates that only 4 CHSCs instead of 35 are listed as “excellent efficiency” after bias correction, while the number of “good efficiency” CHSCs is surging from 1 to 30.

The Categorization of Efficiency Scores and Visual Reporting

In order to have a visual reporting of the distribution of efficiency scores, Figure 4 is composed of a 5-layered spider diagram, in which the 46 CHSCs are scattered into 9 districts. It can be seen that only 4 CHSCs have achieved excellent efficiency, accounting for 8.70%; 32 CHSCs have achieved good efficiency, accounting for 69.57%; 1 CHSC has achieved average efficiency, accounting for 2.71%; 5 CHSCs have achieved poor efficiency, accounting for 10.87%; and 4 CHSCs have achieved failing efficiency, accounting for 8.70%. The more a CHSC is located in the outer layer, the lower the efficiency of the CHSC and the more they need for improvement.
Variance in Health Resources Allocation Among Districts

Reasonable health resource allocation is a requisite condition for sustainable development of CHSCs, which has direct impact on efficiency, quality, capacity building, and so on. In 2012, the inputs of health resources have exhibited substantial variance among CHSCs and districts, which reflects imbalanced development and the need for capacity building among CHSCs. Besides, the variance depends on CHSCs’ locations. Most of the CHSCs with good performance are located at central municipal districts, where there are more residents than suburban districts. These results are also confirmed by Sun et al in their research to Pudong new district in Shanghai, where the southern towns, mainly lying in the rural areas and suburban districts and covering larger areas with a lower population density than the northern urban ones, have their residents who are less likely to afford regular medical treatment, making these centers hard to improve. In contrast, CHSCs located in new suburban districts are larger in area, lower in population density, fewer in the number of CHSCs, and are allocated with less health resources. In fact, in these areas, more township hospitals are built, which have similar functions of CHSCs in providing primary care and public health services. However, in the urbanization process of Wuhan, more township hospitals will be transformed into CHSCs. It is recommended that government optimize health resources allocation based on useful tools and empirical findings and strengthen standardization construction and capacity building of the CHSCs.

Variance in Technical Efficiency Scores

In the 46 CHSCs, 28 of them have efficiency score of 1 before bias correction, which means, in theory, they do not need to make any improvement. However, the scores are all overestimated and below 1 after bias correction and the ranking of CHSCs is sensitive to bias correction. This means, in real situation, no CHSC is in the stochastic frontier, which may be influenced by environmental and random factors, such as gross domestic product (GDP) per capita, market competition, health policy, and so on. Typical DEA applications invariably present point estimates of inefficiency, without measure and only slight or no discussion of uncertainty surrounding these estimates. Moreover, the estimates are subject to uncertainty because of sampling variation, especially small sample size. However, Bootstrapping is based on the idea of repeated simulation of the data-generating process (DGP). Usually, the original estimator is applied to each simulated sample through resampling to make estimates mimic the sampling distribution of the original estimator. In that way, a bias-corrected estimator and confidence intervals are constructed, much more equivalent to the true input and output levels in real situation. In our results, at least 12 of the 46 CHSCs (26.09%) have efficiency scores at average or below average level, indicating big potential for improvement. In particular, 4 CHSCs with failing efficiency are the most concerned ones for urgent improvements. Root causes need to be identified with useful tools and all stakeholders shall work together to solve the identified problems. It is advised that CHSCs with lower efficiency scores can learn from those with best practices on how they made their achievements. In particular, CHSCs with failing efficiency (C42, C21, C46, C32, C33, C40, C27), poor efficiency (C37, C11, C25), and average efficiency (C38, C44) can particularly learn from CHSCs with excellent efficiency (C28, C35, C2, C29). According to international experience, this can be achieved through a variety of activities such as work meetings, seminars, training, and so on. In this way, CHSCs will be able to move in loop through assessment, benchmarking, and interorganizational learning for continuous improvement.

Call for Third Party Performance Evaluation Among CHSCs

Since the implementation of zero-profit drug policy, both the total institution revenue and the personnel income of

| Table 1. Descriptive Statistics of Inputs and Outputs of the 46 CHSCs. |
|-----------------|--------|--------|------------|-----------|
| **Indicators**  | **Mean** | **SD** | **Minimum** | **Maximum** |
| **Inputs**      |        |        |            |            |
| Number of doctors | 23     | 15     | 3          | 88         |
| Number of nurses  | 25     | 17     | 6          | 104        |
| Number of pharmacists | 5     | 5      | 1          | 28         |
| Number of other health technical personnel | 10    | 8      | 1          | 43         |
| Number of nonhealth technical personnel | 13    | 11     | 3          | 57         |
| Number of equipment with value greater than 10 000 RMB Yuan | 25    | 34     | 1          | 165        |
| Actual number of beds | 59    | 39     | 10         | 205        |
| **Outputs**     |        |        |            |            |
| Number of total diagnostic patients | 87459 | 68996  | 9216       | 366309     |
| Number of physical examinations | 14478 | 20109  | 454        | 97952      |
| Number of discharged patients | 1299  | 1282   | 2          | 6669       |
| Number of health records created for urban residents | 40761 | 21631  | 6566       | 86539      |
health professionals have declined, which may affect the service provision at the care provider level and have significant impact on the technical efficiency and overall performance of CHSCs.\footnote{28} Furthermore, efficiency is just a dimension of performance; other dimensions such as quality, financial sustainability, patient satisfaction, and so on are all important for consideration in decision making. Therefore, an overall performance evaluation system is yet

| Table 2. Efficiency Scores and Ranking Before and After Bias Correction. |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|--------------------------------|--|-----------------|-----------------|
| Labeled CHSCs | Efficiency scores before bias correction | Efficiency scores after bias correction | Bias | Lower bound | Upper bound | Ranking before and after bias correction | Efficiency Group |
|----------------|------------------------------------------|------------------------------------------|-----|-------------|-------------|-------------------------------------------|------------------|
| C28            | 0.9889                                   | 0.9225                                   | 0.0664 | 0.6948 | 0.9952 | 1 (30) | Excellent | efficiency |
| C35            | 0.9952                                   | 0.9205                                   | 0.0747 | 0.5954 | 0.6820 | 2 (28) | Good efficiency |
| C2             | 1.0000                                   | 0.9149                                   | 0.0851 | 0.6426 | 0.9954 | 3 (1) | Good efficiency |
| C29            | 1.0000                                   | 0.9012                                   | 0.0988 | 0.6783 | 0.9959 | 4 (1) | Good efficiency |
| C41            | 0.9747                                   | 0.8992                                   | 0.0755 | 0.7478 | 0.9966 | 5 (31) | Good efficiency |
| C17            | 0.9639                                   | 0.8875                                   | 0.0764 | 0.7636 | 0.9956 | 6 (32) | Good efficiency |
| C23            | 1.0000                                   | 0.8841                                   | 0.1159 | 0.6885 | 0.9959 | 7 (1) | Good efficiency |
| C45            | 0.9931                                   | 0.8840                                   | 0.1091 | 0.8512 | 0.9899 | 8 (29) | Good efficiency |
| C9             | 0.9520                                   | 0.8710                                   | 0.0810 | 0.6758 | 0.8412 | 9 (33) | Good efficiency |
| C24            | 1.0000                                   | 0.8683                                   | 0.1318 | 0.7370 | 0.9954 | 10 (1) | Good efficiency |
| C26            | 1.0000                                   | 0.8649                                   | 0.1351 | 0.6926 | 0.9957 | 11 (1) | Good efficiency |
| C36            | 0.9345                                   | 0.8628                                   | 0.0717 | 0.7618 | 0.9957 | 12 (34) | Good efficiency |
| C22            | 1.0000                                   | 0.8591                                   | 0.1409 | 0.6649 | 0.9955 | 13 (1) | Good efficiency |
| C7             | 1.0000                                   | 0.8579                                   | 0.1421 | 0.7328 | 0.9951 | 14 (1) | Good efficiency |
| C43            | 1.0000                                   | 0.8555                                   | 0.1445 | 0.4733 | 0.5704 | 15 (1) | Good efficiency |
| C30            | 1.0000                                   | 0.8506                                   | 0.1494 | 0.7204 | 0.9951 | 16 (1) | Good efficiency |
| C8             | 1.0000                                   | 0.8498                                   | 0.1502 | 0.7579 | 0.9947 | 17 (1) | Good efficiency |
| C34            | 1.0000                                   | 0.8473                                   | 0.1527 | 0.7751 | 0.9958 | 18 (1) | Good efficiency |
| C31            | 1.0000                                   | 0.8466                                   | 0.1534 | 0.4939 | 0.5874 | 19 (1) | Good efficiency |
| C5             | 1.0000                                   | 0.8462                                   | 0.1538 | 0.6834 | 0.9955 | 20 (1) | Good efficiency |
| C14            | 1.0000                                   | 0.8407                                   | 0.1593 | 0.7301 | 0.9964 | 21 (1) | Good efficiency |
| C4             | 1.0000                                   | 0.8386                                   | 0.1614 | 0.7544 | 0.9142 | 22 (1) | Good efficiency |
| C20            | 1.0000                                   | 0.8345                                   | 0.1655 | 0.6935 | 0.9952 | 23 (1) | Good efficiency |
| C3             | 1.0000                                   | 0.8340                                   | 0.1660 | 0.7475 | 0.8611 | 24 (1) | Good efficiency |
| C15            | 1.0000                                   | 0.8293                                   | 0.1707 | 0.7444 | 0.9964 | 25 (1) | Good efficiency |
| C10            | 1.0000                                   | 0.8246                                   | 0.1754 | 0.6380 | 0.9957 | 26 (1) | Good efficiency |
| C16            | 1.0000                                   | 0.8214                                   | 0.1786 | 0.6826 | 0.9946 | 27 (1) | Good efficiency |
| C39            | 0.9030                                   | 0.8200                                   | 0.0830 | 0.7944 | 0.9967 | 28 (35) | Good efficiency |
| C18            | 1.0000                                   | 0.8193                                   | 0.1807 | 0.7481 | 0.9952 | 29 (1) | Good efficiency |
| C6             | 1.0000                                   | 0.8162                                   | 0.1838 | 0.6406 | 0.9969 | 30 (1) | Good efficiency |
| C13            | 1.0000                                   | 0.8156                                   | 0.1844 | 0.7220 | 0.9956 | 31 (1) | Good efficiency |
| C19            | 1.0000                                   | 0.8156                                   | 0.1844 | 0.7842 | 0.9477 | 32 (1) | Good efficiency |
| C1             | 1.0000                                   | 0.8117                                   | 0.1883 | 0.6663 | 0.9954 | 33 (1) | Good efficiency |
| C12            | 1.0000                                   | 0.8108                                   | 0.1892 | 0.8149 | 0.9957 | 34 (1) | Good efficiency |
| C38            | 0.8155                                   | 0.7558                                   | 0.0597 | 0.8639 | 0.9852 | 35 (36) | Good efficiency |
| C44            | 1.0000                                   | 0.7438                                   | 0.2562 | 0.7370 | 0.9957 | 36 (1) | Good efficiency |
| C37            | 0.7182                                   | 0.6589                                   | 0.0592 | 0.3847 | 0.4448 | 37 (37) | Good efficiency |
| C11            | 0.6882                                   | 0.6419                                   | 0.0463 | 0.6823 | 0.9948 | 38 (38) | Good efficiency |
| C25            | 0.6850                                   | 0.6372                                   | 0.0478 | 0.7141 | 0.9962 | 39 (39) | Good efficiency |
| C42            | 0.6272                                   | 0.5816                                   | 0.0456 | 0.4950 | 0.5778 | 40 (40) | Good efficiency |
| C21            | 0.5899                                   | 0.5474                                   | 0.0425 | 0.6049 | 0.6849 | 41 (41) | Good efficiency |
| C46            | 0.5774                                   | 0.5394                                   | 0.0380 | 0.7849 | 0.9302 | 42 (43) | Good efficiency |
| C32            | 0.5801                                   | 0.5367                                   | 0.0434 | 0.7681 | 0.9951 | 43 (42) | Good efficiency |
| C33            | 0.5731                                   | 0.5293                                   | 0.0438 | 0.7938 | 0.9960 | 44 (44) | Good efficiency |
| C40            | 0.5549                                   | 0.5148                                   | 0.0401 | 0.7569 | 0.9956 | 45 (45) | Good efficiency |
| C27            | 0.4467                                   | 0.4136                                   | 0.0331 | 0.8054 | 0.9605 | 46 (46) | Good efficiency |

CHSCs = community health service centers.
to be developed and implemented based on rewarding for the CHSCs. It is recommended that the local government of CHSCs can entrust a third party agency to conduct pilot performance evaluation at municipal level, in which efficiency is part of a performance dimension. Based on performance evaluation and benchmarking, interorganizational learning can be conducted, visual reporting and regular meetings. Special training can also be provided by the third party performance evaluation agency to improve working competence of both managers and staff for better performance. At local level, a bonus system can also be piloted to motivate CHSCs staff.26

**Other Aspects to Be Considered**

Along with more inputs of resources, rules and legislations on primary care and public health services need to be formulated. Innovative policies and mechanisms need to be designed to attract health professionals from hospitals to work in CHSCs. An additional rewarding information system needs to be developed and connect to the performance information system. With resources, incentives, supervision, rules, and legislation in place, the CHSCs will be able to gradually exert their functions as primary care and public health provider, thus consolidating the referral of patients between hospitals and CHSCs.

**Limitations**

This study has some limitations. First, most of the CHSCs lacked reliable information systems and the updating of data was lagged behind, which influenced the quality of data reported. Only 46 out of 125 CHSCs (36.8%) were selected for analysis because of missing data either in input or output indicators. However, this is the best data we can acquire. Our findings and recommendations are meaningful for Wuhan and other cities in China to better estimate the technical efficiency of CHSCs and for continuous improvement. Second, this study is a cross-sectional study and more years of data are yet to be included for longitudinal analysis. However, it can be reviewed as a preliminary study for a good start, and in the future, with the improvement in health information system, more years of data can be acquired for more in-depth analysis and for more scientific decision making.

**Conclusion**

In this study, we have applied Bootstrap-DEA to estimate the technical efficiency of CHSCs in Wuhan. There are lots of aspects to be addressed to improve the technical efficiency of CHSCs, such as resources allocation, information system strengthening, performance evaluation, management, and so on. Moreover, government can allocate resources based on
empirical evidence to strengthen capacity building, innovate incentive mechanisms and legislation, and so on to make the CHSCs fully exert their functions. Besides, as the efficiency scores resulted from Bootstrap-DEA method is more reliable than the classical DEA models, it is suggested to use the former to update the latter to better support decision making.

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