Factors affecting the technical efficiency of rural primary health care centers in Hamadan, Iran: data envelopment analysis and Tobit regression

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Abstract

**Background:** Health houses are the most important providers of primary health care to the rural communities of Iran, mainly based on Behvarz workers. The aim of present study was estimate the technical efficiency of Health houses and ascertain factors that affect this efficiency.

**Methods:** This is a Longitudinal study of rural primary health care centers in Hamadan province (2002-2016). Data Envelopment Analysis was employed to estimate technical efficiency of sampled health facilities while Panel Tobit Analysis was applied to predict factors associated with efficiency levels. The outputs were child mortality rate under one year of age and child mortality rate under five years of age. The input was Behvarzes (rural health workers).

**Results:** The results of efficiency analysis showed that the average efficiency scores of the centers had a fluctuating trend during the period of the study, but the average performance scores generally decreased in 2016, as compared with 2002. The highest and lowest average performance scores were observed in 2003 (0.78) and 2013 (0.56), respectively. Number of physicians and rural primary healthcare centers per population had a positive statistically significant and the number of midwives and the total fertility per population had a negative statistically significant effect on efficiency.

**Conclusions:** The findings suggest some level of wastage of health resources in primary health centers. The policy maker and relevant stakeholders should undertake more effective need analysis, optimizing human resource utilization and reducing fertility in rural areas to promote efficiency.

**Keywords:** technical efficiency, Tobit regression, rural primary health care center, Behvarz, Iran

Introduction

Given the increasing growth in health care costs and the problems associated with financing the expenditures, policymakers have accepted that health care is not a mere social issue and should be addressed economically as well [1,2]. According to the World Bank statistics and the World Health Organization reports, different countries spend an average of about 10% of their GDP on
healthcare [3]. According to the latest reports, it is more than 8% in Iran [4]. However, studies have shown that more than half of national health resources in different countries are wasted, and unlimited resources in underdeveloped countries are inefficiently consumed [5,6]. In fact, the main threat for the health sector in most developing countries is the non-optimal utilization of resources and the inefficient role of resource management in solving problems [7,8].

In health systems, there are various types of centers and facilities that provide health services to people. Health centers and rural health houses are among the most important providers of primary health care. There has been a rapid growth in the number of health centers since the release of the Alma-Ata Declaration that had a key role in ensuring access to health for all people [9]. Iran government has made much efforts to establish a broad network of primary health care facilities, especially in rural areas, through rural health centers and health houses, aimed at reducing the gap between rural and urban services [10,11].

According to most critics and stakeholders of the health sector in the county, the delivery of primary health care in Iran by Behvarz (local health worker), as a forefront of health especially in deprived and rural areas, has been one of the most important activities and achievements of the Iranian health system in the field of health. Health House is the most peripheral unit of service delivery in the health network system of the country that is located in rural areas and mainly based on Behvarz. Each health house may cover one or more villages depending on geographical conditions, especially transportation routes and population. The most important feature of health houses is the selection of Behvarzs according to the social conditions of the community [10,12].

Behvarzs spend two years of theoretical and practical training in selected health education centers designed for Behvarzs and equipped health centers to fulfill educational goals. After the official recruitment, they are monitored and trained on a regular basis to provide their services in the health house for residents of their village called the main village and neighboring villages called satellite villages. Mortality reduction, population control and family planning, vaccination for children, and maternal education can be attributed to the endless and admirable efforts of Behvarzs in rural areas [10,12].

At the present, 29% of the country's population lives in rural areas, so Behvarzs have a crucial role in the health system [10,12]. Given the large number of rural health centers, the considerable population under the coverage of services, and the large number of services provided by these
centers, continuous monitoring of the centers can in turn have an important role in improving the efficiency of health resources and preventing the waste of resources in the country [13,14]. Unfortunately, in developing countries, including Iran, there is limited information on the effectiveness of primary health care centers, especially rural health houses. Various studies in Ghana, Sierra Leone, and Burkina Faso indicate a significant technical inefficiency in utilizing health system resources in primary care centers, especially in rural areas [14-16]. In Rostami et al.’s study, which investigated the efficiency of rural health centers in Qazvin province between 2006 and 2010, it was found that although the technical efficiency of the centers improved over the period of the study, there was still a significant discrepancy between the current use and optimal use resources [17]. Therefore, it is of great importance to evaluate the efficiency of these centers. Depending on the geographical location and demographic features of the target population, health houses may undertake different volumes of activity. Therefore, their performance is affected by the availability of various demographic and geographic resources and their performance should be evaluated. When evaluating health houses, it is also important to consider the existence of a wide variety of indicators to measure in different functional areas. Therefore, considering the nature of these centers, their diverse functional areas of activity, and their inputs and outputs, it can be stated that data envelopment analysis (DEA) is the best model for a comprehensive and clear evaluation of the centers [7].

The utilization of DEA not only helps to determine the relative efficiency and identify weaknesses of the organization, but also defines the organization's policy and approach towards promoting efficiency and productivity through presenting the desirability of performance indicators. It also defines efficient patterns, i.e. units that, as compared with other units, have more outputs while using a similar level of inputs or produce the same output using fewer inputs [18]. In fact, the measurement of the efficiency of rural health centers can serve as a source of feedback for the managers to do the following: enhance professional competence and employee engagement, help to prioritize activities, benchmark efficiency, identify reasons for the increase or decrease in efficiency, help to make decisions to ensure the continuity of actions or stop some activities and programs, and help to optimally allocate resources to units [19]. Therefore, the aim of this study was to evaluate the efficiency of rural health centers in Hamadan province using DEA method.
Methods:

This study was conducted on selected rural primary health care centers (PHCCs) in Hamadan province in Iran. Panel data were collected for the period 2002 to 2016.

Data envelopment analysis (DEA):

\[
Max \ Efficiency_p = Max_{u_r v_i} \sum_{r=1}^{s} U_r Y_{rp} + U_0
\]

\[
S.t: \sum_{r=1}^{s} U_r Y_{rj} - \sum_{i=1}^{m} V_i X_{ij} + U_0 \leq 0; \forall i
\]

\[
\sum V_i X_{ip} = 1
\]

\[
U_r, V_i > 0; \forall r, \forall i
\]

where \(U_0\) is the convexity constant and its sign determines the returns to scale. \(U_0 < 0\) indicates the increasing returns to scale, \(U_0 > 0\) indicates the decreasing returns to scale, and \(U_0 = 0\) indicates constant returns to scale. In this study, we included two outputs and one input. The outputs were child mortality rate under one year of age and child mortality rate under five years of age. The input was Behvarzehs (rural health workers).

Tobit regression:
The DEA efficiency scores were analyzed via regressing them against some characteristics of the PHC center to examine how these factors could affect the efficiency. The censored Tobit model was used since the dependent variable was censored at zero from below. In the regression models, where the range of change in the dependent variable is somehow restricted, the variables that take values in a limited range are defined as "censored" or "truncated" data. If the observations outside a certain range are excluded systematically from sample and completely lost, then they are called "truncated" data, and when observations do not provide any information about the dependent variable, but at least the independent variables could be observed, then they are called "censored" data [20]. If the observations obtained from the analysis of DEA are >1, then they are not excluded
from the sample, which is the same for truncated data. However, they cannot take their own values either and, thus, they are censored to 1 [21]. In this context, since the dependent variables that correspond to 1 can be observed, it has a censored structure.

Estimating a model with a censored dependent variable using Ordinary least squares (OLS) method provides biased and inconsistent results in parametric estimations [22]. Furthermore, DEA scores have a relative efficiency index, rather than an absolute index, and the correlation between the efficiency scores make the OLS regression invalid [23]. Considering the mentioned reasons, Tobit regression, which is one of the limited dependent variable models that takes a censored structure into account, was used in the present study.

For parameter estimations, the Maximum Likelihood Estimation (MLE) method was used in the tobit model. Since the parameters obtained through MLE are non-linear, the predictions of estimations were performed through iteration. Moreover, since it requires less time and fewer iterations as an iteration method, thus to offer other advantages, the Newton-Raphson method was utilized here [24].

The basic formula of panel Tobit used in this study was as follows:

\[ y_{it}^* = \beta' x_{it} + \epsilon_{it} \quad (1) \]

\[ y_{it} = \begin{cases} 
  y_{it}^*, & \text{if } y_{it}^* < 1 \\
  1, & \text{otherwise}
\end{cases} \quad i = 1, \ldots, N \text{ and } t = 1, \ldots, T \quad (2) \]

where subscript \( i \) indicates the country, subscript \( t \) represents the time, \( X_{it} \) is the explanatory variable in the dimension of \( 1 \times k \), and \( \beta \) is the parameter vector on dimension of \( k \times 1 \) [25].

We used this efficiency score as dependent variable and run it against the independent variables. Three models were estimated via panel Tobit analysis. With including … into the first model, the second model was obtained and with including … into the model the third model was generated. The likelihood ratio and p-value help to identify the model which fits significantly better than other models. In this study, the results of DEA were obtained using deep and the results of Panel Tobit were obtained using STATA 12 software.

**Results:**
This study evaluated the efficiency of rural PHCCs at a provincial level. The productivity structure on the centers in eight cities from 2002 to 2016 was investigated through a two-stage analysis. DEA was used to assess the efficiency scores of DMUs, and Tobit regression was applied to evaluate the changes in total factor efficiency by years. The results obtained through applying DEA model and Panel Tobit are presented below.

The assessment of the average technical efficiency scores of the PHCCs by years showed that the trend of efficiency scores changed and began to decrease in 2004. As shown in Figure 1, the standard deviation of the technical efficiency scores in PHCCs was almost constant during the period of the study.

Based on the results presented in Table 1 the highest average technical efficiency score was observed in 2003. The lowest technical efficiency was observed in Malayer district in 2007 and 2013 and in Hamedan district in 2016. The highest dispersion of technical efficiency score was observed in 2007. The assessment of the distribution of PHCCs based on the technical efficiency score showed that the rate of PHCCs with an efficiency score above the average in 2002 to 2005 was approximately 37%, and it even reached 50% in 2006; finally, in 2016, 62% of PHCCs had an efficiency score above the average.

[Insert Table 1]

[Insert Figure 1]

Taking into account the efficiency scores obtained from DEA as a dependent variable, Panel Tobit analysis was applied in the second stage of the study to examine the selected variables affecting the efficiency. The results of estimation through Panel Tobit Random Effects model are presented in Table 2.

Four models were estimated via Panel Tobit analysis. In the first model, the number of physicians, midwives, and rural primary healthcare centers in each district was included in the model, and a negative and significant relationship was observed between the number of midwives and efficiency but no significant relationship between the number of physicians and number of rural PHCCs. However, in the second model, with including the total number of fertility into the first model, it was observed that the number of physicians had a positive and significant relation with efficiency. Also number of midwives and total fertility have a negative and statistically significant relationship with efficiency. In the third model, the number of physicians and midwives per
population and the number of rural PHCCs and total fertility were included. Accordingly, in this model the number of physicians per population and the number of rural PHCCs had a positive statistically significant effect on efficiency, but the number of midwives and the total fertility had a negative significant effect on efficiency. As shown in Table 2 the highest and lowest coefficient were related to the number of physicians per population in the fourth model and the number of midwives per population in third model respectively. In the fourth model, the number of physicians per population and the number of rural primary healthcare centers had a positive effect on efficiency, while the number of midwives per population had a negative effect on efficiency. As shown in Table 2, based on the log likelihood criteria, the fourth model was the best model to explain the factors affecting efficiency in PHCCs.

[Insert Table 2]

Discussion

Efficiency is one of the important indicators of productivity in order to compare the utilization of existing with standard criterion and evaluate the performance of homogeneous and similar units. This study evaluated the efficiency of rural PHCCs in different districts of Hamadan province during 2002-2016 using DEA method. The input of this model is Behvarz and the outputs are infant mortality rate among children under the one and five age years. The results of data analysis showed that the average efficiency scores of the centers had a fluctuating trend during the period of the study, but the average performance scores generally decreased in 2016, as compared with 2002. The highest and lowest average performance scores were observed in 2003 (0.78) and 2013 (0.56), respectively. Assadabad and Tuyoerkan health centers had the highest efficiency scores and stability during 2002-2016. However, Hamedan had the minimum efficiency over this period. In a study in Isfahan, 60% of health centers were operating at an optimum level, and assuming a constant return to scale, the technical efficiency of the centers was 87% [26]. In Yazd province, the efficiency score ranged from 0.6 to 0.9, with only two centers operating at an efficient level [7]. A study examined the efficiency of rural health centers in Qazvin between 2006 and 2010 and showed that the average technical efficiency during the period of the study was 0.77 to 0.89. The lowest and highest efficiency scores were observed in 2006 and 2009, respectively.
Efficiency and health outcomes had improved over the years of the study, which is not in line with the results of the present study. Rural health centers are subordinate to district health centers and, as the results show, rural health centers underwent a decrease in optimal use of inputs over time. Since 2005, family physician program was better organized in rural areas and was implemented more seriously. In addition to improvements in health conditions in rural areas and cities with a population of less than 20,000 people, this project had a complementary and decisive role in health service delivery in rural areas.

Although family physician program has many positive effects, it has reduced the efficiency of health centers due to the overlap of many services. In addition, this may be due to the decrease in the number of births in rural areas, as well as the migration of many villagers to the cities that has resulted in a decrease in rural population.

The costs of many primary health care services provided at health care centers are constant and it will be possible to increase their capacity to use them without increasing the costs. The low efficiency of rural health centers in Hamadan district can be attributed to the high rate of migration, its position as the capital of the province, better access to hospitals and other public or private health centers.

Despite the decreasing trend of the efficiency scores during the period of the study, the average efficiency score was always above 0.5, except for a few cases. Many studies on DEA in Africa, have reported a high level of inefficiency in primary care delivery in the studied countries [15,27,28]. A study by Akzahli et. al. showed that 78% of Ghanaian primary health care facilities were technically inefficient [27]. Kirigia et. al.’s study in 2001 also showed that 70% of primary health care clinics in South Africa were inefficient [28].

In Greece, the average technical efficiency score of inefficient centers was 0.57. More than half of the centers were operating with an efficiency score of above 0.9; in addition, 31% of the centers had poor efficiency (0.5-0.7) and 31.8% of the centers had a very poor efficiency (less than 0.5) [29]. However, in the present study, the overall average efficiency over the period of study was not more than 0.8, and only the health centers in the three districts of Tuyserkan, Asadabad and Bahar had a high efficiency score of 0.9. The second part of this study investigated the factors affecting the efficiency of rural health centers. In this study, the number of physicians, the number of midwives, the ratio of physician to population, the ratio of midwives to population, the fertility
rate, and the number of health houses in each district were considered as factors affecting efficiency.

Previous studies have examined various factors affecting efficiency, such as the following: distance from health centers, number of family members, religion, ethnidistrict, domestic livestock, durable household goods [15], access to safe drinking water, employee motivation [27], information and communication technology [30], socioeconomic variables [28], quality of care proxies, geographic location, site of centers, and the type of ownership on efficiency [31]. The results of Tobit regression indicated that the total number of physicians and the ratio of physician to population had a positive and significant relationship with the efficiency of rural health centers. Various studies have shown that in children under the age of one, respiratory, cardiovascular, genitourinary system diseases, and in children aged one to five years, accidents and cancers are the most important causes of death [32-34].

Considering the nature of causes of child mortality and the complementary and therapeutic role of physicians, since they are more knowledgeable than Behvarzs and other members of the family physician team in health centers, and taking into account their diagnostic and therapeutic role and their ability to refer patients to hospitals, it can be concluded that physicians have a positive and critical role in the prevention and reduction of mortality among children under one year and one to five years of age in rural areas. Therefore, the increase in the number of physicians along with the diagnostic and therapeutic aspects will help to increase the access of people to services and improve the efficiency of health centers via reducing the mortality rate among children and infants. Contrary to the number of physicians, the overall number of midwives and the ratio of midwives to population showed a negative significant relationship with the efficiency. Considering the nature of midwives' job and their duties in rural health centers as well as health houses that is defined by the Ministry of Health and Medical Education, it can be stated that most services provided by midwives are highly overlapping with services provided by Behvarzs. Therefore, the increase in the number of midwives results in an increase in the inputs and thus has a negative effect on the efficiency of health houses.

Furthermore, fertility rate has a negative and significant relationship with efficiency. Various studies conducted around the world have shown that high fertility rates are directly associated with an increase in infant and child mortality [35,36]. As a result, with the increase in fertility rate in different districts, infant and child mortality rate, which are considered as the outputs, are increased
and since the inputs (number of health workers) remain constant, fertility rate is expected to have a negative effect on efficiency.

Regression analysis showed that the number of health houses in each district had a positive and significant relationship with the efficiency of rural health centers. The increase in the number of health houses in a district improves people access to services provided by Behvarzs and other members of primary care teams; furthermore, it facilitates the ongoing monitoring and follow-up of services and ultimately improves health indicators. Facilitating access to services and improving health indicators, directly and indirectly reduces child mortality among those less than one year of age and those aged one to five years. In a study by Marshall et al., which examined efficiency in Burkina Faso villages, it was found that poor utilization of health services facilities was the most important cause of inefficiency in rural health centers [15]. The results of Tobit regression model in Marshall et al.’s study, which examined efficiency in Burkina Faso villages, showed that the prediction of efficiency scores was significantly associated with distance and socioeconomic variables [15].

In Aksali et. al.’s study that was conducted in 88 centers, the “access to healthy drinking water” and “employee motivation” were identified as the most important factors affecting efficiency [27]. In Manuel Dida et. al.’s study in Spain, the results indicated that ICT was one of the important factors in improving the efficiency of rural health centers. In these centers, the capacity of electronic health record was underutilized [30]. In Al-Hassan et. al. study in Ghana, which examined the performance of public and private primary care centers, it was shown that none of the quality care proxies had a significant relationship with technical efficiency, but the geographical location of the centers and the type of ownership had a significant effect on the level of technical efficiency [31].

Some inputs, especially human resource, have always been used without any benefit, and in inefficient centers the increase in resources does not results in the same proportion on increase in outputs and health indicators. Therefore, the increase in utilization or recruitment of human resources and capital only increases the cost of providing services and keeps them away from useful optimization theories. Therefore, lower inputs should be used to achieve higher efficiency in rural health centers. Under such a condition, the best solution is to modify and reduce additional inputs from health centers. In addition, since the costs of many primary health care services are
fixed in rural health care centers, it will be possible to increase their utilization without increasing the costs.

However, in efficiency analyses, especially when analyzing primary health care, external factors such as population size and age should also be included in the analysis, because the failure to consider these factors may affect performance scores. As a result, it does not properly reflect the performance of centers and ultimately does not lead to optimal allocation of resources. The study of primary health care providers in Greece showed that the efficiency of centers depended on the size of the population under the coverage of services [31]. The health centers in districts of Tuyserkan, Asadabad, and Bahar had the highest level of efficiency; hence, they must serve as role models and benchmarks for other districts.

**Conclusion**

The aim of this study was to investigate the efficiency of rural health houses and factors affecting their efficiency in Hamadan province. Except for the three districts (Asadabad, Bahar, and Tuyserkan), the health houses in most of districts did not operate at their maximum level of efficiency. It was found that the number of physicians, the number of midwives, the overall fertility rate, and the number of health houses in each district affected efficiency. According to the results, it is recommended to introduce the best units (best practices and benchmarks) to each of the inefficient units and executives in order to increase their efficiency and make plans for achieving the optimal performance in inefficient units. It is also recommended to control the overall fertility of rural women by conducting appropriate and educational programs by health workers. Because of the overlap of the services provided by midwives and Behvarzs, it is recommended to recruit a flexible number of midwives in rural health centers to cover more centers and increase the efficiency of health houses while adjusting the workforce.

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**Authors' contributions:**

SM, RJ and JJN were overall in charge of designing the study, data collection, analysis, drafting the first version of the article and finalization of the article. MZ and MN provided critical review,
in-puts comments and revisions on the article throughout its course. ShY provided guidance for
the study and in-puts and comments on the article throughout its course. All authors read and
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Consent for publication is not applicable as this study did not include names, images, or videos relating to
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Table 1. Technical efficiency values of eight primary health care centers

| Cities          | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  | 2008  | 2009  | 2010  | 2011  | 2012  | 2013  | 2014  | 2015  | 2016  |
|-----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| ASADABAD        | 0.937 | 1     | 0.895 | 0.81  | 1     | 1     | 1     | 1     | 0.936 | 0.876 | 0.726 | 0.63  | 0.68  | 0.523 | 0.63  |
| BAHAR           | 1     | 0.913 | 0.667 | 1     | 0.872 | 1     | 0.623 | 1     | 1     | 0.52  | 0.863 | 1     | 1     |       |       |
| TOYERKAN        | 0.993 | 1     | 1     | 1     | 1     | 0.9   | 0.875 | 0.85  | 0.97  | 0.783 | 0.912 | 1     | 1     | 0.923 | 0.82 |
| RAZAN           | 0.64  | 0.672 | 0.373 | 0.62  | 0.744 | 0.615 | 0.567 | 0.81  | 0.617 | 0.551 | 0.486 | 0.52  | 0.458 | 0.494 | 0.43 |
| KABOODARAHANG   | 0.486 | 0.691 | 0.469 | 0.474 | 0.489 | 0.413 | 0.508 | 0.48  | 0.587 | 0.784 | 0.499 | 0.46  | 0.376 | 0.387 | 0.43 |
| MALAYER         | 0.458 | 0.406 | 0.339 | 0.44  | 0.584 | 0.313 | 0.497 | 0.39  | 0.35  | 0.592 | 0.43  | 0.33  | 0.601 | 0.55  | 0.46 |
| NAHAVAND        | 0.564 | 0.733 | 0.448 | 0.63  | 0.613 | 0.353 | 0.595 | 0.36  | 0.495 | 0.614 | 0.685 | 0.63  | 0.689 | 0.665 | 0.6  |
| HAMADAN         | 0.585 | 0.491 | 0.581 | 0.41  | 0.474 | 0.399 | 0.559 | 0.66  | 0.393 | 0.532 | 0.438 | 0.41  | 0.487 | 0.487 | 0.33 |
| Mean            | 0.708 | 0.738 | 0.597 | 0.700 | 0.722 | 0.624 | 0.653 | 0.694 | 0.669 | 0.717 | 0.647 | 0.562 | 0.644 | 0.629 | 0.587|
| SD              | 0.230 | 0.222 | 0.243 | 0.243 | 0.215 | 0.299 | 0.183 | 0.261 | 0.264 | 0.170 | 0.221 | 0.203 | 0.211 | 0.220 | 0.227|
Table 2. Results of random effects Tobit regressions

| Variables                                  | Model I      | Model 2      | Model 3      | Model 4      |
|--------------------------------------------|--------------|--------------|--------------|--------------|
| Number of physicians                       | 0.0116734    | 0.0103544    | (-0.0069119) | (-0.006829)* |
| Number of midwives                         | -0.0040891   | -0.0030833   | (-0.0057493)*| (-0.0056645)**|
| Number of primary healthcare centers       | 0.0084836    | 0.0111017    | (-0.0027772) | (-0.0034194) |
| Total fertility                            |              | -0.0967611   | -0.0234858   |              |
| Number of physicians per population        |              | (-0.0642264)**| (-0.0658905)**|
| Number of midwives per population          |              | -1118.806    | -1111.251    |              |
| Number of primary healthcare centers per population |              | 850.818      | 796.3428     |              |
| Log likelihood                             | -26.635495   | -25.492471   | -30.20784    | -30.271497   |
Figure 1. Mean and Standard deviation of efficiency score in time period