ABSTRACT

The purpose of this paper is to compare two measures of hospital productivity in the presence of undesirable output: the traditional Malmquist productivity index and the new Malmquist-Luenberger productivity index (ML) recently developed by Chung, Färe, and Grosskopf. Undesirable output in this study is defined by patient deaths. The study is limited to three diagnostic technologies commonly used in Portuguese hospitals during a three year time period: the Computerised Tomography Scan, Electrocardiogram and Echocardiogram which are considered to be important aids in the diagnosis of two of the most frequent non-obstetric Diagnosis Related Groups: Cerebrovascluar Disorders Except Ischemic Attack and Heart Failure and Shock.

First, total factor productivity growth (TFPG) along with its components of technical efficiency change and technological change is calculated using both measures for each technology and hospital type. The hospitals are then ranked on the basis of TFPG for both indices and changes in ranking that occur under the ML index are presented. Finally, Spearman correlation coefficients are calculated for the technical efficiency component of the indices.

The results show that the direction and intensity of TFPG and its components often differ for the two indices. Furthermore, a number of hospitals change rank considerably when the ML index is used. Most importantly, Spearman correlation coefficients for the efficiency score component of the indices are mostly negative, indicating that when hospitals have large increases in output given a level of technology (efficiency increases under the Malmquist index), much of that output may be in the form of patient deaths (a decline in efficiency under the ML index). Obviously, this study is limited to three technologies and two DRGs so that the conclusions cannot necessary be generalised for all hospital inputs and outputs. However, the ML index is clearly superior in measuring hospital productivity when patient deaths are considered to be undesirable output.

1. Introduction

The use of frontier estimation techniques in the evaluation of hospital efficiency and productivity has been often criticised for problems related to output definition. (Newhouse, 1994). More specifically, the concern is that these efficiency measures are based on output measures that do not take into account the quality of the output produced such as patient days, number of patients and DRG weighted output. [1] (Linna, 1998)

The definition of quality-adjusted output is also a polemic issue though hospital mortality rates are the most commonly employed indicator of the quality of inpatient hospital services.[2] (Tomal, 1998) There are a number of studies which have used a two-stage estimation procedure whereby first technical or allocative efficiency is estimated and then the efficiency scores are regressed on controls for quality such as the ratio of predicted to actual mortality rates (Linna, Häkkinen and Linakko, 1998; Ferrier and Valdmanis, 1996; Morey et al., 1995; Zukerman Hadley and Iezzoni, 1994) or re-admissions (Linna, 1998). However, no hospital efficiency study to our knowledge has incorporated the quality aspect into the actual calculation of the efficiency scores.

A recent study from the environmental literature introduces a new productivity index developed by Chung, Färe and Grosskopf which allows for the joint production of desirable and undesirable outputs. (Chung, Färe, and Grosskopf, 1997). This new index, the Malmquist-Luenberger (ML) index, credits institutions for being able to simultaneously increase good output and decrease bad output without requiring shadow prices for the bad output. Hence, this index allows the distinction between good and bad outputs of the hospital in the form of live and dead patients whereby the hospital is viewed as increasing its productivity by simultaneously increasing production of live patients and decreasing deaths. The ML index is more appealing conceptually than the two-stage technique, which considers that variations in mortality rates may influence variations in efficiency but mortality is not in and of itself considered a component of the efficiency measurement. The ML index incorporates the mortality of a patient as a defect in production for whatever reason it may occur. A hospital always risks incurring patient deaths for various reasons: treatment or diagnostic failure, faulty judgement on the part of the hospital staff or as a random occurrence beyond the control of the medical staff.

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[1] The DRG system was developed in order to provide a measure of the final product of the hospital , i.e. the bundle of goods and services provided to the patient with a particular illness. (Fetter 1991) According to Fetter, the first function of a hospital is to convert raw materials such as labour, supplies and equipment into intermediate products such as diagnostic procedures, surgeries, etc. The second and major function of the hospital is to receive human beings who have a problem and supply physicians and other health professionals with the intermediate products deemed necessary for their evaluation and treatment. It is this bundle of goods and services that comprise the final output of the hospital which can then be classified into DRGs.

[2] Though there are many investigators who argue that the usefulness of mortality rates is questionable and more reliable instruments should be used, these alternative instruments often require expensive and time consuming data collection procedures such as physician chart reviews and questionnaires which are not always feasible to obtain. (Guadagnoli and McNeil, 1994).

The purpose of this paper is to compare the traditional Malmquist productivity index with the new ML index in the measurement of hospital productivity. This study is limited to three diagnostic technologies commonly used in Portuguese hospitals during a three year time period. These technologies, the Computerised Tomography Scan, Electrocardiogram and Echocardiogram are considered to be important aids in the diagnosis of two of the most frequent non-obstetric Diagnosis Related Groups: Cerebrovascluar Disorders Except Ischemic Attack and Heart Failure and Shock. First, total factor productivity growth (TFPG) along with its components of technical efficiency change and technological change is computed using both productivity measures for each technology and hospital type.[3] The hospitals are then ranked on the basis of total factor productivity growth for both indices and changes in ranking that occur under the ML index are presented. Finally, Spearman correlation coefficients are calculated for the technical efficiency component of the indices.

The results show that the direction and intensity of total factor productivity growth and its components often differ under the ML and Malmquist indices. Furthermore, a number of hospitals change rank considerably under the ML index. Most importantly, Spearman correlation coefficients for the efficiency score component of the indices are mostly negative, indicating that when hospitals have large increases in output given a level of technology (efficiency increases by the Malmquist index), much of that output may be undesirable, i.e. in the form of dead patients (a decline in efficiency under the ML index).

The structure of the paper is as follows. Section 2 provides a model of hospital production with undesirable output. Section 3 contains a description of the methodology for production measurement while Section 4 contains a description of the data. The results are presented in Section 5 and Section 6 provides some conclusions and suggestions for further research.

2. Model of Hospital Production with Undesirable Output

The problem of the hospital's medical staff who make decisions regarding the utilisation of diagnostic technologies in order to improve the treatment of patients and thus the patient's probability of survival is that in the effort to save lives there is a risk of incurring patient deaths. Patient deaths may occur for any number of reasons: diagnostic or treatment failure, errors in judgement of medical staff, or as a random occurrence beyond the medical staff's control.

This simultaneous production of desirable (alive patients) and undesirable (patient deaths) output implies that reducing the bad output is costly in terms of increased technological capability or increased diagnostic and treatment capability of the medical staff.

[3] Hospitals are classified as district, central-teaching and central non-teaching.

More formally, following Chung, Färe and Grosskopf, if we denote live patients in a particular DRG by $y \in \Re_+^M$, dead patients by $b \in \Re_+^I$, and the diagnostic technologies by $x \in \Re_+^N$, then the production technology can be characterised through the output sets:

(1.1) $P(x) = \{(y,b) : x \text{ can produce } (y,b)\}$.

Since the reduction of deaths is costly (i.e. there is weak disposability of undesirable outputs) then:

(1.2) $(y,b) \in P(x)$ and $0 = \theta \leq 1$ imply $(\theta y, \theta b) \in P(x)$. In other words, a reduction in deaths is feasible only if total production is reduced given a fixed level of diagnostic technologies.

The model also assumes that the desirable output, live patients are freely disposable, i.e.

(1.3) $(y,b) \in P(x)$ and $y' \leq y$ imply $(y',b) \in P(x)$.

The joint production of desirable (live) and undesirable (dead) outputs is shown by:

(1.4) if $(y,b) \in P(x)$ and $b=0$ then $y=0$.

This equation states that the desirable outputs are "nulljoint" with the undesirable outputs if the only way to not produce undesirable outputs is by not producing desirable output. In other words, the hospital must risk having some deaths in the effort to produce live patients.

The original Malmquist index, using Shephard (1970) output distance functions to represent technology are defined as:

(1.5) $D_0(x,y,b) = \inf\{\theta : ((y,b)/\theta) \in P(x)\}$ where the function expands both desirable and undesirable outputs (y,b) proportionally as much as feasible. This function therefore does not give institutions credit for reduction in undesirable outputs since both types of output are expanded at the same rate[4].

Chung, Färe and Grosskopf use a directional output distance function instead of the Shephard distance function to represent the production technology. Their directional output distance function, as opposed to Shepherd's, credits institutions for the simultaneous reduction of undesirable outputs and an increase in desirable outputs. For hospitals, this implies an increase in production of live patients, while simultaneously decreasing the production of dead patients.

[4] This is one reason that Chung, Färe, and Grosskopf decided to modify the original Malmquist index.

Formally, their directional output distance function is defined as:

(1.6) $\vec{D}_0(x,y,b;g) = \sup\{\beta : (y,b) + \beta g \in P(x)\}$

where "g" is the vector of "directions" in which outputs are scaled. In the case of hospital production, g = (y, -b), where production of live patients is increased and dead patients is decreased.[5]

3. Hospital Productivity Measurement

Färe, Grosskopf, Lindren and Roos (1989) defined a productivity index based on Shepherd's output distance function. Their index (FGLR) is the geometric mean of two Malmquist productivity indices which were developed by Caves, Christensen and Diewert (1982).

The FGLR output-oriented Malmquist productivity index can be defined by:

(2.1) $$M_t^{t+1} = \left[\frac{D_0^t\left(x^{t+1},y^{t+1},b^{t+1}\right)}{D_0^t\left(x^t,y^t,b^t\right)}\frac{D_0^{t+1}\left(x^{t+1},y^{t+1},b^{t+1}\right)}{D_0^{t+1}\left(x^t,y^t,b^t\right)}\right]^{\frac{1}{2}}$$ where t=1,...,T time periods.

The Malmquist index (2.1) can be decomposed into two components, technical efficiency change (MEFFCH) and technological change (MTECH) where:

(2.2) $$MEFFCH_t^{t+1} = \frac{D_0^{t+1}\left(x^{t+1},y^{t+1},b^{t+1}\right)}{D_0^t\left(x^t,y^t,b^t\right)}$$

(2.3) $$MTECH_t^{t+1} = \left[\frac{D_0^t\left(x^{t+1},y^{t+1},b^{t+1}\right)}{D_0^{t+1}\left(x^{t+1},y^{t+1},b^{t+1}\right)}\frac{D_0^t\left(x^t,y^t,b^t\right)}{D_0^{t+1}\left(x^t,y^t,b^t\right)}\right]^{\frac{1}{2}}$$ and

(2.4) $$M_t^{t+1} = MEFFCH_t^{t+1} * MTECH_t^{t+1}.$$

The FGLR output-oriented Malmquist index is a total factor productivity index which only requires information on input and output quantities and thus makes it applicable to the hospital industry where prices are often difficult to measure. Although this index has these desirable features it does not allow hospitals to be credited for reductions in undesirable output, i.e. dead patients. In order to allow this possibility, we use a new index developed by Chung, Färe, and Grosskopf which substitutes the directional distance functions for the output distance functions in

[5] A more detailed comparison of Shepherd's and the Chung, Färe, Grosskopf distance function can be found in Chung, Färe, Grosskopf (1997).

the Malmquist index.

This new index, the output-oriented Malmquist-Luenberger productivity index. with undesirable output, can be defined as:

(2.5) $$ML_t^{t+1} = \left[\frac{\left(1+\vec{D}_0^t\left(x^t, y^t, b^t; y^t, -b^t\right)\right)}{\left(1+\vec{D}_0^t\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right)} \frac{\left(1+\vec{D}_0^{t+1}\left(x^t, y^t, b^t; y^t, -b^t\right)\right)}{\left(1+\vec{D}_0^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right)} \right]^{\frac{1}{2}}$$

Under this definition, when the direction of g is (y,b) rather than (y,-b), the Malmquist-Luenberger (ML) index coincides with the Malmquist index. The ML index can also be decomposed into two components of technical efficiency (MLEFFCH) and technological change (MLTECH):

(2.6) $$MLEFFCH_t^{t+1} = \frac{1+\vec{D}_0^t\left(x^t, y^t, b^t; y^t, -b^t\right)}{1+\vec{D}_0^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)}$$

(2.7) $$MLTECH_t^{t+1} = \left[\frac{\left(1+\vec{D}_0^t\left(x^t, y^t, b^t; y^t, -b^t\right)\right)}{\left(1+\vec{D}_0^{t+1}\left(x^t, y^t, b^t; y^t, -b^t\right)\right)} \frac{\left(1+\vec{D}_0^t\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right)}{\left(1+\vec{D}_0^{t+1}\left(x^{t+1}, y^{t+1}, b^{t+1}; y^{t+1}, -b^{t+1}\right)\right)} \right]^{\frac{1}{2}}$$

so that their product is equal to ML_t^{t+1}.

The ML index like the Malmquist index indicates productivity increases if the value is greater than one and productivity declines if the value is less than one. In order to calculate both indices and their composite measures, it is necessary to compute four distance functions for each index. If k represents each hospital and z_k represents intensity:

the model can be shown as: (2.8)

$P(x) = (y,b)\!:\sum_{k=1}^{K} z_k y_{km}^t \geq y_m^t$ where m=1,...,M,

$\sum_{k=1}^{K} z_k b_{ki}^t = b_i^t$, where i = 1,...I,

$\sum_{k=1}^{K} z_k x_{kn}^t \leq x_n^t$, where n = 1,...N, and

$z_k \geq 0$, where k = 1,...,K.

This model exhibits constant returns to scale so that:

(2.9) $P(l x) = l P(x), l > 0$ and strong disposability of inputs:

(2.10) $x' \geq x \Rightarrow P(x') \supseteq P(x)$.

The inequalities for inputs and good outputs in (2.8) reflect the assumption that they are freely disposable. The bad outputs are assumed to be costly to dispose of and therefore are modelled as equalities. The non-negativity constraints on the intensity variables, z_k, allow the model to exhibit constant returns to scale.[6]

Both the distance functions for the Malmquist index and the directional distance functions for the Malmquist-Luenberger index can be calculated as solutions to linear programming problems[7].

For the directional distance function case:

(2.11) $\vec{D}_0^t\left(x^{tk,'}, y^{tk,'}, b^{tk,'}; y^{tk,'}, -b^{tk,'}\right) = \max b$

s.t. $\sum_{k=1}^{K} z_k y_{km}^t \geq (1+b) y_{k'm}^t$, where m = 1,....,M (good output)

$\sum_{k=1}^{K} z_k b_{ki}^t = (1-b) b_{k'i}^t$, where i = 1,....,I (bad output)

$\sum_{k=1}^{K} z_k x_{kn}^t \leq x_{k'n}^t$, where n = 1,....N (input)

$z_k \geq 0$, k = 1,....,K.

4. Data

The original data used in this analysis consist of all adult public hospital discharge abstracts for the two most frequent non-obstetric Diagnosis Related Groups in Portugal during the years 1992-1994: DRG 14-Specific Cerebrovascular Disorders Except Transient Ischemic Attack and DRG 127- Heart Failure and Shock. The data were provided by the Instituto de Gestão Informática e Financeira da Saúde (IGIF), the institute responsible for collecting and managing health care financing information in the Portuguese Health Ministry.

The hospital inpatient discharge abstracts contain a wealth of information regarding patient age and sex, primary and secondary diagnostic codes (ICD-CM-9), primary and secondary procedure codes, discharge status, intensive care utilisation and length of stay. A coded hospital identifier is used to match hospital characteristics with discharge records.

[6] A necessary condition for the resulting productivity indices to be true total factor productivity indices (Färe and Grosskopf; 1996).

[7] The linear programming problem for the Malmquist index is explained in detail in Chung, Färe, and Grosskopf (1997).

In constructing the data set used in the empirical analysis, discharges for which patient information was missing as well as discharges for patients who were transferred to another acute care hospital were omitted. Transfers are considered incomplete outputs for the hospital and therefore outputs for which the hospital should neither be credited nor penalised.

The remaining discharges were then aggregated by hospital type. Hospitals in Portugal are classified as central, district and level one depending on the number of specialities which the hospital is equipped to treat. Since level one hospitals, those with the fewest number of specialities, are rarely equipped with technology such as the Computerised Axial Tomography Scanner (CAT), we only consider discharges from central and district hospitals where such technology is available. The final sample thus consists of 37,232 discharges in DRG 14 and 24,904 discharges in DRG 127 from 52 hospitals during the 1992-1994 time period. [8]

5. Results

Total factor productivity growth (TFPG) as computed by both Malmquist-Luenberger and traditional Malmquist indices along with their components of technical efficiency change and technological change are shown in tables 1-18 (ML indices in the odd number tables and traditional Malmquist in the even number). These indices were calculated for the three diagnostic technologies of interest for both district and central (where these latter have been further divided between teaching and non-teaching hospitals) hospitals. Both indices have been computed using the DEA model presented in (2.11). Specifically, the chosen DEA model is output-oriented, solved under the assumption of constant return technology. In these tables, as is generally done in the empirical literature, the convention is assumed that a score equal to one indicates no change, a score greater than one indicates an improvement in productivity and a number less than one indicates a decline in productivity.

A cursory glance at tables 1-18 shows that under the Malmquist-Luenberger index both district and central teaching hospitals had positive productivity growth for all three technologies between 1993 and 1994. On the contrary, the traditional Malmquist index only shows productivity growth for the Echocardiogram in the district hospitals and the Electrocardiogram in the central hospitals during this time period. Among, central non-teaching hospitals, the ML index indicates productivity growth during this time period only for the Computerised Tomography Scan while the traditional Malmquist indicates productivity decline for all three technologies in these hospitals. In fact, for all three types of scores, total factor productivity growth, efficiency change and technological change, agreement between the two indices is exactly 50% though agreement is not consistent over scores. In other words, the two indices may agree on the direction of efficiency change but not on the direction of productivity or technological change.

[8] These restrictions resulted in the deletion of approximately 30% percent of discharges from the original data set. 36 hospitals are considered to be district and 16 central of which 6 are teaching hospitals.

Changes in TFPG rankings of the hospital from the traditional Malmquist to the Malmquist-Luenberger index are presented in tables 19-23. Only considerable changes in rank (changes from one group to another) are shown. Even so, it is clear that among central hospitals for all three technologies, more hospitals decline in rank than improve under the ML index. The most remarkable results in these tables are for the Computerised Tomography Scan in District hospitals. In this case, between 63% and 72% of hospitals (depending on the year) which were in the last group improved rank under the ML index.

While the scores for technological change may be interesting, the reality is that in Portugal, technological improvement is often beyond the control of the hospital. When a hospital desires to purchase a new technology, a request must be made to the Health Ministry and often the hospital may only receive the technology a year or two from the time it is deemed necessary. However, the manner in which the technology is utilized is most definitely within the hospital's control. For this reason, a closer look is taken at the agreement among efficiency scores computed under the ML and Malmquist index by computing correlation coefficients for the efficiency scores. The results of the non-parametric Spearman correlation coefficients for the efficiency component provide some interesting insights. Except for the Computerised Tomography Scan and the Echocardiogram in the last two years) in district hospitals, the correlations between the ML and the traditional Malmquist indices are negative and significant. The explanation for this phenomenon appears to be that those hospitals which are increasing output in relatively large amounts given the technology (increasing efficiency under the traditional Malmquist index), may be doing so at the cost of producing undesirable output (declining efficiency under the ML index). There is a concern in Portugal that hospitals are understaffed, particularly by physicians and qualified nurses. It may be that rapid output expansion without accompanying human resource expansion results in a greater amount of patient deaths.

6. Conclusions

The objective of this paper has been to compare two measures of hospital productivity in the presence of undesirable output: the traditional Malmquist productivity index and the new Malmquist-Luenberger productivity index (ML) recently developed by Chung, Färe, and Grosskopf. where undesirable output is defined as patient deaths. The study is limited to three diagnostic technologies commonly used in Portuguese hospitals during a three year time period: the Computerised Tomography Scan, Electrocardiogram and Echocardiogram which are considered to be important aids in the diagnosis of two of the most frequent non-obstetric Diagnosis Related Groups: Cerebrovascluar Disorders Except Ischemic Attack and Heart Failure and Shock.

The results show that the direction and intensity of TFPG and its components often differ for the two indices. Furthermore, a number of hospitals change rank considerably when the ML index is used. Most importantly, Spearman correlation coefficients for the efficiency score component of the indices are mostly negative, indicating that when hospitals have large increases in output given a level of technology (efficiency increases under the Malmquist index), much of that output may be in the form of patient deaths (a decline in efficiency under the ML index). The obvious policy implication is that hospitals who are encouraged or expected to expand output quickly given a state of technology and without accompanied expansion in human resources, may be doing so at the risk of that output being in the form of dead patients.

This study is clearly limited in its scope since it considers only three diagnostic technologies used in the production of two major Diagnostic Related Groups. Further studies using other inputs and DRGs for longer time periods would be useful in verifying whether or not these results can be generalised for the entire hospital. However, this study has demonstrated that if patient deaths are an undesirable hospital output, the Malmquist-Luenberger index provides a superior measure of hospital productivity and technical efficiency.

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Table 1. The **Malmquist-Luenberger** Productivity Indexes and Components for **District Hospitals - Computerised Tomography Scans**

	Efficiency change	Technical change	ML index
1992-3	1.059856	0.843148	0.92128
1993-4	0.956663	1 .209076	1.011814

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 2. The **Malmquist** Productivity Indexes and Components for **District Hospitals - Computerised Tomography Scans**

	Efficiency change	Technical change	Malmquist index
1992-3	0.713	1.074	0.766
1993-4	1.544	0.421	0.649

Note: All Malmquist Index Averages are Geometric Means

Table 3. The **Malmquist-Luenberger** Productivity Indexes and Components for **District Hospitals - Electrocardiograms**

	Efficiency change	Technical change	ML index
1992-3	1.096394	0.791001	0.972863
1993-4	0.953175	1.201064	1.036393

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 4. The **Malmquist** Productivity Indexes and Components for **District Hospitals-Electrocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	0.879	1.298	1.140
1993-4	0.830	0.840	0.697

Note: All Malmquist Index Averages are Geometric Means

Table 5. The **Malmquist-Luenberger** Productivity Indexes and Components for **District Hospitals - Echocardiograms**

	Efficiency change	Technical change	ML index
1992-3	1.096439	0.771554	0.960753
1993-4	0.983352	1.057493	1.008241

Note: All Malmquist -Luenberger Index Averages are Geometric Means

Table 6. The **Malmquist** Productivity Indexes and Components for **District Hospitals- Echocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	0.887	1.170	1.038
1993-4	1.013	1.034	1.048

Note: All Malmquist Index Averages are Geometric Means

Table 7. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Non-teaching Hospitals - Computerised Tomography Scans**

	Efficiency change	Technical change	ML index
1992-3	0.941886	1.048012	0.963863
1993-4	1.085622	0.876785	1.01814

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 8. The **Malmquist** Productivity Indexes and Components for **Central Non-teaching Hospitals - Computerised Tomography Scans**

	Efficiency change	Technical change	Malmquist index
1992-3	0.23	3.92	0.924
1993-4	1.67	0.409	0.756

Note: All Malmquist Index Averages are Geometric Means

Table 9. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Non-teaching Hospitals - Electrocardiograms**

	Efficiency change	Technical change	ML index
1992-3	1.003162	1.120213	1.054807
1993-4	1.150588	0.668249	0.942822

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 10. The **Malmquist** Productivity Indexes and Components for **Central Non-teaching Hospitals - Electrocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	1.065	0.876	1.020
1993-4	0.544	1.700	0.920

Note: All Malmquist Index Averages are Geometric Means

Table 11. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Non-teaching Hospitals - Echocardiograms**

	Efficiency change	Technical change	ML index
1992-3	1.030013	0.977494	1.016629
1993-4	1.051817	0.867703	0.977849

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 12. The **Malmquist** Productivity Indexes and Components for **Central Non teaching hospitals - Echocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	1.431	0.730	1.077
1993-4	0.564	0.942	0.522

Note: All Malmquist Index Averages are Geometric Means

Table 13. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Teaching Hospitals - Computerised Tomography Scan**

	Efficiency change	Technical change	ML index
1992-3	0.985339	1.039876	1.004957
1993-4	1.085752	0.885036	1.021494

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 14. The **Malmquist** Productivity Indexes and Components for **Central Teaching Hospitals - Computerised Tomography Scan**

	Efficiency change	Technical change	Malmquist index
1992-3	0.24	3.92	0.94
1993-4	2.00	0.509	0.998

Note: All Malmquist Index Averages are Geometric Means

Table 15. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Teaching Hospitals - Electrocardiograms**

	Efficiency change	Technical change	ML index
1992-3	0.87584	1.134358	0.930976
1993-4	1.284812	0.694358	1.061862

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 16. The **Malmquist** Productivity Indexes and Components for **Central Teaching Hospitals - Electrocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	0.965	0.976	0.941
1993-4	4.193	1.721	7.010

Note: All Malmquist Index Averages are Geometric Means

Table 17. The **Malmquist-Luenberger** Productivity Indexes and Components for **Central Teaching Hospitals - Echocardiograms**

	Efficiency change	Technical change	ML index
1992-3	0.993794	0.953317	0.970194
1993-4	1.05751	0.972636	1.045785

Note: All Malmquist-Luenberger Index Averages are Geometric Means

Table 18. The **Malmquist** Productivity Indexes and Components for **Central Teaching Hospitals - Echocardiograms**

	Efficiency change	Technical change	Malmquist index
1992-3	2.48	0.748	1.95
1993-4	0.432	0.942	0.417

Note: All Malmquist Index Averages are Geometric Means

Table 19. Change of Ranking of **Central Hospitals** Under Malmquist-Luenberger Index

Computerised Tomography Scan - 1992

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	6	-	3
0.26-0.50	8	2	4
0.51-0.75	1	-	-
0.76-1.00	1	-	-

Computerised Tomography Scan - 1993

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	5	-	2
0.26-0.50	8	2	3
0.51-0.75	1	-	-
0.76-1.00	1	-	-

Computerised Tomography Scan-1994

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	11	-	4
0.26-0.50	4	1	2
0.51-0.75	2	-	-
0.76-1.00	1	-	-

Table 20. Change of Ranking of **Central Hospitals** Under Malmquist-Luenberger Index

Electrocardiograms-1992

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	5	-	1
0.26-0.50	5	2	2
0.51-0.75	4	1	-
0.76-1.00	1	-	-

Electrocardiograms-1993

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	5	-	2
0.26-0.50	3	2	1
0.51-0.75	7	1	-
0.76-1.00	1	-	-

Electrocardiograms-1994

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	9	-	2
0.26-0.50	5	1	1
0.51-0.75	0	-	-
0.76-1.00	1	-	-

Table 21. Change of Ranking of **Central Hospitals** Under Malmquist-Luenberger Index

Echocardiograms - 1992

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	7	-	-
0.26-0.50	5	1	1
0.51-0.75	3	-	-
0.76-1.00	1	-	-

Echocardiograms - 1993

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	10	-	4
0.26-0.50	1	-	
0.51-0.75	4	1	-
0.76-1.00	1	-	-

Echocardiograms - 1994

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	12	-	5
0.26-0.50	2	-	-
0.51-0.75	1	-	-
0.76-1.00	2	-	-

Table 22. Change of Ranking of **District Hospitals** Under Malmquist-Luenberger

Computerised Tomography Scan - 1992

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	1	-	-
0.26-0.50	0	-	-
0.51-0.75	0	-	-
0.76-1.00	35	25	-

Computerised Tomography Scan - 1993

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	2	-	-
0.26-0.50	0	-	-
0.51-0.75	2	-	-
0.76-1.00	32	23	-

Computerised Tomography Scan - 1994

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	1	-	-
0.26-0.50	0	-	-
0.51-0.75	0	-	-
0.76-1.00	35	22	-

Table 23. Change of Ranking of **District Hospitals** Under Malmquist-Luenberger

Electrocardiograms - 1992

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	10	-	4
0.26-0.50	16	5	3
0.51-0.75	7	1	4
0.76-1.00	1	-	-

Electrocardiograms - 1993

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	15	-	3
0.26-0.50	14	4	2
0.51-0.75	2	-	-
0.76-1.00	1	-	-

Electrocardiograms - 1994

Range	N. of units	N. of units improving rank	N. of units worsening rank
0.00-0.25	11	-	2
0.26-0.50	19	4	1
0.51-0.75	4	-	-
0.76-1.00	12	7	-

Table 24. Spearman-Correlation Coefficients For **Efficiency Scores** Under Both Indices

Technology and Hospital Type	**1992**	**1993**	**1994**
CAT - Central	-0.302	-0.347	-0.247
EEG - Central	-0.397	-0.245	-0.490
ECO - Central	-0.314	-0.212	-0.441
CAT - District	+0.037	+0.080	+0.254
EEG - District	-0.250	-0.130	-0.035
ECO - District	-0.070	+0.078	+0.044

Note: All coefficients are significant at the 95% confidence level.