Evaluating the Comparative Performance of District Head Quarters Hospitals, 2002-07: A Non-parametric Malmquist Approach

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Abstract

The objective of this article was to measure the productivity of District's Head Quarter Hospitals in the state of Tamil Nadu over the period of 2002-07. We calculated the Malmquist productivity index by using the nonparametric-frontier approach, and decomposed the index into two components: technical change and efficiency change. Empirical results showed that the productivity change of hospitals in Tamil Nadu ranged from 0.82 (Theni) to 2.21 (Nagapattinam) over the sampled period. The results also showed that the productivity growth was attributed more to the efficiency change than technical change.

1. Introduction

Productivity measurement has been accepted by the economists as a standard tool for evaluating the performance within hospitals or health systems. A comprehensive measurement of productivity is of great importance to both policy makers and administrators. Intra-hospital comparisons of productivity can indicate how competitive a particular hospital is relative to its counterparts. Accordingly, the purpose of this paper is to assess the recent productivity growth of District Head Quarters Hospitals taking into account changes in both efficiency and technology. Though the Malmquist Index has been used by various authors to study different issues in Energy Sector, Financial services sector (Mahlberg & Url, 2003; Sturm & Williams, 2004; Worthington, 1999)., education (Flegg, Allen, Field, and Thurlow (2004) and Johnes, Johnes, Thanassoulis, Lenton, and Emrouznejad (2004) and other services sector, it is one of the very few studies (Maniadakis & Thanassoulis, 2000; Ventura, Gonzalez, & Carcaba, 2004) to focus exclusively on productivity, efficiency and technological change at a

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district/provincial hospitals using readily available panel data dated within the last 5 years.

The paper is divided into four main sections. Section 2 focuses on the specification used to measure productivity, efficiency and technological change in DHQH set up. Section 3 presents the results. The paper ends with some concluding remarks.

2. Methodology: the Malmquist DEA model

The DEA model used is the Malmquist productivity index (Malmquist, 1953). The Malmquist productivity index estimates the total productivity index of the units (hospitals) analysed, allowing for changes in productivity to be broken down into changes in technical efficiency and changes in technological efficiency.

This section briefly explains the foundations of the computation of Malmquist productivity indexes and their decomposition with non-parametric techniques. In order to estimate efficiency and productivity growth in the hospitals included in the sample, we will follow a non-parametric approach to the computation and decomposition of the Malmquist productivity index. Several different decompositions of the Malmquist index have been proposed in the literature. The most commonly used are those proposed by Fare et al., 1994, which assumes a constant returns to scale (CRS) technology, and Ray and Desli (1997), which does not require that assumption. A third decomposition has been suggested by Simar and Wilson (2000) and Zofío and Lovell (1998), which extends the Ray and Desli (1997) decomposition. More concretely, the technical change component in Ray and Desli (1997) is further decomposed into a “pure” technical change of the frontier plus a residual measure of the scale change of the technology. This residual measure evaluates the separation between the constant returns to scale and the variable returns to scale (VRS) technologies. In this paper, we will follow this extended decomposition because it adds more information about the sources of productivity change.

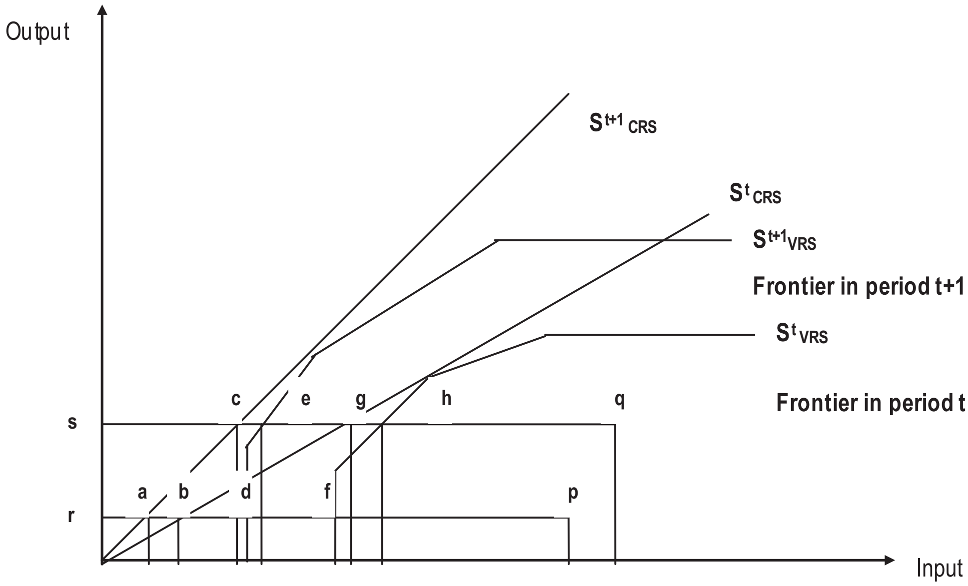

Figure 1. Productivity change with one input and one output

The Malmquist index, M, as comprising two main elements, M=E X T, where E is the technical efficiency change and T is technical change. The technical efficiency change can be broken down into pure technical change and scale technical change. The breakdown of the technical efficiency change into its components is based on the variable-return-to-scale (VRS) hypothesis (Fare et al., 1994). The VRS scores only measure pure technical efficiency, while the constant-return-to-scale (CRS) index is composed of a non-additive combination of pure technical and scale efficiencies. A ratio of the overall efficiency (CRS) scores to pure technical efficiency scores (VRS) provides us with a measurement of scale efficiency and therefore, the estimation of pure technical change. The difference between the CRS scores and the scale-efficient change allows us to obtain the pure efficiency change:

$M = (PXS)XT$, ...(1)

Where P: is the pure efficiency change, and

S: is the scale efficiency change

The pure efficiency change P for hospital A between period t and t+1 is given by the ratio: $P = \frac{(se/sq)}{(rd/rp)}$ ……………………………………………………………….(2)

This simply indicates the change in the hospital's distance from the current technically efficient frontier from one period to the next.

The change in the scales efficiency S is given by calculating the efficiency of hospitals A relative to the CRS and VRS Technology in each period as follows:

$$S = \frac{(sc/sq)}{(se/sq)} \Big/ \frac{(rb/rp)}{(rf/rp)} \quad \text{……………………………………………………………….(3)}$$

The technical efficiency change term E (E=P X S) refers to efficiency change calculated under CRS, while P is efficiency change calculated under VRS. S captures the change in the deviation between the VRS and CRS technologies.

The change in the scale-efficient technology indicated by the CRS frontier is estimated by : $T = \sqrt{\left[\frac{(sg/sq)}{(sc/sq)} X \frac{(rb/rp)}{(ra/rp)}\right]}$ ……………………………………………………….(4)

Note that while was calculated relative to the VRS technology, the frontier shift in T is measured relative to the constant returns to scale technology.

The Malmquist index is constructed using the radial distance function. The Malmquist is then given by :

$$M = \frac{(se/sq)}{(rd/rp)}\left[\frac{(sc/sq)}{(se/sq)} \Big/ \frac{(rb/rp)}{(rf/rp)}\right]\sqrt{\left[\frac{(sg/sq)}{(sc/sq)} X \frac{(rb/rp)}{(ra/rp)}\right]} \quad \text{…………………………….(5)}$$

We obtain productivity growth if $M > 1$ and productivity regression if $M < 1$. The limitations of the DEA model and hence this approach are as follows: DEA does not impose any functional form on the data nor make any distributional assumptions for the inefficiency term. Nor does it make *a priori* distinctions between the relative importance of any combination of inputs and outputs. These limitations are precisely the most distinctive and appealing characteristics of DEA. This efficiency measurement assumes that the production function of the fully-efficient hydroelectric plant is known. In practice, this is not the case, and the efficient isoquant must be estimated from the sample data. Under such conditions, the frontier is relative to the sample considered in the analysis (Bessent and Bessent, 1980). A less appealing characteristic is that, without statistical distribution hypotheses, DEA does not allow for random errors in the data, assuming away measurement error and chance as factors affecting outcomes (Seiford and Thrall, 1990).

In this paper, while modeling the health services production three inputs and six outputs were used. Hospitals provide three major services: outpatient services, in-patient and laboratory services. Given this homogeneity in types of services provided, the number of cases treated/handled under each category, six outputs were selected to reflect the overall responsibilities of these district hospitals. The outputs considered here were inpatients (IP), out patients (OPD), number of surgeries undertaken (SUR), emergency cases handled (EMR), medico legal cases (MLC) and, deliveries (DEL). While the inputs considered were number of beds (BED), number of nursing staff (NUR), and number of physicians (Surgeon). The inclusion of capital as an input would have increased the usefulness of the results, but due to unavailability of the capita data, the difference in efficiency would be analyzed on the basis of the availability of beds and manpower used as listed above.

For the empirical analysis, data were collected for 29 district head quarter hospitals of the State of Tamil Nadu from 2002-2007, which are under the Directorate of Medical and Rural Health Services (DMRHS). These input and output variables were chosen after consultation with the administration and through review of the hospital management literature. Six output variables were selected to represent service outcome. While there may be other salient factors, we chose these six to avoid any problem related to limited number of observation. The efficiency scores (technical as well as scale efficiency) and the Malmquist Index were produced by the DEA software efficiency measurement system (EMS), developed by the Operations Research Department at the University of Dortmund.[†]

[†] The EMS Homepage. http://www.wiso.uni-dortmund.de/lsfg/or/scheel/ems/ [visited 12 February 2008].

3. Results and Analysis

A hospital is said to be efficient if it uses all it resources optimally and there is no scope of increasing the output without altering the amount of inputs used. The Technical Efficiency(TE) score for such hospitals are going to be 100%. On the other hand the

Table 1. Technical Efficiency Score of the District Head Quarters Hospitals during 2002-03 to 2006-07.

S.No	Name of the DHQH	Technical Efficiency 2006-07	Technical Efficiency 2005-06	Technical Efficiency 2004-05	Technical Efficiency 2003-04	Technical Efficiency 2002-03
1	Kancheepuram	100.00%	100.00%	100.00%	100.00%	100.00%
2	Walajapet	100.00%	100.00%	100.00%	100.00%	100.00%
3	Tiruvannamalai	100.00%	100.00%	100.00%	98.12%	100.00%
4	Cuddalore	85.20%	64.18%	71.66%	81.68%	100.00%
5	Dharmapuri	82.24%	80.56%	73.78%	87.10%	69.23%
6	Salem @ Metturdam	96.78%	86.52%	90.69%	94.77%	83.51%
7	Erode	100.00%	81.72%	82.99%	100.00%	100.00%
8	Coimbatore@Tiruppur	100.00%	100.00%	100.00%	100.00%	100.00%
9	Udhagamandalam	100.00%	100.00%	100.00%	100.00%	100.00%
10	Manapparai	100.00%	100.00%	100.00%	100.00%	100.00%
11	Pudukkottai	100.00%	81.05%	100.00%	100.00%	100.00%
12	Dindigul	96.87%	100.00%	100.00%	100.00%	100.00%
13	Madurai @ Usilampatti	71.84%	82.41%	100.00%	100.00%	84.78%
14	Virudhunagar	84.93%	79.21%	97.76%	76.39%	85.54%
15	Sivaganga	96.94%	85.39%	96.94%	100.00%	100.00%
16	Ramanathapuram	69.86%	75.66%	88.95%	74.39%	86.86%
17	Tirunelveli @ Tenkasi	80.65%	82.00%	88.29%	74.57%	79.31%
18	Kovilpatti	100.00%	100.00%	100.00%	100.00%	100.00%
19	Padmanabhapuram	85.59%	100.00%	100.00%	100.00%	100.00%
20	Nagapattinam	62.46%	42.76%	42.67%	100.00%	100.00%
21	Kumbakonam	93.12%	81.89%	96.29%	100.00%	100.00%
22	Villupuram	100.00%	100.00%	90.74%	100.00%	100.00%
23	Karur	100.00%	83.07%	72.72%	78.27%	100.00%
24	Perambalur	100.00%	100.00%	98.40%	98.17%	100.00%
25	Thiruvallur	77.87%	100.00%	95.05%	100.00%	77.45%
26	Thiruvarur	82.75%	71.38%	80.28%	100.00%	100.00%
27	Theni @Periyakulam	68.44%	55.14%	65.88%	75.71%	79.29%
28	Namakkal	100.00%	67.40%	73.29%	79.45%	75.66%
29	Krishnagiri	100.00%	100.00%	84.88%	89.23%	71.77%

hospital is said to be inefficient,if there is a scope of reducing the usage of some of the inputs without affecting the current level of output. The TE score of inefficient hospitals would be less than one. For example the TE score of Dharmapuri DHQH was 82.2% which indicated that the hospital could reduce its inputs by approximately 18% without altering the existing output. The average TE score of the inefficient hospitals over the last five years were 0.79, 0.84, 0.83, 0.75 and 0.82 respectively, whilst the numbers of inefficient hospitals were 10, 12, 18, 16, and 15 respectively.

Thus it shows compared to 2002-03, in 2006-07 though the average TE score of the relatively inefficient hospitals have increased from 0.79 to 0.82, the number of inefficient hospitals has also increased significantly from 10 to 15. As shown in the Table 1., the DHQH's of Kancheepuram, Walajapet, Coimbatore, Udhagamandalam, Manapparai, Kovilpatti are efficient throughout the period, whereas hospitals such as Dharmapuri, Salem(Metturdam), Virudhunagar, Ramanathpuram, Tirunelveli(Tenkasi), Theni (Periyakulam) were inefficient during the period considered. It is further observed that hospitals such as Sivaganga, Nagapattinam, Kumbakonam and Thiruvarur which were efficient during 02-03 and 04-05 became inefficient in the following two sub periods. The remaining hospitals have shown mixed trends.

The Malmquist index can be calculated in several ways (Caves et al., 1982). In this study, we estimated an input-oriented Malmquist productivity index, based on DEA. Input-oriented efficiency measurements are appropriate if we assume that DHQHs operate in an uncompetitive market where the objective is to increase utilization and coverage. In input-oriented models, such as the one adopted in this paper, DEA seeks to identify technical inefficiency as a proportional decrease in input usage. As far as public health is concerned, input orientation seems to be the natural choice, due to their competitive position in the market. However, since the input and output Malmquist indices are equal (Thanassoulis, 2001, p. 182), this specification is more of a theoretical issue than a practical one.

DEA allows for the estimation of total productivity change in the form of the Malmquist index. Three primary issues are addressed in the computation of Malmquist indices of productivity growth over the sample period. The first is the measurement of productivity growth over the period. The second is to decompose changes in productivity growth into what are generally referred to as a 'catching-up' effect (technical efficiency change) and a 'frontier shift' effect (technological change). The third is that the 'catching-up' effect is further decomposed to identify the main source of improvement, through either enhancements in pure technical efficiency or increases in scale efficiency.

The results are presented in Table 2, with the Malmquist index, denoted total productivity change, broken down into technically efficient change (the diffusion or catch-up component) and technologically efficient change (the innovation or frontier-shift component). Moreover, we break down technically efficient change into pure efficient change and scale-efficient change. In Table 2, we can see that the total productivity change score (the Malmquist index presented in column 7) is higher than one for 22 DHQHs, showing that a large section of the DHQHs experienced gains in total productivity in the period considered. The mean Malmquist score is 1.24, which, since it is higher than one, signifies that for the majority of the hospitals, total productivity increased in the period. However, there are seven hospitals with a Malmquist index lower than one, signifying that these hospitals have experienced a negative growth. The change in the technical efficiency score (column 5) is defined as the diffusion of best-practice technology in the management of the activity and is attributed to investment planning, technical experience and management and organisation in the hospital sector. In the table, an hospital, which has been efficient at time t and t+1, will naturally show no change in relative efficiency, i.e. efficiency scores in Table 2 would be equal to 1. We found Kancheepuram, Udhagamandalam, Manapparai, to be efficient in all time periods. For the period under analysis, we can see that it is higher than one for twenty-four hospitals, signifying that there was an increase in technical efficiency in the period. However, for four hospitals namely Ramanathpuram, Padmanabhapuram, Villipuram and Karur, the change in technical efficiency is lower than one, signifying that there was a regression in this respect in the period. The breakdown of the score for the change in technical efficiency into pure technical efficiency change (column 3) and scale-efficiency change (column 4) shows mixed results, with some hospitals obtaining simultaneous gains in both areas and others obtaining gains in one, but losses in the other. The improvement in pure technical efficiency, which signifies an improvement in managerial skills, shows that there was investment in organisational factors associated with the management of hospitals, such as a better balance between inputs and outputs, best-practice initiatives, more accurate reporting, an improvement in quality, and so on. The scale efficiency, which is the consequence of size, increases in the period for many hospitals, due to the increase in capacity utilisation. It is important to note that the mean amount of technical efficiency improvement is 1.153 (mean), the mean value of pure technical efficiency change is 1.128 and the mean value of scale-efficiency change is 1.021. This is a relatively high improvement in efficiency. Technological change (column 6) is the consequence of innovation, i.e. the adoption of new technologies, by best-practice hospitals. Its mean value is 1.07 and this index is higher than one for only nineteen hospitals, whilst its negative for 10 hospitals out of the 29 analysed. This indicates that innovation didn't have significant impact in the period for almost all hospitals, meaning that there was less investment in new technologies (methodologies, procedures and techniques) and in the commensurate skills upgrades related to this. Therefore this is a primary area of concern. Overall, we observe four combinations of technical efficiency change and technological change:

(i) In the first group, we find eighteen hospitals in which improvements in technical efficiency coexist with improvements in technological change. These are the best-performing hospitals in the period under study, with improvements registered in technical efficiency, denoting upgraded organisational factors associated with the use of inputs and outputs, as well as the relationship between inputs and outputs. These are Kancheepuram, Tiruvannamalai, Cuddalore, Dharmapuri,Erode, Coimbatore (Tiruppur), Manapparai, Pudukkottai, Dindigul, Madurai (Usilampatti), Virudhunagar, Sivaganga, Tirunelveli (Tenkasi), Nagapattinam, Kumbakonam, Perambalur, Thiruvarur, Krishnagiri.

Table 2. Average technically efficient change and technological change observed in District Hospitals in Tamil Nadu : 2002–2007

S. No	Name of the DHQH	Pure Efficiency P	Scale Efficiency S	Technical Efficiency E=PXS	Technological Change T	Total Productivity Change
1	Kancheepuram	1	1	1	1.01258	1.0125836
2	Walajapet	1	1.0699	1.06986	0.94285	1.0087183
3	Tiruvannamalai	1.05245	1	1.05245	1.03824	1.0926928
4	Cuddalore	1.09817	1.0531	1.15646	1.22454	1.4161227
5	Dharmapuri	1.26946	1.0138	1.28694	1.17157	1.5077412
6	Salem (Metturdam)	1.44582	1.0748	1.55394	0.94502	1.4685033
7	Erode	1.15481	1	1.15481	1.07082	1.2365899
8	Coimbatore (Tiruppur)	1.26294	1	1.26294	1.04513	1.3199326
9	Udhagamandalam	1	1	1	0.98925	0.9892529
10	Manapparai	1	1	1	1.01988	1.0198773
11	Pudukkottai	1.25661	1	1.25661	1.12738	1.4166797
12	Dindigul	1.16226	1	1.16226	1.03556	1.2035855
13	Madurai (Usilampatti)	1.07578	1.0408	1.11962	1.2414	1.3899074
14	Virudhunagar	1.09932	1.0134	1.11404	1.05407	1.1742807
15	Sivaganga	1.30754	1.0641	1.3913	1.00103	1.3927328
16	Ramanathapuram	0.92671	1.0007	0.92735	1.04443	0.9685587
17	Tirunelveli (Tenkasi)	1.17046	1.1646	1.36313	1.12372	1.5317716
18	Kovilpatti	1.19693	1	1.19693	0.98218	1.1756094
19	Padmanabhapuram	0.99281	1	0.99281	0.96536	0.958419
20	Nagapattinam	1.12072	1	1.12072	1.96971	2.2074842
21	Kumbakonam	1.19441	1.0033	1.19837	1.17637	1.4097269
22	Villupuram	0.91269	1	0.91269	0.94785	0.8650989
23	Karur	0.94293	1	0.94293	0.961	0.9061561
24	Perambalur	1.23457	1	1.23457	1.07882	1.3318842
25	Thiruvallur	1.01736	1.0602	1.07864	0.89305	0.9632839
26	Thiruvarur	1.01191	1	1.01191	1.06483	1.0775132
27	Theni (Periyakulam)	0.82276	1.0071	0.82862	0.99	0.8203299
28	Namakkal	1.37468	1.0262	1.41066	0.82739	1.1671757
29	Krishnagiri	1.61015	1.0296	1.65773	1.09012	1.8071154
	Average					1.2358389

(ii) In the second group, we find seven hospitals in which improvements in technical efficiency co-exist with deterioration in technology. These are plants with upgraded organisational factors, but without the innovation inherent in investment in new technology, which would provide leverage for the organisational factors. These hospitals need to acquire new technology and the necessary commensurate skill upgrades in order to improve their performance. The group includes seven hospitals namely; Walajapet, Salem (Metturdam), Udhagamanadalam, Kovilpatti, Villupuram, Thiruvallur, and Namakkal.

(iii) In the third group, we find one hospital namely Ramanathpuram in which improvements in technological efficiency co-exist with deterioration of technical efficiency. This hospital needs to upgrade its managerial skills and scale in order to improve its performance.

(iv) In the fourth possibility, in which deteriorating technical efficiency co-exists with deteriorating technology, we find three hospitals namely Villupurum, Karur and Theni (Periyakulam).

4. Conclusion

The results of our analyses have interesting policy implications for development of the health system. We wish to stress here that findings of the study are critically based on the choice of attributes, and, hence, the policy implications discussed below should be considered within this perspective. As shown in column 7 in the last row of Table___, there was an annual mean growth in TFP of 24% for the period 2002-07 across the DHQH of Tamil Nadu. Given that productivity growth is the sum of technical efficiency and technological change, the major cause of productivity growth can be ascertained by comparing the values of the efficiency change and technological change. Put differently, the productivity growth can be the result of efficiency gains, technological improvements, or both. In the case of DHQHs, the overall improvement in productivity over the period is composed of an average efficiency increase (movement towards the frontier) of 15%, and average technological progress (upward shift of the frontier) of 7% annually. The technical efficiency can be further decomposed into pure technical efficiency and scale efficiency and this indicates a 13% and 2% improvement respectively. Clearly, across all District Head Quarters Hospitals, the improvement in productivity over the period 2002–2007 is the result of both an expansion in the frontier relating inputs to outputs and improvements in efficiency. Therefore in relative terms, the DHQH is relatively efficient and that technological improvements have not been well spread across the sector.

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Appendices

Table 3. Pure Efficiency change observed in District Hospitals in Tamil Nadu :2002–07

	Name of the DHQH	Malmquist Index 06-05 Pure Efficiency = P	Malmquist Index 05-04 Pure Efficiency = P	Malmquist Index 04-03 Pure Efficiency (P)	Malmquist Index 03-02 Pure Efficiency (P)	Cumulative Change
1	Kancheepuram	1.00	1.00	1.00	1.00	1
2	Walajapet	1.00	1.00	1.00	1.00	1
3	Tiruvannamalai	1.07	1.00	1.00	0.98	1.05245
4	Cuddalore	1.54	0.95	0.72	1.04	1.09817
5	Dharmapuri	1.15	1.16	0.74	1.29	1.26946
6	Salem (Metturdam)	1.25	1.11	0.91	1.15	1.44582
7	Erode	1.27	1.09	0.83	1.00	1.15481
8	Coimbatore (Tiruppur)	1.00	1.17	1.00	1.08	1.26294
9	Udhagamandalam	1.00	1.00	1.00	1.00	1
10	Manapparai	1.00	1.00	1.00	1.00	1
11	Pudukkottai	1.41	0.89	1.00	1.00	1.25661
12	Dindigul	0.97	1.00	1.01	1.18	1.16226
13	Madurai (Usilampatti)	0.96	0.95	1.00	1.18	1.07578
14	Virudhunagar	1.27	0.89	0.98	0.99	1.09932
15	Sivaganga	1.27	0.99	0.97	1.07	1.30754
16	Ramanathapuram	1.10	0.89	0.94	1.01	0.92671
17	Tirunelveli (Tenkasi)	1.09	1.06	0.93	1.09	1.17046
18	Kovilpatti	1.17	1.02	1.00	1.00	1.19693
19	Padmanabhapuram	0.86	1.16	1.00	1.00	0.99281
20	Nagapattinam	1.46	1.00	0.61	1.27	1.12072
21	Kumbakonam	1.26	0.94	0.96	1.05	1.19441
2	Villupuram	1.00	1.01	0.91	1.00	0.91269

2						
23	Karur	1.39	1.20	0.73	0.78	0.94293
24	Perambalur	1.06	1.20	0.98	0.98	1.23457
25	Thiruvallur	0.78	1.06	0.95	1.30	1.01736
26	Thiruvarur	1.21	1.04	0.80	1.00	1.01191
27	Theni (Periyakulam)	1.37	0.95	0.66	0.96	0.82276
28	Namakkal	1.64	1.05	0.73	1.09	1.37468
29	Krishnagiri	1.29	1.22	0.85	1.20	1.61015

Table 4. Scale Efficiency change observed in District Hospitals in Tamil Nadu :2002–07

	Name of the DHQH	Malmquist Index 06-05 Scale Efficiency = S	Malmquist Index 05-04 Scale Efficiency = S	Malmquist Index 04-03 Scale Efficiency (S)	Malmquist Index 03-02 Scale Efficiency (S)	Cumulative change
1	Kancheepuram	1.00	1.00	1.00	1.00	1
2	Walajapet	1.00	1.19	0.98	0.92	1.0699
3	Tiruvannamalai	1.00	1.00	1.01	0.99	1
4	Cuddalore	1.04	0.96	1.04	1.01	1.0531
5	Dharmapuri	1.03	0.98	1.00	1.01	1.0138
6	Salem (Metturdam)	1.16	1.17	0.87	0.91	1.0748
7	Erode	1.01	1.01	0.97	1.00	1
8	Coimbatore (Tiruppur)	1.00	1.00	1.00	1.00	1
9	Udhagamandalam	1.00	1.00	1.00	1.00	1
10	Manapparai	1.00	1.00	1.00	1.00	1
11	Pudukkottai	1.01	0.99	1.00	1.00	1
12	Dindigul	1.00	1.00	1.00	1.00	1
13	Madurai (Usilampatti)	1.16	0.92	0.94	1.04	1.0408
14	Virudhunagar	1.09	1.01	0.98	0.94	1.0134
15	Sivaganga	1.15	1.08	0.86	0.99	1.0641
16	Ramanathapuram	1.02	1.00	1.03	0.96	1.0007
1	Tirunelveli (Tenkasi)	1.21	1.06	0.92	0.99	1.1646

7						
18	Kovilpatti	1.00	1.00	1.00	1.00	1
19	Padmanabhapuram	1.00	1.16	1.26	0.69	1
20	Nagapattinam	1.13	1.03	0.89	0.97	1
21	Kumbakonam	1.01	1.01	0.98	1.00	1.0033
22	Villupuram	1.00	1.17	0.85	1.00	1
23	Karur	1.07	0.98	0.97	0.97	1
24	Perambalur	1.00	1.12	1.00	0.89	1
25	Thiruvallur	1.00	1.30	0.77	1.06	1.0602
26	Thiruvarur	1.09	1.05	0.88	0.99	1
27	Theni (Periyakulam)	1.07	1.06	0.91	0.97	1.0071
28	Namakkal	1.16	1.09	0.84	0.96	1.0262
29	Krishnagiri	1.00	1.03	1.01	0.99	1.0296

Table 5. Technical Efficiency change observed in District Hospitals in Tamil Nadu: 2002–07

	Name of the DHQH	Malmquist Index 06-05 E = P X S	Malmquist Index 05-04 E + P X S	Malmquist Index 04-03 E = P X S	Malmquist Index 03-02 E = P X S	Cumulative change
1	Kancheepuram	1.00	1.00	1.00	1.00	1
2	Walajapet	1.00	1.19	0.98	0.92	1.06986
3	Tiruvannamalai	1.07	1.00	1.01	0.97	1.05245
4	Cuddalore	1.60	0.92	0.75	1.05	1.15646
5	Dharmapuri	1.18	1.14	0.74	1.30	1.28694
6	Salem (Metturdam)	1.45	1.30	0.79	1.05	1.55394
7	Erode	1.29	1.11	0.81	1.00	1.15481
8	Coimbatore (Tiruppur)	1.00	1.17	1.00	1.08	1.26294
9	Udhagamandalam	1.00	1.00	1.00	1.00	1
10	Manapparai	1.00	1.00	1.00	1.00	1
11	Pudukkottai	1.43	0.88	1.00	1.00	1.25661
12	Dindigul	0.97	1.00	1.01	1.18	1.16226
13	Madurai (Usilampatti)	1.11	0.88	0.94	1.23	1.11962
14	Virudhunagar	1.39	0.90	0.96	0.93	1.11404
15	Sivaganga	1.47	1.07	0.84	1.06	1.3913
16	Ramanathapuram	1.12	0.89	0.96	0.96	0.92735
17	Tirunelveli (Tenkasi)	1.32	1.12	0.85	1.08	1.36313
18	Kovilpatti	1.17	1.02	1.00	1.00	1.19693
19	Padmanabhapuram	0.86	1.34	1.26	0.69	0.99281
20	Nagapattinam	1.65	1.02	0.54	1.23	1.12072
21	Kumbakonam	1.28	0.95	0.94	1.05	1.19837
22	Villupuram	1.00	1.18	0.77	1.00	0.91269
23	Karur	1.49	1.18	0.71	0.76	0.94293
24	Perambalur	1.06	1.35	0.98	0.88	1.23457
25	Thiruvallur	0.78	1.38	0.73	1.38	1.07864
26	Thiruvarur	1.32	1.09	0.70	0.99	1.01191
27	Theni (Periyakulam)	1.46	1.01	0.60	0.94	0.82862
28	Namakkal	1.91	1.15	0.62	1.04	1.41066
29	Krishnagiri	1.29	1.26	0.86	1.19	1.65773

Table 6. . Technology change observed in District Hospitals in Tamil Nadu :2002–07

	Name of the DHQH	Malmquist Index 06-05 Technical Change (T)	Malmquist Index 05-04 Technical Change (T)	Malmquist Index 04-03 Technical Change (T)	Malmquist Index 03-02 Technical Change (T)	Cumulative
1	Kancheepuram	1.00	1.00	1.00	1.01	1.01258
2	Walajapet	1.04	0.89	0.92	1.11	0.94285
3	Tiruvannamalai	1.04	1.00	0.99	1.01	1.03824
4	Cuddalore	1.14	1.09	0.84	1.17	1.22454
5	Dharmapuri	1.18	1.09	0.87	1.06	1.17157
6	Salem (Metturdam)	1.05	0.93	0.82	1.18	0.94502
7	Erode	1.06	1.08	0.93	1.00	1.07082
8	Coimbatore (Tiruppur)	1.01	1.08	0.92	1.04	1.04513
9	Udhagamandalam	1.07	0.98	1.00	0.95	0.98925
10	Manapparai	1.02	1.00	1.00	1.00	1.01988
11	Pudukkottai	1.07	1.10	0.96	1.00	1.12738
12	Dindigul	1.01	1.00	0.94	1.09	1.03556
13	Madurai (Usilampatti)	1.14	1.09	0.95	1.05	1.2414
14	Virudhunagar	1.17	1.03	0.74	1.19	1.05407
15	Sivaganga	1.07	0.99	0.87	1.09	1.00103
16	Ramanathapuram	1.16	1.03	0.70	1.25	1.04443
17	Tirunelveli (Tenkasi)	1.11	0.98	0.85	1.22	1.12372
18	Kovilpatti	1.10	1.01	0.88	1.00	0.98218
19	Padmanabhapuram	1.08	1.00	0.68	1.31	0.96536
20	Nagapattinam	1.06	0.93	1.73	1.15	1.96971
21	Kumbakonam	1.10	1.08	0.97	1.03	1.17637
22	Villupuram	1.00	0.86	1.10	1.00	0.94785
23	Karur	1.06	1.03	0.84	1.04	0.961
24	Perambalur	1.04	1.03	0.92	1.09	1.07882
25	Thiruvallur	1.07	0.88	0.96	0.99	0.89305
26	Thiruvarur	1.13	1.05	0.91	0.99	1.06483
27	Theni (Periyakulam)	1.20	1.05	0.76	1.04	0.99
28	Namakkal	1.00	0.98	0.78	1.09	0.82739
29	Krishnagiri	1.14	1.01	0.89	1.07	1.09012

Table 7. Total Productivity change observed in District Hospitals in Tamil Nadu: 2002–07

	Name of the DHQH	Malmquist Index 06-05 M = E X T	Malmquist Index 05-04 M = E X T	Malmquist Index 04-03 M = E X T	Malmquist Index 03-02 M = E X T	Cumulative change
1	Kancheepuram	1.00	1.00	1.00	1.01	1.0125836
2	Walajapet	1.04	1.06	0.90	1.02	1.0087183
3	Tiruvannamalai	1.11	1.00	1.00	0.99	1.0926928
4	Cuddalore	1.84	1.00	0.62	1.23	1.4161227
5	Dharmapuri	1.39	1.23	0.64	1.37	1.5077412
6	Salem (Metturdam)	1.52	1.21	0.65	1.24	1.4685033
7	Erode	1.37	1.20	0.75	1.00	1.2365899
8	Coimbatore (Tiruppur)	1.01	1.27	0.92	1.12	1.3199326
9	Udhagamandalam	1.07	0.98	1.00	0.95	0.9892529
10	Manapparai	1.02	1.00	1.00	1.00	1.0198773
11	Pudukkottai	1.52	0.97	0.96	1.00	1.4166797
12	Dindigul	0.97	1.00	0.95	1.30	1.2035855
13	Madurai (Usilampatti)	1.26	0.95	0.89	1.29	1.3899074
14	Virudhunagar	1.62	0.93	0.71	1.10	1.1742807
15	Sivaganga	1.56	1.06	0.73	1.16	1.3927328
16	Ramanathapuram	1.30	0.92	0.67	1.20	0.9685587
17	Tirunelveli (Tenkasi)	1.46	1.10	0.72	1.31	1.5317716
18	Kovilpatti	1.29	1.03	0.88	1.00	1.1756094
19	Padmanabhapuram	0.93	1.34	0.85	0.90	0.958419
20	Nagapattinam	1.74	0.95	0.94	1.42	2.2074842
21	Kumbakonam	1.41	1.02	0.91	1.08	1.4097269
22	Villupuram	1.00	1.02	0.85	1.00	0.8650989
23	Karur	1.58	1.22	0.60	0.79	0.9061561
24	Perambalur	1.10	1.39	0.91	0.96	1.3318842
25	Thiruvallur	0.83	1.21	0.70	1.37	0.9632839
26	Thiruvarur	1.49	1.15	0.64	0.98	1.0775132
27	Theni (Periyakulam)	1.76	1.05	0.46	0.97	0.8203299
28	Namakkal	1.91	1.12	0.48	1.13	1.1671757
29	Krishnagiri	1.47	1.26	0.76	1.28	1.8071154
						1.2358389