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Performance of Public Hospitals in Malaysia and its Determinants: An Analysis Using Data Envelopment and Tobit Model

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Abstract

The aim of this paper is to examine the efficiency of public hospitals in Malaysia and identify the factors affecting their performance. We used the non-parametric Data Envelopment Analysis (DEA) in the first stage to find the efficiency score and utilized Tobit model in the second stage to identify the determinants of inefficiency. Our analysis was based on 25 public hospitals in the northern region of Malaysia which were divided into two main classifications - specialist and non-specialist. Data were obtained for three years from 2008 to 2010. The results showed that the technical efficiency scores for specialist hospitals ranged between 0.728 and 1 while for non-specialist, it was between 0.726 and 1 over the period of study. The scale efficiency scores revealed that the majority of specialist hospitals exhibited decreasing returns to scale (DRS) but as for the non-specialist, the majority manifested increasing returns to scale (IRS). From the tobit model, it was found that the daily average number of admission, the number of outpatient per doctor and hospital classification have significant influence on hospital inefficiency.
Keywords: DEA, scale efficiency, technical efficiency, Tobit model.

1. Introduction

Cost control and efficient resource allocation in public services is a catalyst for efforts to transform the health sector towards a more efficient and effective health system (Tenth Malaysia Plan, 2010). Public hospitals exist within the system, primarily to provide secondary care to the population. In Malaysia, public hospitals are classified into five classifications which are district hospitals, district hospitals with specialist, general hospitals, national referral centres and teaching hospitals. In this study, focus for efficiency analysis is given to the first three classifications which were later combined into two main classifications - specialist and non-specialist. District hospitals are located in each district of a state where specialist services are offered on special visiting hours. Services provided include outpatient care, inpatient and accident and emergency services (A&E) which covers non-complicated medical cases. In the case of complication, patients will be referred to district hospitals with specialist services or to the general hospitals. District hospitals with specialist services are located in bigger districts. The services offered in these hospitals are more comprehensive as compared to that of district hospitals. These hospitals also serve as referral to district hospitals without specialist. In each state, there is a general hospital which is located at the state capital. This hospital could accommodate a large number of beds and act as a referral to all hospitals in the state. It provides all level of secondary care and some level of tertiary care as some tertiary care are provided at particular hospitals within the region.

In the delivery of health care services, the issue of efficiency is very important in determining the optimal level of resources used in producing a given output. Despite for being non profit-oriented entities, the efficiency of public hospitals needs to be reviewed because it involves cost to the government and the cost is rising each year, coupled with the high expectations of the population for this service. Therefore, the main objective of the study are to estimate the relative technical efficiency (TE) and scale efficiency (SE) of public hospitals in the northern region of Malaysia and to determine the main factors that influence the inefficiency.

In this study we use the Data Envelopment Analysis (DEA) approach to estimate the technical and scale efficiency and Tobit model in the second stage. The study is structured as follows. After the introduction, Section 2 discusses the research methods that cover the scope and data of the study, the DEA approach and specification of Tobit model. Section three presents the results and analysis while the last section concludes the paper.

2. Research Methods

2.1. Scope and Data of the Study

In this study we focused on efficiency issues of public hospitals in the northern region of Malaysia which consists of Perlis, Kedah, Pulau Pinang and Perak states. Due to the fact that the operation of hospitals may vary according to its classification (Gannon, 2005; Mc. Killop et al., 1999) the analysis is divided into two parts based on the classifications (specialist and non-specialist). The division allows us to distinguish between services provided and the differences in size. The distribution of hospitals with their classification is shown in Table 1. Generally the DEA analysis requires that the number of the data management units (DMUs), in this case are hospitals, to be 3 times greater than the sum of inputs and outputs. In this analysis, a minimum of 21 [(3+4)*3] of DMUs are needed for each classification. Therefore, to satisfy this condition, the data for three years are pooled[1] to create a total of 39 DMUs for specialist and 36 DMUs for non-specialist classifications. For pooled data, efficiency scores are estimated based on one common frontier for three years (2008-2010) whereby each hospital at a particular year is treated as a different DMU (Gannon, 2005; Donthu & Yoo,1998; McKillop et al., 1999; Wolszczak-Derlacz & Parteka, 2011).

The data for DEA analysis consist of three inputs (number of doctors, nurses and beds) and four outputs (number of inpatients, outpatients, surgeries and deliveries) from 25 public hospitals in the state of Kedah, Perlis, Pulau Pinang and Perak. The combination of input and output used is based on many efficiency studies on hospitals (Gannon, 2005, McKillop et al., 1999; Sahin et al., 2011; Zere et al., 2001) and also subject to the availability of the data. Data were collected for three years from 2008 to 2010. Due to data constraint five hospitals from Pulau Pinang state were not included in the analysis. For confidentiality reason, the real names of hospitals were not specifically mentioned in the analysis.

[1] The pooled data are obtained by using the formula of n*number of years where n represents the number of hospitals in each classification.

Table-1. List Of Hospitals in Northern Region, Malaysia

Administrative Districts	Hospitals' name	Hospital classification[a]
KEDAH		
Kota Setar	Sultanah Bahiyah	State
Kuala Muda	Sultan Abdul Halim	Major specialist
Kulim	Kulim	Major specialist
Kubang Pasu	Jitra	District
Langkawi	Langkawi	Minor specialist
Padang Terap	Padang Terap	Non-specialist
Sik	Sik	Non-specialist
Baling	Baling	Non-specialist
Yan	Yan	Non-specialist
Pendang	-	-
Bandar Baharu	-	-
Pokok Sena	-	-
PERLIS	Tuanku Fauziah	State
PERAK		
Batang Padang	Slim River	Minor specialist
	Tapah	Non-specialist
Manjung	Seri Manjung	Minor specialist,
	Sg. Siput	Non-specialist
Kinta	Raja Permaisuri Bainun	State
	Bahagia	Specialist institution
Kuala Kangsar	Kuala Kangsar	Minor specialist
	Changkat Melintang	Non-speacialist
Larut and Matang	Taiping	Major specialist
	Selama	Non-specialist
Kerian	Parit Buntar	Non-specialist
Hilir Perak	Teluk Intan	Major specialist
Hulu Perak	Grik	Minor specialist
Perak Tengah	Batu Gajah	Non-specialist
Kampar	Kampar	Non-specialist
PULAU PINANG		
Seberang Perai Tengah	Bukit Mertajam	Minor specialist
	Seberang Jaya	Major specialist
Seberang Perai Utara	Kepala Batas	Minor specialist
Seberang Perai Selatan	Sungai Bakap	Non-specialist
Timur Laut	Pulau Pinang	State
Barat Daya	Balik Pulau	Non-specialist

[a]Source: Ministry of Health, Specialty and Subspecialty Framework of Ministry of Health Hospitals: 10 MP (2010-2015)

2.2. Data Envelopment Analysis (DEA)

2.2.1. Technical Efficiency (TE)

The original DEA model was developed by Charnes, Cooper and Rhodes (1978) and referred to as the CCR model. It assumes a production technology with constant returns to scales. In this study we utilized the input oriented DEA model which was developed by Banker, Charnes and Cooper (1984) or also known as the BCC model. The BCC model is more flexible that it relaxes the assumption of constant returns to scale to allow for variable returns to scale (VRTS). The input oriented DEA model minimizes inputs while maintaining the current levels of output and environmental factors (refer to Banker et al. (1984) for detail specification).

2.2.2. Scale Efficiency (SE)

A hospital might experience inefficiency due to its own inefficient operation or being disadvantage due to certain operating environments. We can therefore extent the discussion above to reposition these inefficiencies into specific classification. By using the CCR and BCC scores, scale efficiency (SE) can be obtained by:

$$SE=\frac{\theta_{CCR}}{\theta_{BCC}}$$

where θ_{CCR} is the efficiency score from the CCR model and θ_{BCC} is the score from BCC model. An efficient DMU with a CCR will also be found to be efficient with BCC model and this particular DMU will exhibit constant returns to scale (CRS). For BCC efficient with CRS characteristics (the most productive scale size), its scale efficiency is one.

2.3. Second Stage Analysis - Tobit Model

2.3.1. Empirical Specification

The result from DEA will be extended to the second stage analysis by using econometric model. In this stage, one could determine the factors that may lead to different hospitals' performance. Standard multiple regression that uses ordinary least squares (OLS) assumes a normal and homoscedastic distribution of the disturbance term and dependent variable which is not suitable for limited dependent variable (Maddala, 1983). The expected value of the error term for limited dependent does not comply with the assumption of normality which equals zero. Therefore, a censored Tobit is used in determining factors that influence inefficiency as the scores by DEA fall between 0 and 1 and mainly clustered at 1. Among studies on hospital efficiency that utilized Tobit model are Zere et al., (2001) and Chilingerian (1995). For computational convenience, we transform the technical efficiency scores in such a way that the censoring point is concentrated at zero (Gillen & Lall, 1997; Greene, 1993; Chilingerian, 1995). The score is transformed by using the formula:

$$y_i = (1/\theta) - 1$$

where y_i is the inefficiencies scores and θ is the technical efficiency scores. With this transformation, hospitals that are fully efficient with the score of 1, are transformed to 0. In the Tobit model, it supposes that there is a latent variable y_i^* that linearly depends on a vector of explanatory variables, x_i and can be written as:

$$y_i^* = \beta x_i + u_i \ , \ u_i \sim N(0, \sigma^2)$$

where u_i is normally distributed error term with mean 0 and variance σ^2 and β is a vector of unknown parameters.

We observe dependent variable y_i that linking to y_i^* by:

$$y_i = \begin{cases} y_i^* \ if \ y_i^* > 0 \\ 0 \ \ if \ \le 0 \end{cases}$$

The likelihood function of the model is therefore

$$L = \prod_{y_i=0}(1-F_i)\prod_{y_i>0}\frac{1}{(2\pi\sigma^2)} \text{x}\, e^{-\left[1/(2\sigma^2)(y_i-\beta' x_i)^2\right]}, \quad F_i = \int_{-\infty}^{\beta x_i/\sigma}\frac{1}{(2\pi)^{1/2}}e^{-t^{2/2}}dt$$

2.3.2. Data and Variables for Tobit Models

The data used in this section is a combination of data from 25 hospitals for 3 consecutive years (2008-2010), which produces a total number of 75 observations (N=75). Among explanatory factors that have been considered in a general model include ownership status, competitiveness, regulatory pressure, demand patterns, patient characteristics, provider practice, organizational setting, managerial practices, and illness characteristics (Cooper et al., 2011:p. 473). Due to data constraint, the choice of factors to be included in our model is quite limited. We concentrated on demand pattern (*bedrate, adm, stay, turnover*), distribution of resources (*DocNurse, DocOP, DocIP*), and organizational setting (*specialist*). The possible exploratory variables used in the model are explained in Table 2, together with their summary statistics.

Table- 2. Dependent and Exploratory Variable

Variable	Definition	Mean	Std. Dev	Min	Max
score	Transformed inefficiency score	0.052	0.094	0	0.408
bedrate	Bed occupancy rate (%)	52.805	16.904	24.140	90
adm	Daily average number of admission	47.432	46.843	9.120	169
stay	Mean length of stay (days)	2.909	0.619	1.870	4.560
turnover	Turnover interval for beds (days)	2.876	1.537	0.400	7.480
DocNurse	Number of nurse per doctor	8.127	6.964	1.041	37
DocOP	Number of outpatient (‘000) per doctor	6.850	6.003	0.576	0.272
DocIP	Number of inpatient (‘000) per doctor	0.577	0.440	0.054	2.264
specialist	1 if specialist hospital, 0 otherwise	0.520	0.503	0	1

3. Results and Analysis

3.1. Technical and Scale Efficiency of Hospitals with specialist

Table 3 shows the technical and scale efficiency scores for years 2008 to 2010. In 2008, all hospitals, except for AE and AF were found to be technically efficient. In 2009 and 2010, the numbers of inefficient hospitals have increased to three and seven hospitals respectively. The average technical efficiency scores for inefficient hospitals are 0.932 (2008), 0.833 (2009) and 0.905 (2010). Similar to the previous analysis, hospital AE is not efficient in all years considered. This implies that AE could have reduced its inputs combination up to 17% in 2010 while maintaining the same number of outputs. Besides AE, the other two hospitals which were found to be inefficient in year 2009 and again in 2010 were RA and AB. The efficiency score for RA was 0.813 in year 2009 but decreased to 0.728 in 2010. The findings show that hospital RA required a maximum of 19% and 27% reduction of its input in year 2009 and 2010 respectively while maintaining the same output level in the mentioned years. The average scale efficiencies of hospitals were 0.941 (2008 and 2009) while 0.933 for year 2010. This means that, on average, these hospitals might respectively needed only 94.1 percent (2008 and 2009) and 93.3 percent (2010) of the current inputs to get the current outputs. In other words, their average operation inefficiency was respectively 5.9 percent (2008 and 2009) and 6.7 percent (2010).

The average scale efficiency score for scale-inefficient hospitals were 0.905 (2008) and 0.904 (2009 and 2010). In year 2008, only five hospitals (38%) had a scale efficiency of 1, which implies that they had the most productive size for that particular input-output mix. Thus, about 62% of the remaining considered hospitals were scale-inefficient in the year 2008. In year 2009 the number of scale-inefficient hospitals remained same as in year 2008 and increased to 69% in 2010.

In addition, three out of eight scale-inefficient hospitals showed that they were operating under increasing returns to scale (IRS) in year 2008, meaning that the hospitals could have improved their efficiency levels if they had increased inputs. Conversely, five out of eight hospitals were shown to be operating under decreasing returns to scale (DRS) in the same year. In simple words, these hospitals should reduce their inputs to achieve better efficiency. While, in year 2009 only two of the eight scale-inefficient hospitals experienced IRS, while six hospitals manifested DRS. In year 2010, there are 9 hospitals with scale-inefficient and from this number three manifested IRS while six DRS.

On average, the specialists' hospitals are using more inputs than they need to produce output to what they are currently producing. In other words, these hospitals could increase the outputs, but since we do not expect hospitals to look for more patients, input minimization might be the best way. Technical efficiency scores also indicate the overall extent to which all the inputs have to be reduced in order to attain 100 per cent efficiency for the inefficient units. The hospitals producing on the efficient frontier define the best practice and thus could be regarded as role models.

3.1.1. Technical and Scale Efficiency of Hospitals without Specialists

Table 4 shows the technical and scale efficiency scores for hospitals without specialists. Similar to the analysis for hospitals with specialists, the performance of these 36 DMUs is based on one common frontier for the three years. Overall, there were 19 efficient DMUs over considered years. Table 4 displays the scores by year for easy interpretation. In 2008, six hospitals were technically

Table-3. Technical and Scale Efficiency of Hospitals with Specialists, 2008-2010

	Efficiency -2008			Efficiency -2009			Efficiency -2010		
DMU	VRSTE	SE	Return to Scale	VRSTE	SE	Return to Scale	VRSTE	SE	Return to Scale
KA	1	0.857	DRS	1	0.883	DRS	1	0.886	DRS
KB	1	0.984	DRS	1	0.973	DRS	0.986	0.924	DRS
KC	1	1	CRS	1	1	CRS	0.977	0.999	IRS
KD	1	0.988	IRS	1	1	CRS	1	1	CRS
RA	1	1	CRS	0.813	0.97	DRS	0.728	0.986	DRS
AA	1	0.667	DRS	1	0.628	DRS	1	0.573	DRS
AB	1	0.851	DRS	0.860	0.896	DRS	0.844	0.878	DRS
AC	1	0.953	DRS	1	0.988	DRS	0.988	0.971	DRS
AD	1	1	CRS	1	1	CRS	1	1	CRS
AE	0.939	0.966	IRS	0.827	0.938	IRS	0.828	0.919	IRS
AF	0.925	0.970	IRS	1	1	CRS	1	1	CRS
AG	1	1	CRS	1	0.956	IRS	1	1	CRS
PA	1	1	CRS	1	1	CRS	0.982	0.999	IRS
No. of Efficient Hospitals	11	5		10	5		6	4	
Average score (overall)	0.990	0.941		0.962	0.941		0.949	0.933	
Average score (inefficient hospitals)	0.932	0.905		0.833	0.904		0.905	0.904	

Table-4. Technical and Scale Efficiency of Hospitals without Specialists, 2008-2010

	Efficiency -2008			Efficiency -2009			Efficiency -2010		
DMU	VRSTE	SE	Return to Scale	VRSTE	SE	Return to Scale	VRSTE	SE	Return to Scale
KE	0.991	0.997	DRS	1	1	CRS	0.991	0.989	DRS
KF	0.857	0.991	IRS	0.850	0.996	IRS	0.726	0.999	IRS
KG	1	1	CRS	1	1	CRS	0.932	0.999	DRS
KH	1	1	CRS	1	1	CRS	1	1	CRS
KI	1	1	CRS	1	1	CRS	1	0.936	IRS
AH	0.967	0.985	DRS	1	1	CRS	0.936	0.999	IRS
AI	1	1	CRS	0.999	0.981	IRS	1	0.995	IRS
AJ	0.973	0.997	IRS	1	1	CRS	0.874	0.997	IRS
AK	1	0.850	IRS	0.974	0.819	IRS	0.958	0.642	IRS
AL	1	1	CRS	1	0.958	IRS	1	0.812	IRS
AM	0.921	0.936	IRS	0.850	0.898	IRS	0.816	0.836	IRS
AN	0.967	0.653	IRS	1	0.691	IRS	1	0.689	IRS
No. of Efficient Hospitals	6	5		8	6		5	1	
Average score (overall)	0.973	0.951		0.973	0.945		0.936	0.908	
Average score (inefficient hospitals)	0.946	0.916		0.918	0.891		0.890	0.899	

efficient with overall efficiency average of 0.973. There were six inefficient hospitals which contribute to an average score of 0.946. In 2009, the number of efficient hospitals has increased to eight but the overall average score remain the same. The efficiency score for seven inefficient hospitals has declined to 0.918 and further declined to 0.890 in 2010. The average efficiency score of inefficient hospitals without specialists in 2008 and 2009 were higher than the score of those with specialist but lower in year 2010. The mixed trend also occurred in overall average where the score of hospitals without specialist were lower in both 2008 and 2010 but higher in 2009. Of 12 hospitals, it shows that three (KH, KI, AL) were efficient in all three years while two (KF, AM) were consistently inefficient. On average the inefficient hospitals are able to reduce their inputs used by 8.2% while maintaining the same number of outputs.

Scale efficiency shows the efficiency of a DMU based on its operation size. It shows that some hospitals were technically efficient (based on VRTS scores) but not scale-efficient. When this happens, a DMU is said to be operating locally efficient but not globally. In year 2008, five hospitals had a scale efficiency of 1 with overall average of 0.951. Of seven scale-inefficient hospitals, five hospitals had decreasing return to scale (DRS) while two exhibited increasing returns to scale (IRS). The number of scale-efficient hospitals has increased to six in 2009 but fall again to five in 2010. On average, the scale efficiency scores (both overall and inefficient hospitals average) in 2008 were the highest of the three years.

3.2. Tobit model

In developing the model, we begin by including every possible variable as described in Table 2 one at a time to see the effect. We continuously refined the model until we come to the final model as reported in Table 5. In the final model, we dropped bed occupancy rate (*bedrate*), mean length of stay (*stay*), turnover interval for beds (*turnover*) and number of inpatient per doctor (*DocIP*).

The values of Variance Inflation Factors (VIF) are found to be ranged from 1.92 to 3.22 with the mean value of 2.41. Given that the value is less than 10, the estimated tobit model does not suffer from serious multicollinearity problem. The likelihood ratio test is conducted by calculating the log-likelihood statistics given by -2 log(λ), where log λ represents the difference between the log of maximized values of the likelihood function when all dependent variables equal to zero and the values of similar maximization when dependent variables are as observed in the regression. The model chi-square, with four degree of freedom is 16.67 and it is significant at 1% level.

From Table 5, it shows that the daily average number of admission (*adm*), number of outpatient per doctor (*DocOP*), and type of hospitals (*specialist*) are significant in determining inefficiency with expected sign. For one unit increase in *adm*, there is a 0.0017 point decrease in the predicted value inefficiency score (*score*). This means that an increase in daily average number of admission would reduce inefficiency. It shows that the number of outpatient (in thousands) per doctor has negative relationship with *score* whereby a thousand unit increases in outpatient per doctor would drop the predicted value of *score* by 0.0215 units. The predicted value of specialist hospitals is 0.1032 lower than the non-specialist that suggests that the former are more efficient than the latter. Service characteristics also play a significant role in Chilingerian (1995) but not in Zere et al. (2001).

4. Conclusion

In this paper, we analyzed the technical and scale efficiencies of 25 public hospitals in the northern region of Malaysia according to its classification. The efficiency level for both hospital types can be considered as high with an average above 90% efficiency score. However, focus and further investigation should be given to individual hospitals which score is far below average every year, for example hospital AE. As for scale efficiency, it is found that in general the hospitals are scale-efficient with 24 hospitals are efficient in year 2008 and dropped to 20 in year 2009 and 2010. One noticeable trend for scale efficiency is that majority of scale-inefficient hospitals with specialist were over utilized, especially the state hospitals. We extended the DEA analysis by identifying environmental factors that may affect inefficiency by using Tobit model. It is found that admission rate, number of outpatient per doctor and types of hospitals have significant influence on inefficiency. From managerial perspective, identifying major gaps in performance can drive a hospital to rethink how it manages its operation. Higher operational efficiency of hospitals is likely to help better utilization of resources, help control the cost of medical services, and consequently to provide more affordable cares and improved access to the public.

Table- 5. Estimation Result for Tobit Model

	Coefficient	**Std. Dev**	**P>t**
adm	-0.0017	0.0007	0.021**
DocNurse	-0.0014	0.0062	0.825
DocOP	-0.0215	.00768	0.007***
specialist	-0.1032	0.0615	0.098*
_cons	0.2547	0.0780	0.002***
Sigma	0.1530	0.0207	
LogLikelihood	-6.613		
LR chi2(4)	16.67		
	(p<0.01)		

The symbols ***,**,and * denote 1, 5 and 10% level of significance, respectively.

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