Technical Efficiency and Scale Efficiency of District Hospitals: A Case Study

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The Government of Tamil Nadu state in India has been implementing various health sector reforms (for example, expansion and upgradation of public health facilities, provision of round the clock services in selected primary health centres and continuous availability of quality medicines decentralisation) in a bid to improve efficiency in health care. However, few attempts have been made to make an estimate of the efficiency of hospitals in Tamil Nadu as well as in India till date. The objectives of this study are: (i) to estimate the relative technical efficiency (TE) and scale efficiency (SE) of a sample of public hospitals in Tamil Nadu; and (ii) to demonstrate policy implications for health sector policy makers. The Data Envelopment Analysis (DEA) approach, a well-known operations research (OR) technique for evaluating the relative efficiency of a set of similar decision making units (DMU), was used to estimate the efficiency of these hospitals. To do so we made use of the data collected from the Directorate of Medical and Rural Health Services (DMRHS) for 29 districts of Tamil Nadu in 2004–05. The output data included are outpatient visits, number of inpatients, number of surgeries undertaken, number of deliveries and number of emergency cases. The numbers of staff members and bed strength were used as input. Of the 29 hospitals, it was found that 52 per cent were technically efficient as they had relative efficiency score 1.00 and lie on the efficiency frontier, while the remaining 48 per cent were technically inefficient and can use some of the efficient hospitals as their peers to improve their efficiency. Further, the average scale efficiency among the inefficient hospitals was 81 per cent, which implies that the scale inefficient hospitals could reduce their size by 19 per cent without reducing their current output levels.

Keywords: *Data envelopment analysis, technical efficiency, scale efficiency, district hospital*

Introduction

India has made significant progress in the past several decades in improving the health and well-being of its people. Over the past 40 years, life expectancy has risen by 17 years to 61 years, and infant mortality has fallen by more

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than two-third to 74 deaths per 1,000 live births. Despite these significant strides, India is behind many less wealthy nations on indicators of health system performance (World Bank 2005). On an index of overall performance of health systems, India was ranked 112th out of 191 WHO member countries, while on the basis of the responsiveness of health systems, level and distribution: 108, 110 and 127 respectively (World Bank 2005). Public hospitals are less efficient because of bureaucratic processes and excessive hierarchical channels in the implementation of cost control measures (Clark 1980). Moreover, the fallback option of government support in financial terms also contributes towards the inefficiencies of public hospitals (Bhat et al. 2001). Spurred by the fiscal crisis and slowing growth, the state has embarked on a series of reforms to improve overall health and patient satisfaction, technical and allocative efficiency and to provide more equitable access through the reorganisation of national health agencies, user charges for publicly provided services, health insurance schemes and service contracting.

Despite dramatic increases in levels of health care expenditures in developing countries like India, insufficient research has been directed to the issues of technical efficiency and scale efficiency in resource use and of measuring relative efficiency among hospitals or different facilities offered by the states. From a managerial perspective, understanding the cost structure of hospitals and their inefficiency in utilising resources is crucial for making health care policies and budgeting decisions. Higher operational efficiency of hospitals is likely to help control the cost of medical services, and consequently to provide more affordable care and improved access to the public.

This article examines how efficiently different district headquarters' hospitals use their resources to achieve their health outputs. Technical efficiency is obtained when output is maximised for a given level of inputs, or alternately, when input is minimised for a given amount of output. The findings motivate an examination of the policy implications of this comparative analysis of efficiency in the production of health care. We conclude that the hospitals may have something to learn from others that are more economical in their allocation of resources to health care.

Public Health System in Tamil Nadu

The health care sector in Tamil Nadu, as in the other states of India, consists of both private and public providers. Recent studies (NSSO 2006) have shown that public institutions in Tamil Nadu cater to 29 per cent of all outpatients (ambulatory) care (rural and urban) compared to the all-India average of 19 per cent. In rural Tamil Nadu, they account for 32 per cent as compared to the Indian average of 18.3 per cent. Also, it is worth noting that public institutions account for 52 per cent of the total inpatient days for childbirth (rural and urban) while they account for about 35 per cent of the total institutional deliveries in the state.

The public health care system in the state as in the other states of India, is structured as follows: at the lowest level, there are health sub-centres (HSCs) covering a population of about 5,000 each. Above this level, there are primary health centres (PHCs) offering primary (ambulatory) care, delivery and minor surgical, and public health services for a population of about 30,000. At the higher levels, there are community health centres roughly for a population of about 1,00,000, and district hospitals offering services up to the level of secondary health care. The CHCs are designed to accommodate about 30 beds, while the size of district hospitals is not governed by any norms and therefore their sizes vary from 66 beds to 608 beds (as shown in Appendix 1). There are a few public hospitals located in the state capital and other larger towns offering tertiary health care, besides catering to the primary and secondary care needs of the population. Typically, there is no referral system in practice within the government health system. As a result, patients from any part of the state can approach providers in tertiary care institutions without being referred to by providers at the lower levels of care. However, recent reform efforts are addressing this issue, as it may significantly affect the overall technical efficiency of these institutions.

Tamil Nadu is the fifth largest economy and the sixth most populous state in India with the third-highest Human Development Index amongst 29 Indian states (HDR Govt. of Tamil Nadu 2003). The health sector in Tamil Nadu is improving rapidly in terms of health indicators including infant mortality rate and maternal mortality rate. Infant mortality rate in Tamil Nadu declined from 68 in 1980s to 44 per 1,000 live births in 2002.

Data Envelopment Analysis

Data envelopment analysis (DEA) is a method for mathematically comparing different decision making units' (DMUs) productivity based on multiple inputs and outputs. The ratio of weighted inputs and outputs produces a single measure of productivity called relative efficiency. DMUs that have a ratio of 1 are referred to as efficient given the required inputs and produced outputs. The units that have a ratio less than 1 are less-efficient relative to the most efficient unit. Because the weights for input and output variables of a DMU are computed to maximise the ratio and then compare it to similar ratios of best-performing DMUs, the measured productivity is also referred to as relative efficiency.

Charnes et al. (1978) first proposed DEA as an evaluation tool to measure and compare a decision making unit's productivity. Outside of the health sector, DEA has been used extensively in such areas as production (Fare et al. 1994 ; Banker and Maindiratta 1988), school performance (Charnes et al. 1981), and evaluating maintenance units of the US Air Force (Charnes et al. 1985). A literature survey by Seiford (1990) offers a few hundred published articles that use DEA. In health care literature, DEA has been used to analyse efficiency in hospitals and nursing home industries. Among previous applications of DEA with hospital data are studies by Banker et al. (1986), Chang (1998), Chattopadhy and Ray (1996), Ehreth (1994), Ersoy et al. (1997), Giuffrida and Gravelle (2001), Grosskoff and Valdmanis (1987), Hollingsworth and Parkin (2001), Jacobs (2001), Kirigia et al. (2002), Linna et al. (2002), Morey et al. (1992), Salinas-Jimenez and Smith (1996), Sherman (1984), Shroff et al. 1998,Wan et al. (2002), White et al. (1996) and Zavras et al. (2002).

The original DEA model, proposed by Charnes et al. (1978) and referred to as the CCR model in literature, assumes a production technology with constant returns to scales. Their model implies that any proportional change in every input usage would result in the same proportional change in every output. A more flexible and refined model is then developed by Banker et al. (1984). Their so-called BCC model relaxes the assumption of constant returns to scale to allow for variable returns to scale.

Input Oriented Model

The input oriented DEA model, which is solved for each district headquarter hospital individually, minimises inputs while maintaining the current levels of output and environmental difficulty. Let x_{ij} = input i for hospital j, where $i = 1, \ldots, 4$ and $j = 1, \ldots, 29$ and let y_{rj} be the level of output r for hospital j, where $r = 1, 2..4$ and j = 1,..29. The objective of the model, for the particular hospital being solved for, is to minimise the efficiency score denoted by Θ, where $0 < \Theta < 1.0$. Θ is the amount by which all inputs can be contracted for each individual hospital under consideration, while holding output and other environment constant. The decision variables λ_j ($j = 1, \ldots, 29$) represent the weights that will be used to form a weighted average frontier composite. The solution to the input minimisation model locates the point on the frontier that allows the inputs of the hospital under consideration, denoted by j_o, to be contracted as much as possible. The input oriented model for hospital j_o, adapted from the BCC model, is:

Minimize Θ

s:t:

$$\sum_{j=1}^{29} \lambda_j x_{ij} \leq \Theta x_{ijo} \forall i = 1, 2..4 \tag{1.1}$$

$$\sum_{j=1}^{29} \lambda_j y_{rj} \geq y_{rjo} \forall r = 1, 2,..4 \tag{1.2}$$

$$\sum \lambda_j = 1 \tag{1.3}$$

$$\lambda_j \geq 0 \text{ j} = 1 \ldots\ldots\ldots j0 \ldots 29$$

$$\text{where } \lambda_j \geq 0, j = 1, \ldots, j0, \ldots, 29$$

The frontier composite must be the same or better than hospital j_o in every dimension, with the model seeking the frontier point that allows maximum input reduction. The efficiency score (Θ) indicates the amount by which inputs can be contracted, and as can be seen in the model, Θ is applied only to the four health inputs in constraint (1.1). For example, $\Theta = 0.80$ suggests that hospital j_o should be able to use only 80 per cent of its current level of inputs and still be able to produce the same level of output within its current environment. This would allow a 20 per cent reduction in inputs. A hospital that is on the frontier cannot find any composite of other hospitals that dominates it. Thus, the only feasible solution to the model will be to choose itself as the frontier composite, where $\lambda j_o = 1$ and $\Theta = 1$. This says that relative to other hospitals, hospital j_o cannot be found inefficient.

Output Oriented Model

The objective of the output oriented model is to maximise output while maintaining the levels of inputs. Let $Yj = (y_{1j}; \ldots y_{rj}) \geq 0$ and $Xj = (x_{1j}; \ldots x_{ij}) \geq 0, j = 1;\ldots N$, be the observed output and input vectors generated from an underlying production possibility set T = {(X; Y)| outputs Y can be produced from inputs X} for a sample of N hospitals in Tamil Nadu. Using the same definitions as the input oriented model the efficiency score for hospital j_o, which is the reciprocal of the inefficiency, $\hat{\Theta}_j$ is obtained by solving the following BCC model of DEA:

Maximize Θ
s:t:

$$\sum_{j=1}^{29} \lambda \; x_{ij} \leq x_{ijo} \forall i = 1, 2..4 \qquad (2.1)$$

$$\sum_{j=1}^{29} \lambda_j y_{rj} \geq \Theta \, y_{rjo} \forall r = 1, \ldots 4. \qquad (2.2)$$

$$\sum_{j=1}^{29} \lambda_j = 1 \qquad (2.3)$$

$$\lambda_j \geq 0 \text{ j} = 1 \ldots\ldots\ldots j0 \ldots 29$$

$$\text{where } \lambda_j \geq 0, j = 1, \ldots, j0, \ldots, 29$$

This model is similar to the input oriented model and must be run once for each hospital and for each output. The difference is that in this model we maintain the inputs of hospital j_o, while seeking to maximise the output with $\hat{\Theta}$ being the 'expansion' factor. If a hospital is on the frontier, then $\hat{\Theta} = 1.0$ and the output cannot be improved without increasing its level of inputs.

However, for the purpose of analysis in this article we have used the input oriented approach with variable returns to scale (VRS).

Data and Variables

In this article, while modelling the health services production, four inputs and five outputs are used. Hospitals provide three major services: outpatient services, inpatient services and laboratory services. Given this homogeneity in the types of services provided, the number of cases treated/handled under each category, five outputs were selected to reflect the overall responsibilities of these district hospitals. The outputs considered here are inpatients (IP), outpatients (OPD), number of surgeries undertaken (SUR), emergency cases handled (EMR) and deliveries (DEL). While the inputs considered are number of beds (BED), number of nursing staff (NUR), assistant surgeons employed (ASUR), and number of civil surgeons employed (CSUR). The inclusion of capital as an input would have increased the usefulness of the results, but due to unavailability of capital data, the difference in efficiency is analysed on the basis of availability of beds and manpower used as listed earlier.

For an empirical analysis, data were collected for 29 district headquarter hospitals of Tamil Nadu which are under the Directorate of Medical and Rural Health Services (DMRHS) and therefore appropriate for internal benchmarking. These input and output variables were chosen after consultation with the administration and through a review of the hospital management literature. Five output variables were selected to represent service outcomes. While there are likely other salient factors, we chose these five to avoid any problems related to a limited number of observations. The efficiency scores (technical as well as scale efficiency) and the identification of best-practice units were produced by the DEA software efficiency measurement system (EMS), developed by the Operations Research Department at the University of Dortmund.[1]

Results

Table 1 presents means and standard deviations for the input and output variables of 29 district hospitals. In 2004–05 a district hospital, on an average, employed 83 doctors and 97 staff nurses, had a mean capacity of 294 beds and served an average population of 2 million. The variability in utilisation of resources, and more evidently in the production of outputs, indicates

Table 1
Descriptive Statistics of Input and Output Variables Used

Variables	*Mean*	*Standard deviation*	*Minimum*	*Maximum*
Beds	294	148.06	66	608
Staff Nurse	97	32.33	44	167
Asst. Surgeon	67	19.79	36	117
Civil Surgeon	16	6.12	5	31
No. of Outpatients (in thousands)	633	338	164	1,493
No. of Inpatients (in thousands)	94	50	28	209
Surgeries (in thousands)	9.6	9.4	2.1	47.8
Emergency cases (in thousands)	16.8	36.7	0.7	196
No. of Deliveries (in thousands)	2.9	1.6	0.6	6.9

that these facilities have expanded their activities to different extents. For example, district hospitals serving similar-sized populations were found to differ even nine to 10 times with respect to the outputs they produce. The average number of outpatients treated was 633,000, ranging from 164,000 to 1,493,000 providing a first-hand indication of increased overall inefficiency in the operation of these facilities.

Technical efficiency scores and scale efficiency scores are presented in Table 2. Of the 29 hospitals, 15 (52 per cent) were technically efficient as they had relative efficiency score of 1.00 and therefore lie on the efficiency frontier. The remaining 14 (48 per cent) of the hospitals were technically inefficient with scores ranging from 0.69 (Tenkasi district hospital) to 0.99 (Walajapet district hospital). These scores indicate that Tenkasi and Walajapet district headquarters hospitals could reduce their current input endowments by 31 per cent and 1 per cent respectively. The average TE score among the inefficient hospitals was 80 per cent (standard deviation = 2.5 per cent), which means that the technically inefficient hospitals could reduce their resource use by 20 per cent to maintain their current output levels.

Inappropriate size of a hospital (too large or too small) may sometimes be a cause for technical inefficiency. This is referred to as scale inefficiency and takes two forms—decreasing returns to scale and increasing returns to scale (Seiford and Zhu 1999). Decreasing returns to scale (also known as diseconomies of scale) implies that unit costs increase as output increases and thus the hospital is too large for the volume of activities that it conducts. In contrast, a hospital with increasing returns to scale (economies of scale), since unit costs decrease as outputs increase, is relatively small for its scale of operations. A hospital that is scale-efficient is said to operate under constant

Table 2
Relative Efficiency Scores of the District Hospitals

Hospital ID	*Name of the hospital*	*Technical efficiency*	*Scale efficiency*	*Scale*
1	Kancheepuram	1.00	1.00	CRS
2	Walajpet	0.99	0.70	IRS
3	Tiruvannmalai	1.00	0.97	IRS
4	Cuddalore	0.79	1.00	CRS
5	Dharamapuri	1.00	1.00	CRS
6	Mettur Dam	0.67	0.82	IRS
7	Erode	0.80	0.93	DRS
8	Tiruppur	1.00	0.81	DRS
9	Uthagamandalam	0.72	0.64	IRS
10	Manapparai	1.00	1.00	IRS
11	Pudukkottai	1.00	1.00	CRS
12	Dindigul	1.00	1.00	CRS
13	Usilampatti	1.00	0.94	IRS
14	Virudhunagar	0.77	0.98	IRS
15	Sivaganga	0.67	0.79	IRS
16	Ramanathapuram	1.00	1.00	CRS
17	Tenkasi	0.69	0.93	IRS
18	Kovilpatti	1.00	1.00	CRS
19	Padhmanabapuram	1.00	0.83	IRS
20	Nagapattinam	0.73	0.72	IRS
21	Kumbakonam	0.82	1.00	CRS
22	Villupuram	0.73	0.91	CRS
23	Karur	1.00	0.94	IRS
24	Perambalur	1.00	0.95	IRS
25	Thiruvallur	0.82	0.84	IRS
26	Thiruvarur	0.83	0.90	IRS
27	Periakulam	0.90	0.76	IRS
28	Namakkal	0.74	0.76	IRS
29	Krishnagiri	1.00	1.00	CRS

returns to scale. Ten of the hospitals (34 per cent) had a scale efficiency of 100 per cent, which implies that they had the most productive size for that particular input-output mix. Thus, about 66 per cent of the district headquarters hospitals were scale inefficient. The average scale efficiency among inefficient hospitals was 81 (standard deviation = 2.1 per cent), which implies that the scale inefficient hospitals could reduce their size by 19 per cent without reducing their current output levels. Sixteen of the 19 scale-inefficient hospitals had increasing returns to scale (IRS), while three revealed decreasing returns to scale (DRS). In order to operate at the most productive scale size (MPSS), a hospital exhibiting DRS should scale down both its outputs and inputs. Similarly, if a hospital is displaying IRS, it should expand both its outputs and inputs.

Further, technical efficiency scores 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. DEA calculates slacks which specify the amount by which an input or output must be improved in order for the unit to become efficient. For example, in the case of our inefficient hospital 9 we see that there are two input slacks of staff nurses and civil surgeons. In order for hospital 9 to become efficient, it must cut beds by 42.94 (or approximately 43), staff nurses by 26.52 (or approximately 27), and reduce the number of civil surgeons by 3.76 (or approximately 4), while maintaining its current level of outputs (see Table 3). This represents the DMU moving horizontally towards the efficiency frontier. Or, hospital 9 does have slacks in the outputs of number of outpatients, inpatients and surgeries. This means that hospital 9 can move toward the efficiency frontier vertically by further improving its outputs of outpatients, inpatients, surgeries and deliveries by 354,250, 28,358, 1,436 and 346 respectively.

The hospitals producing on the efficient frontier define the best practice and thus could be regarded as role models. For each inefficient hospital, the DEA model has identified efficient hospitals that could be used as comparators. The inefficient hospitals could learn from their efficient peers by observing their production processes. Individual facets or cones of the envelopment surface (or the efficiency frontier) and the slack variables for each of the inefficient hospitals are given in the Table 4.

Conclusion

In this article, we used the non-parametric DEA approach to assess the technical efficiency and scale efficiency of district headquarters' hospitals in Tamil Nadu. DEA provides the diagnostic information necessary for effecting productivity-based performance improvements. As we have shown in our analysis, DEA provides specific measures that identify areas of underperformance at the unit level. The slacks serve as guiding posts for focused managerial action. Since DEA accounts for multiple inputs and outputs, hospital administrators/policy makers have the flexibility of achieving maximum efficiency by either increasing outputs or decreasing inputs or both. Tracking productivity over time is meaningful from a long-term perspective.

Table 3
Peer Group and Benchmarking for the Relative Inefficient Hospital 9 (0.72)

Hospital ID	*Beds*	*Staff Nurses*	*Asst. Surgeon*	*Civil Surgeon*	*No. of Outpatients*	*Surgeries*	*Emergency Cases*	*No. of Deliveries*
9	421	108	51	18	163,743	3,715	5,577	2,200
Slack	42.94	26.52	0	3.76	354,250.8	1,436.85	0	346.48
1	409	86	87	24	1,492,855	47,765	196,312	5,482
5	438	72	41	15	604,439	4,952	4,529	3,996
11	563	111	74	20	727,240	20,722	13,003	6,923

Table 4
The Group of Best Performers and Slack Variables for the Inefficient Hospitals

DMU	*Score*	*Benchmarks*	*BEDS*	*Staff Nurses*	*Asst. Surgeon*	*Civil Surgeon*
2	0.99	1 (0.05) 10 (0.93) 13 (0.02)	0	56.47	26.95	0.39
4	0.79	1 (0.56) 5 (0.04) 11 (0.04) 29 (0.36)	44.64	27.83	0	0
6	0.67	1 (0.03) 18 (0.02) 19 (0.77) 24 (0.01) 29 (0.17)	0	9.23	0	0
7	0.80	1 (0.50) 11 (0.25) 18 (0.25)	99.54	43.64	2.42	0
9	0.72	1 (0.02) 23 (0.98)	42.94	26.52	0	3.76
14	0.77	10 (0.36) 12 (0.43) 19 (0.21)	0	9.73	0	1.62
15	0.67	1 (0.05) 18 (0.04) 19 (0.59) 24 (0.07) 29 (0.24)	0	14.06	0	3.43
17	0.69	1 (0.18) 10 (0.28) 19 (0.54)	0	0	2.42	2.7
20	0.73	1 (0.32) 23 (0.14) 29 (0.54)	49.25	2.91	0	0
21	0.82	1 (0.04) 8 (0.00) 11 (0.31) 18 (0.65)	0	0	0	2.74
22	0.73	1 (0.18) 10 (0.26) 13 (0.17) 18 (0.15) 24 (0.24)	0	5.55	0	0
25	0.82	1 (0.03) 19 (0.13) 23 (0.04) 24 (0.74) 29 (0.06)	0	1.08	0	3.03
26	0.83	18 (0.21) 19 (0.16) 24 (0.63)	0	2.98	1.5	0
27	0.90	1 (0.04) 19 (0.08) 23 (0.60) 24 (0.28)	0	21.05	0	4.12
28	0.74	1 (0.05) 19 (0.53) 23 (0.23) 29 (0.19)	0	21.42	0	0

Administrators may consider evaluating internal diagnostic units or a hospital as a whole on a continuous basis using DEA. This will help managers to monitor the progress of the identified underperforming units. The results of our analyses have interesting policy implications for developing the health system in Tamil Nadu. We wish to stress here that the findings of the study are critically based on the choice of attributes, and, hence, the policy implications arising out of such an analysis should be considered accordingly.

The inefficiency levels observed suggest a substantial amount of input savings, which could go a long way in injecting additional resources into the health system to address the backlog of inequities and/or further improve the quality of available health care. The study shows that the inefficient (48 per cent) hospitals taken together have 151 excess beds; the excess numbers of staff nurses, assistant surgeons and civil surgeons are 220, 43 and 33 respectively. Therefore, given the need for strengthening health services at the primary levels, these excess medical officers and staff nurses can be transferred to the under staffed sub-district hospitals or CHCs/PHCs to provide primary health care. We believe that this would provide better access to health care and quality of services provided at the primary level. Alternatively, these excess resources can be redeployed to increase the size in those district headquarter hospitals that are technically efficient and experience increasing returns to scale (IRS) like Tiruvannmalai, Usilampatti, Karur and Perambalur.

Returns to scale have important applications in business organisations such as hospitals, which are commonly non-profit and closely regulated. As competition intensifies for the resources, health organisations need to attain a level of capital investment and labour expenditure to achieve the level of utmost efficiency. In this context, policy makers/regulators can evaluate the health care organisations to determine where on the efficiency frontier particular institutions fall. In many states of India such as Tamil Nadu, hospitals must submit a 'certificate of need' in order to add capacity or services. The government at the state level should analyse each hospital's production performance to determine the effectiveness of resource utilisation. If an institution falls in a region of increasing returns to scale that may provide institution administrators with evidence that increasing resources will enable better and more efficient service. An institution falling in a region of declining returns to scale can provide regulators with evidence to reduce resources or to decline any request for additional resources.

Following this analysis, some hospitals like Erode, Tiruppur and Padhamanabapuram which though technically efficient are scale inefficient and exhibiting decreasing returns to scale and therefore to operate at the most productive scale size (MPSS) should scale down both their outputs as well as inputs.

The study reveals that 16 out of 19 scale inefficient hospitals are increasing returns to scale. In the presence of increasing returns to scale, expansion of output reduces unit costs. However, increasing the level of outputs requires an increase in the demand for health care which can to a greater extent be achieved through an effective referral and patient transport system as against the current system. In taking such decisions, however, the equity implications should always be viewed carefully.

Several limitations exist in this research. This study focuses mainly on the technical efficiency and scale efficiency of hospitals. A common drawback of DEA is that efficiency is often defined in terms of a single aggregate measure represented by a derived DEA efficiency score. Therefore, although these models are capable of measuring the relative overall efficiency of a given hospital, they fail to explain why certain hospitals outperform others in their operational efficiency, identifying the level of inefficiency for a specific input factor and addressing questions on what causes inefficiency of a specific input factor. A handful of studies propose using some form of a 2-step analysis by employing econometric models and/or any judiciously selected qualitative tools like institutional analysis in the second step to explain variations in the overall inefficiency derived from the first step for a decision making unit (DMU). However, this study limits its scope of analysis only to the aggregate overall inefficiency. Second, a principal limitation is our inability to get a proxy metric to measure the quality of service in each hospital and therefore the measure of quality of care is not included in the analysis. DEA efficiency of a hospital reflects only the operational efficiency in providing patient care. A better performance measure of hospitals would include both quality of care and efficiency of the process in providing care and services. Third, selecting a set of most appropriate input and output variables for studying hospital efficiency is always challenging. One may question why certain inputs and outputs are included or excluded from an analysis. Depending on the size and availability of data, we can further expand the number of input and output variables to enrich future analysis. Finally, it is impossible to statistically test whether DEA provides 'better' results than other methods, for example, regression or simple ratio analyses. DEA uses a radically different approach. Since DEA is a deterministic procedure, it does not provide fit statistics such as r-square or p-value that can be used for statistical inferences.

Appendix 1

Inputs and Outputs of the District Headquarters' Hospital during 2004–05

Sl. No.	*Hospital*	*Beds*	*Staff Nurses*	*Asst. Surgeon*	*Civil Surgeon*	*No. of Outpatients*	*No. of Inpatients*	*Surgeries (Major + Minor)*	*Emergency Cases*	*No. of Deliveries Conducted*
1	Kancheepuram	409	86	87	24	1,492,855	205,346	47,765	196,312	5,482
2	Walajpet	84	134	89	15	174,779	28,276	4,509	9,874	1,115
3	Tiruvannmalai	314	90	59	17	766,461	94,111	20,988	7,994	4,130
4	Cuddalore	488	131	87	21	1,067,051	159,774	15,146	6,626	4,515
5	Dharamapuri	438	72	41	15	604,439	134,496	4,952	4,529	3,996
6	Mettur Dam	200	85	64	13	416,413	59,466	4,312	8,384	1,190
7	Erode	608	167	98	23	1,042,836	209,081	15,186	13,362	5,264
8	Tiruppur	433	163	117	31	894,743	150,071	8,348	2,719	6,054
9	Uthagamandalam	421	108	51	18	163,743	54,433	3,715	5,577	2,200
10	Manapparai	66	76	60	14	325,560	34,917	2,134	962	1,679
11	Pudukkottai	563	111	74	20	727,240	153,366	20,722	13,003	6,923
12	Dindigul	377	146	87	23	1,419,383	132,644	20,777	13,693	3,863
13	Usilampatti	135	71	61	15	393,308	32,618	14,761	725	1,104
14	Virudhunagar	272	142	88	24	800,948	96,189	5,391	1,363	2,230
15	Sivaganga	226	98	67	18	461,139	63,864	5,630	12,795	1,585

(*Appendix 1 continued*)

(*Appendix 1 continued*)

Sl. No.	*Hospital*	*Beds*	*Staff Nurses*	*Asst. Surgeon*	*Civil Surgeon*	*No. of Outpatients*	*No. of Inpatients*	*Surgeries (Major + Minor)*	*Emergency Cases*	*No. of Deliveries Conducted*
16	Ramanathapuram	510	123	70	18	1,260,400	132,491	7,864	2,476	3,129
17	Tenkasi	220	88	83	23	549,686	64530	3,787	3,628	1,723
18	Kovilpatti	153	74	54	5	446,990	92,599	5,420	12,192	3,133
19	Padhmanabapuram	108	44	41	9	347,846	32,197	3,825	1,270	625
20	Nagapattinam	445	93	77	16	522,856	98,520	2,890	64,889	2,229
21	Kumbakonam	354	105	75	16	489,840	98,246	3,903	13,694	4,401
22	Villupuram	238	107	83	18	512,709	120,921	15,297	35,638	2,519
23	Karur	259	51	36	9	500,565	80,600	4,390	2,167	2,494
24	Perambalur	156	60	46	8	509,289	44,822	11,658	8,280	1,789
25	Thiruvallur	200	72	56	14	519,526	37,831	4,763	12,826	1,848
26	Thiruvarur	177	76	58	9	457,807	67,591	9,084	7,245	1,327
27	Periakulam	250	84	46	15	532,155	86,793	4,863	11,919	2,034
28	Namakkal	235	96	57	12	456,293	79,754	3,125	10,574	1,543
29	Krishnagiri	200	56	43	5	503,395	66,943	3,729	2,496	2,800

Note

1. The EMS Homepage. http://www.wiso.uni-dortmund.de/lsfg/or/scheel/ems/ [accessed 12 September 2006].

References

Banker, R.D., A. Charnes and **W.W. Cooper** (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management Science*, 30(9), 1078–92.

Banker, R.D., R.F. Conrad and **R.P. Strauss** (1986). A comparative application of data envelopment analysis and translog methods: An illustrative study of hospital production. *Management Science*, 32(1), 30–44.

Banker, R.D. and **A. Maindiratta** (1988). Nonparametric analysis of technical and allocative efficiencies in production. *Econometrica*, 56(6), 1315–32.

Bhat, Ramesh, B.V. Verma and **E. Reuban** (2001). An empirical analysis of district hospitals and grant in-aid hospitals in Gujarat state of India. Available at: http://www.*iimahd.ernet.in*/ publications/data/2001-07-05.

Chang, H. (1998). Determinants of hospital efficiency: The case of central government-owned hospitals in Taiwan. *Omega International Journal of Management Science*, 26(2), 307–17.

Charnes, A., W.W. Cooper and **B. Golany** (1985). A developmental study of data envelopment analysis in measuring the maintenance units in the US Air Force. *Ann Oper Res*, 22(May), 103–18.

Charnes, A., W.W. Cooper and **E. Rhodes** (1978). Measuring the efficiency of decision making units. *European Journal of Operation Research*, 2(6), 429–44.

——— (1981). Evaluating program and managerial efficiency: An application of data envelopment analysis to program follow through. *Management Science*, 27, 668–97.

Chattopadhy, S. and **C.S. Ray** (1996). Technical, scale, and size efficiency in nursing home care: A nonparametric analysis of Connecticut homes. *Health Economics*, 5, 363–73.

Clark, R. (1980). Does the non-profit form fit the hospital industry? *Harvard Law Review*, 93, 1416–89.

Ehreth, J.L. (1994).The development and evaluation of hospital performance measures for policy analysis. *Medical Care*, 32(6), 568–87.

Ersoy, K., S. Kavuncubasi, Y.A. Ozcan and **Harris J.M II** (1997). Technical efficiencies of Turkish hospitals: DEA approach. *Journal of Medical Systems*, 21(2), 67–74.

Fare, R., S. Grosskopf, M. Norris and **Z. Zhang** (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review*, 84(1), 66–83.

Giuffrida, A. and **H. Gravelle** (2001). Measuring performance in primary care: Econometric analysis and DEA. *Applied Economics*, 33, 163–75.

Government of Tamil Nadu (2003). *Statistical handbook of Tamil Nadu*.

Grosskopf, S. and **V. Valdmanis** (1987). Measuring hospital performance: A non-parametric approach. *Journal of Health Economics*, 6, 89–107.

Hollingsworth, B. and **D. Parkin** (2001). The efficiency of the delivery of neonatal care in the UK. *Journal of Public Health Medicine*, 23(1), 47–50.

Jacobs, R. (2001). Alternative methods to examine hospital efficiency: Data envelopment analysis and stochastic frontier analysis. *Health Care Management Science*, 4, 103–15.

Kirigia, J.M., A. Emrouznejad and **L.G. Sambo** (2002). Measurement of technical efficiency of public hospitals in Kenya: Using Data Envelopment Analysis. *Journal of Medical Systems*, 26(1), 39–45.

Linna, M., A. Nordblad and **M. Koivu** (2002). Technical and cost-efficiency of oral health care provision in Finnish health centres. *Social Science and Medicine*, 56, 343–53.

Morey, R.C., D.J. Fine, S.W. Loree, D.L. Retzlaff-Roberts and **S. Tsubakitani** (1992). The trade-off between hospital cost and quality of care. *Medical Care*, 30(8), 677–98.

NSSO (2006) Morbidity and Health Care Report, *Ministry of Statistics and Programme Implementation*, New Delhi.

Salinas-Jimenez, J. and **P. Smith** (1996). Data envelopment analysis applied to quality in primary health care. *Annals of Operational Research*, 67, 141–6.

Seiford, L.M. (1990). Models, extensions, and applications of data envelopment analysis: A selected reference set. *Computers, Environment and Urban Systems*, 14(2), 171–5.

Seiford, L.M. and **J. Zhu** (1999). An investigation of returns to scale in data envelopment analysis. *The International Journal of Management Science*, 27, 1–11.

Sherman, H.D. (1984). Data envelopment analysis as a new managerial audit methodology—test and evaluation. *Auditing: A Journal of Practice and Theory*, 4(1), 35–53.

Shroff, H.F.E., T.R. Gulledge, K.E. Haynes and **M.K. Oneill** (1998). Sitting efficiency of long-term health care facilities. *Socio-Economic Planning Science*, 32(1), 25–43.

United Nations Development Programme (2003). *Human Development Report 2003: Millennium Development Goals: A compact among nations to end human poverty*. New York: Oxford University Press.

Wan, T.T.H., N. Hsu, R. Feng, A. Ma, S. Pan and **M. Chou** (2002). Technical efficiency of nursing units in a tertiary care hospital in Taiwan. *Journal of Medical Systems*, 26(1), 21–7.

White, K.R., R.N. Fache and **Y.A, Ozcan** (1996). Church ownership and hospital efficiency. *Hospital and Health Services Administration*, 41(3), 297–310.

World Bank (2005). *World development report 2005: A better investment climate for everyone.* Oxford University Press, World Bank.

World Health Organisation (2002). *The World Health Report 2002.* Geneva.

Zavras, A.I., G. Tsakos, C. Economou and **J. Kyriopoulos** (2002). Using DEA to evaluate efficiency and formulate policy within a Greek national primary health care network. *Journal of Medical Systems*, 26(4), 285–92.

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