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Healthcare expenditure efficiency and its determinants in Iran: a data envelopment analysis and Tobit regression (2000-2019)

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Abstract

Based on evidence of links between health expenditure and healthcare efficiency, this study aims to measure the performance of the health system in terms of macro-efficiency of healthcare expenditures in Iran over the period 2000-2019, and to investigate efficiency drivers. To this end, at the first stage an input-oriented data envelopment analysis (DEA) under the assumption of variable return-to-scale is developed to measure health expenditure efficiency scores with the use of historical data during 20 years. We explore the efficiency of health expenditure by estimating the contribution of healthcare spending to life expectancy, infant survival rate, and cause of death. Next, we examine the link between the efficiency and its determinants through Tobit regression analysis. According to DEA results, it is revealed that the efficiency score of 20 years is 0.82 on average and the standard deviation is 0.11. Findings of the Tobit regression indicate per capita GDP and public health expenditure (% of GDP) have significant negative effects, while control of corruption, and population density are found to have a statistically significant and positive effect on the efficiency of healthcare expenditures in Iran ($P<0.05$). But education is not statistically significant in determining efficiency. Variation in efficiency during the years suggests significant potential for improvement in population health status given the current level of health resources allocated to healthcare. Also, the positive impact of governance measures on efficiency indicates that the management of resources is important in the healthcare system, especially in the existence of corruption.

Keywords: health system, macro-efficiency, health expenditure

1. Introduction

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As countries progress towards the achievement of universal health coverage, prioritization of health issues and expenditures becomes more difficult [1]. Growth in health expenditures has become a major issue for health policymakers. Countries' health expenditures increased significantly in recent decades, not just in absolute terms but also as shares of their gross domestic product (GDP) [2]. The increase in health expenditure globally is projected to continue over the coming years and reach more than US$24 trillion by 2040 [3].

Confronting growing health expenditures, many researchers are investigating the efficiency of the healthcare sector [4]. The increasing burden of healthcare spending on the countries' limited resources has a clear policy implication to maximize the value of investments in healthcare [5]. Governments and the public are concerned about waste and inefficiency in the health sector. Policymakers, managers, providers, and service users should feel responsible for making the best use of existing resources [6]. The World Health Organization has estimated that due to inefficiency, about 20%–40% of total healthcare resources are wasted annually among its member countries. Furthermore, in low and middle-income countries, this rate is higher [7]. Thus, this is of great importance for public health researchers and policymakers in Iran as a middle-income country to measure the efficiency of healthcare expenditure and its changes over the past years considering that the healthcare expenditure has increased during this period.

Building upon decades of continuous reforms, Iran's health system has implemented various initiatives to access universal health coverage [8], and has strived to improve health indicators [9]. To mention some of the improvements in health indicators, according to World Bank during the years 2000 to 2019; life expectancy at birth has reached 76.68 by around 6 years increase. The maternal mortality ratio (per 100000 live births) declined from 48 in 2000 to 16 in 2017. The infant mortality ratio (in 1000 live births) dropped from 29.7 in 2000 to 11.5 in 2019. Mortality caused by communicable diseases, maternal, prenatal, and nutrition conditions (as % of total) has decreased from 14.60 in 2000 to 8.09 in 2019. The country has been prosperous to some extent. Nevertheless, there is still room for improvement.

Despite the improvements and successes, the countries' healthcare expenditures have grown over the years. The increase in health spending is derived by various factors, from the implementation of healthcare reforms to aging. In the year of 2019 total health expenditure of Iran reached 6.71% of the GDP, while it was 4.78% in 2000. Also, the total healthcare expenditure share from the public budget is considerable.

Improving efficiency is a solution to decelerate the rising healthcare expenditure and overcome the challenges of increasing expenses and a crucial intermediate policy objective for universal health coverage [8]. Efficient health systems provide a maximum of quality healthcare at a minimum cost. Few countries, if any, reach this standard of economic efficiency however, almost all countries including Iran, have the potential to improve their healthcare expenditure efficiency, while it is unrealistic to expect utterly efficient healthcare delivery [10].

Many studies have tried to measure and analyze the healthcare sectors efficiency levels. Regarding to Iran's health system efficiency, Mohamadi et al. [11] reported that the average efficiency score was 0.791 from 2009 to 2015. According to Sajadi et al. [8] the efficiency scores were 0.75, 0.77, 0.74, 0.74, 0.97, and 0.84 over the period 2010–2015, respectively.

It is difficult to determine how much a society should spend on healthcare, because additional health expenditures imply lower spending on other types of consumption [4]. Countries are increasingly allocating a significant portion of their resources to health services [12]; in Iran, about 15 % of the public budget is allocated to the health sector annually. However, medical care as a determinant of health is insufficient for ensuring better health outcomes. Medical care account for only 10-20 percent of the modifiable contributors to healthy outcomes for a population. The other 80 to 90 percent are sometimes broadly called the social determinants of health (SDoH): health-related behaviors, socioeconomic factors, and environmental factors [13]. Thus, increasing the efficiency of healthcare expenditures would release scarce inputs for other uses [5].

National evaluation of health system efficiency can provide good evidence for policy decisions about public health. Therefore, it is crucial to analyze the performance of healthcare system by quantifying healthcare expenditure efficiency and determining efficiency drivers. In this study, at the first stage, we proceed with the use of non-parametric DEA as a mathematical tool to analyze health expenditure efficiency in Iran at macro level. Historical data is used to measure and compare the efficiency scores from 2000 to 2019, unlike other studies that provide cross-sectional comparisons with other countries. Building on the methodology of previous studies, we explore the efficiency of health expenditure by estimating the contribution of health care spending to life expectancy, infant survival rate, and cause of death (by communicable diseases and maternal, prenatal, and nutrition conditions). In the next stage, we examine the link between efficiency and its determinants through Tobit regression analysis.

2. Method

DEA model

Two approaches have dominated the productivity literature: econometric methods, mainly various forms of statistical methods such as panel data models and stochastic frontier analysis (SFA), and the descriptive methods known as DEA [14].

DEA was developed by Charnes et al. It is a linear programming-based non-parametric analysis to measure the relative/comparative efficiency of a group of Decision-Making Units (DMU) that incorporates multiple inputs to produce multiple outputs [15]. A score of 1 is assigned to DMUs found to be efficient, and a score less than 1 is set to those found to be inefficient [12]. The approach is closely related to cost-utility and cost-effectiveness analyses in health economics [16] and it is the most appropriate for estimating efficiency in the public sector environment, and more specifically in

healthcare [17]. Various researchers have employed it to determine the efficiency of the healthcare sector.

The performance of a DMU can be assessed in either a cross-sectional or a time-series manner. For both types of comparison, DEA is a useful method. For the former, a group of DMUs are compared with each other at the same time point, while for the latter, a DMU is compared with itself at different time points and judges whether a DMU is performing better as time progresses. Hence, to make the necessary improvements, the units with declining performance must be identified [15].

A growing body of literature shows a high association between health expenditures and health outcomes [18]. In this study amount of health expenditures per capita by purchasing power parity is used as the input variable, while life expectancy at birth, infant survival rates, and cause of death (by communicable diseases and maternal, prenatal, and nutrition conditions (% of total)) are used as output variables.

Life expectancy indicates a country's modernization and respect for its citizens, whose well-being depends on living long and healthy [4].

Infant mortality rate (IMR) is transformed into the infant survival rate (ISR) by the following formula:

$$ISR = 1 - IMR/1000$$

This can be explained as the proportion of surviving infants compared to the number of children that died in the first year of life, a high level of which reflects better health status [19].

Cause of death refers to the share of all deaths for all ages by underlying causes. Communicable diseases and maternal, prenatal, and nutrition conditions include infectious and parasitic diseases, respiratory infections, and nutritional deficiencies such as underweight and stunting. This is a negative output, since the DEA technique is applied in such a way that "more is better," the inverse of the data is used, thus satisfying the more is better approach by converting the largest number to the smallest, and vice versa [20].

The relationship between health expenditure and outcomes considered here is consistent with the view that additional spending beyond a certain level has a relatively smaller incremental effect on health status or health expenditure has diminishing returns [21].

Various DEA models have been presented based on returns-to-scale and input/output orientation in the literature. In this study, the assumption of variable returns-to-scale (VRS) was considered, because the constant returns-to-scale assumption is appropriate only in specific scenarios and is very rigid for many real-life processes [22]. Also, Input-oriented DEA was applied in this study because the planning and control of outputs in healthcare systems are difficult, and managers have more control of inputs than outputs. Therefore, input-oriented models are appropriate for studies of healthcare systems [12].

The following formula indicates the input-oriented VRS model used in the study:

Table 1. Descriptive statistics of input and output variables (2000-2019)

Variable	Obs	Mean	Std. dev.	Min	Max
Life expectancy (years)	20	73.64	2.14	70.18	76.68
Infant survival rate	20	0.98	0.0057	0.97	0.98
Cause of death (by communicable diseases and maternal, prenatal, and nutrition conditions (% of total))	20	10.96	2.054	8.089	14.59
Health expenditure per capita (PPP)	20	899.78	238.54	499.15	1225.07

$$MAX\ Z_0 = \sum_{r=1}^{s} u_r\, y_{r0} + w$$
$$St: \qquad (1)$$
$$\sum_{i=1}^{m} v_i x_{i0} = 1$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + w \leq 0$$
$$u_r, v_i \geq 0 \qquad (j = 1,2, \dots, n)$$

w is unrestricted in sign.

Were,

Y_{rj} =amount of output r in year j.

X_{ij} =amount of input i in year j.

u_r =weight given to output r.

v_i =weight given to input i.

n =number of years.

s =number of outputs.

m =number of inputs.

In our case, n DMUs are considered years from 2000 to 2019, and the performance of DMUs are evaluated in a time series manner.

The technical efficiency score ranges between 0.00 and 1.00; if it is equal to 1.00, the production from the DMU is efficient; while if it is less than 1.00, then the DMU is inefficient.

The descriptive statistics of the selected input and output variables for Iran are presented in Table 1.

Tobit regression

After DEA modeling, at the second stage of analysis it is attempted to identify the drivers of healthcare expenditure efficiency. Tobit regression analysis as a powerful tool is conducted to determine the impact of variables regarded as efficiency scores' drivers under investigation [23].

One of the limitations of the DEA approach is the serial correlation of the efficiency scores. In other words, the correlation between inputs and outputs, and consequently with the generated efficiency scores results in this serial correlation. Thus, the score of one DMU is not independent on that of the other DMUs.

Furthermore, since the DEA efficiency scores truncate from zero to one, it is a censored dependent variable, and the ordinary least square (OLS) regression results in biased and inconsistent estimations [24]. To handle these limitations, econometric models like Probit, Logit, and Tobit can be used to identify the impact of environmental variables on efficiency [21]. The general formula of the Tobit regression model in this study is as follows:

$$\begin{cases} Y_t = \beta X_t + \mu_t & \text{if} \quad 1 > \beta X_t + \mu_t > 0, \\ 0 & \text{if} \quad \beta X_t + \mu_t \leq 0, \\ 1 & \text{if} \quad \beta X_t + \mu_t \geq 1 \end{cases} \qquad t = 1, \dots, n \qquad (2)$$

Y_t is the dependent variable; X_t is the independent variable vector; β is the unknown coefficients, and μ_t is the independent distribution error assumed to be a normal distribution with an average of zero. The Tobit estimation on time series

data for the years 2000-2019 is specified as below:

$$EFF_t = \beta_0 + \beta_1 LGDPC_t + \beta_2 PUBHEX_t + \beta_3 CORR_t + \beta_4 POPDENSE_t + \beta_5 EDUC_t \quad (3)$$

Were,

EFF= Efficiency scores computed from the DEA model

GDPC= Gross domestic product per capita (L is logarithm)

PUBHEX= Public health expenditure (% of GDP)

CORR= Control of corruption index (-2.5 worst, +2.5 best)

POPDENSE= Population density (people per square kilometer of land area)

EDUC= Literacy rate of adults 15 and above

Following Grossman's health investment theory, healthcare expenditure is a key investment in health and potential productivity. Based on research, higher healthcare spending by governments, mainly assessed as a percentage of the GDP, is related to better health outcomes, such as increased life expectancy or longevity [25]. However, simply increasing public health expenditure may not significantly affect health outcomes if the efficiency of this spending is low [26], and a significant strand of the literature suggests higher expenditure in countries is associated with lower efficiency [27].

GDP per capita as an important and potential determinant of healthcare expenditure efficiency, is also included in the set of exogenous variables. Some studies have found a positive relationship between efficiency scores and GDP per capita [28], while other studies have reported a negative relationship.

Control of corruption is the potential variable of governance. Transparency of government practice and fighting against corruption in the health sector has increased in developing countries, raising public pressure to use scarce resources more efficiently [27].

Education is admitted to be an important factor in determining healthcare expenditure and health status. Higher educational attainment leads to higher income which, in turn, can secure a healthy lifestyle and access to healthcare, and therefore, affect efficiency.

Additionally, population density is included as another variable in the efficiency regression. This is because population density can affect the quality of healthcare services and thus efficiency.

The data used are extracted from the World Bank, and the DEA and regression model analysis are conducted using Stata MP 17.

Table 2. Descriptive statistics of Tobit regression variables (2000-2019)

Variable	Obs	Mean	Std. dev.	Min	Max
Public health expenditure (% of GDP)	20	2.62	0.88	1.80	4.35
GDP per capita	20	15493.09	2323.65	10858.04	19415.61
Control of corruption	20	-0.64	0.24	-1.05	-0.19
Education	20	82.58	3.29	75.68	86.9
Population density	20	45.26	3.24	40.29	50.906

3. Results

Table 3 presents the macro-efficiency scores that indicate how the healthcare system is performing. According to DEA results, health expenditure efficiency is found to vary during time in the current study. It is revealed that the efficiency score of 20 years is 0.83 on average, and the standard deviation is 0.11. Variations in the efficiency of health expenditures are depicted in Figure 1. Our findings indicate that only three years are identified as efficient over the evaluated period, years of 2000, 2002, and 2019 (score of 100%), and 2010 was the worst performing year (score of 65.36%).

The result of Tobit regression analysis is assumed to make it possible to analyze factors that affect healthcare expenditure efficiency. Table 4 shows the empirical results of the Tobit regression model.

Table 3. Efficiency scores

Year	Efficiency (%)
2000	100
2001	94.62
2002	100
2003	90.22
2004	90.09
2005	86.23
2006	85.61
2007	84.62
2008	83.12
2009	69.36
2010	65.36
2011	65.71
2012	75.51
2013	88.84
2014	79.51
2015	80.98
2016	69.96
2017	69.29
2018	73.60
2019	100

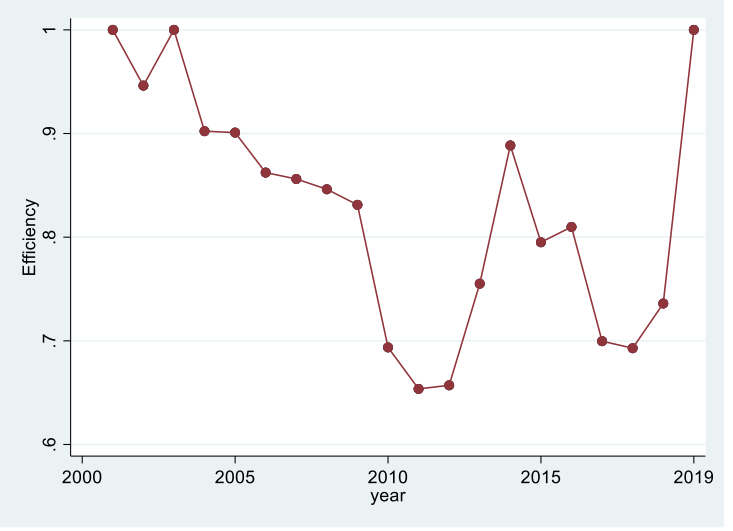

Figure 1. The annual efficiency score for healthcare expenditure in Iran

Table 4. Tobit regression results

Variable	Coefficient	Std. Error	t-statistic	p-value
PUBHEX	-0.178	0.027	-6.70	0.000
LGDPPC	-0.918	0.151	-6.06	0.000
EDUC	0.023	0.013	1.71	0.108
CONCORR	0.185	0.089	2.08	0.056
POPDENSE	0.036	0.015	2.35	0.033
Constant	6.711	0.996	6.73	0.000
log-likelihood = 36.077965	LR chi2(5) = 41.03		Prob > chi2	= 0.0000

Per capita GDP, public health expenditure (% of GDP), control of corruption, and population density are found to have statistically significant effects on the efficiency of healthcare expenditure in Iran ($P<0.05$). However, education is not statistically significant (See Table 4).

Furthermore, the results from the Tobit model showed that governance variable positively and significantly impacts efficiency. The indicator of control of corruption has a score ranging from -2.5 to +2.5, with a higher score implying better performance. The results show a positive relationship between the higher control of corruption score and efficiency. A point increase in the control of corruption leads to a 0.18 percentage point rise in efficiency. This reveals that corruption plays a notable role in determining health expenditure efficiency in Iran, and relatively improved control of corruption level is expected to indicate better efficiency performance. Novignon [29] also revealed high corruption reduced health expenditure efficiency in Sub-Saharan Africa. According to Dhaoui [27], control of corruption affects positively and significantly efficiency scores.

Educational level has a positive but non-significant impact on the efficiency of healthcare expenditure. In the study of Gou et al. [30] and Dhaoui [27], it is also reported that education is not found to have a statistically significant effect.

The negative and significant coefficient for GPD per capita indicates that higher income levels are associated with lower efficiency. Based on results, a percentage point increase in GDP per capita leads to approximately a 0.92 percentage point decrease in the efficiency of health expenditure. It is suggested that high-income areas will lead the government to support idle workers, meaning that the government will lose the incentive to control costs, and efficiency will weaken. However, some researchers find that GDP per capita can impact the efficiency of healthcare expenditure positively; because wealthier residents will put more pressure on local authorities to meet the level of demand for efficient public services [30].

The findings also demonstrate that public health expenditure as a share of GDP influences efficiency levels in a negative way. The estimates affirm that one point rise in public health expenditure (as % of GDP) leads to a 0.17 percentage point fall in the efficiency of healthcare expenditure. This finding is consistent with that of Samut and Cafri [31], who claim public health spending affects efficiency negatively, implying that public spending not only influences health outcomes but also reflects demographic factors such as age structure and health behavior. Due to

the high rate of the aged population in Iran, this is thought to have affected efficiency negatively as a result of an increase in the care costs for the elderly, chronic diseases, and mortality rates.

The population density was another significant determinant of health expenditure efficiency. A positive relationship was established between the variable and efficiency in the analysis. This implies that one point rise in population density led to a 0.03 percentage point increase in the efficiency of the health care expenditure. Theoretically speaking, this confirms that, when the population per unit area in a region is larger, the local public service network will be closer, the scale economy effect of government public expenditure will be more significant, and government public spending will be higher. However, this is challenged by Guo et al. [30]. They claim that population density is negatively correlated with health care expenditure efficiency.

4. Discussion

The healthcare system is an imperative element for any community, as it extremely affects the development of the socioeconomic system. Reducing inefficiency leads to substantial improvement in the healthcare system.

In much more recent years, the attention of empirical studies on efficiency has been on the health system as a whole. This type of macro-level analysis of how health resources are used to generate population health outcomes is fast gaining ground in the health economics literature.

Unlike the micro-based studies on efficiency, healthcare expenditure per capita has been widely applied as the input variable [29]. Life expectancy, infant survival rate, and maternal mortality rate have broad applications as measures of health system output. Thus, these variables are used in the current study as input and outputs to measure the macro-level efficiency of health expenditures in Iran during 2000-2019.

Evidence from the DEA model indicated variation in the efficiency of health expenditure over the years. This suggests significant potential for improvement in population health status given the current level of resources invested in healthcare.

The main findings of this paper represented that about 85% of the DMUs (in our case years) are technically inefficient with respect to used healthcare resources (per capita health expenditure). Also, 30% of the years had healthcare expenditure efficiency greater than 90%. This result suggests in these years, good health at a low cost is produced, and therefore, health systems resources are appropriately used.

Healthcare system efficiency in Iran has been researched, but previous studies were based on cross-sectional data for measuring efficiency, and thus results imported within countries comparisons. This makes it impossible to analyze the dynamic trend of efficiency in the health care expenditure of the country. Therefore, in this study, time series data is implied to measure efficiency scores and compare it with itself over time.

Building upon decades of continuous reforms, Iran has made progress in

providing better healthcare services impressively, especially those targeted towards improving maternal and infant health and increasing life expectancy. While the health system performance was reviewed in 2000, the Family Physician and Rural Insurance Program were introduced in 2005 to develop primary healthcare [32]. By implementing these programs, some of the health indices have significantly improved. Despite the increase in performance indices, the costs of healthcare services have increased.

Another endeavor, entitled Health Transformation Plan, was conducted in 2014. The aim of the extensive plan was to provide sustainable financial resources in the health sector, protect the population against health expenses, increase access to high-quality healthcare services, and improve the performance of health service delivery. To implement this plan, the government injected more than INT$10316 million additional funds into the healthcare system. As a result, the total health expenditure increased by 39%, and its share as % of GDP rose from 6.1% in 2013 to 8.13% in 2016 [33]. Such reforms by increasing the costs could have adverse effects on efficiency.

5. Conclusion

This study provides an empirical image of the technical efficiency of healthcare expenditure in Iran. In this regard, a two-stage performance assessment over 20 years from 2000 to 2019 was carried out. At the first stage of the study, the macro efficiency scores of each year were measured using one input and three outputs by DEA. In the second stage, the factors affecting the efficiency scores obtained in the first stage were determined by Tobit regression Analysis. The findings indicate that inefficiency exists in the healthcare expenditure of most of the years studied, and Variations in the efficiency are observed while it is revealed that the efficiency score of 20 years was 0.83 on average. As a result of the estimation of the Tobit model, there was found that GDP per capita and public health expenditure (% of GDP) affect efficiency negatively; also, a positive relationship between population density and control of corruption as a governance indicator with efficiency is observed. The significant positive impact of control of corruption on healthcare expenditure efficiency indicates that level of efficiency in the management of resources may be more crucial than the number of resources invested in the healthcare system, especially in the existence of corruption and ineffective bureaucracy.

Conflict of interests

The authors declare that there is no conflict of interest.

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