Total Factor Productivity Growth in Hospitals in Ireland 1995-1998:

*A Non-Parametric Approach**

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Abstract

This paper analyses the development of productivity and efficiency in the production of hospital care in Ireland from 1995 to 1998. Using Malmquist Productivity Indices, we look at changes in efficiency over time. This approach provides information on the types of hospitals that have increased or decreased efficiency during each time frame, and the type of inefficiency involved – pure technical, scale, or technological. Our results show that on average between 1995 and 1998, both technological and efficiency changes contribute to higher levels of productivity in General and Regional hospitals, but lead to lower levels of productivity in County hospitals. However, the contribution of these components of productivity varies over time.

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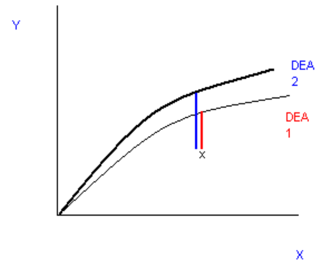
1. Introduction

This is the second paper in a programme of research on hospital efficiency in Ireland. While the previous paper (see Gannon, 2005) focused on efficiency scores at different points between 1995 and 2000, the purpose of this paper is to analyse the development of productivity and efficiency in the production of hospital care during the same time period. This approach will provide information on the types of hospitals that have increased or decreased efficiency during each time frame, and the type of inefficiency – pure technical, scale, or technological. Pure technical inefficiency occurs when more of an input is used than should be required to produce a given level of output, sometimes known as managerial inefficiency. If a hospital is scale inefficient, then efficiency gains could be achieved by expanding or reducing production levels, if there are increasing or decreasing returns to scale respectively. Technological inefficiency results in failure to keep up with best practice, due to increased knowledge, better productions techniques, new innovations, financial reasons or greater competition.

In measuring efficiency over time, we need to account for the production frontier shifting over time and we use a DEA type analysis to derive Malmquist productivity indices. The basic DEA analysis provides measures of average efficiency over 1995-1998 but this allows us look at changes in efficiency during the same time frame.

2. Measuring Changes in Hospital Production

As shown in the previous paper, in DEA, measuring efficiency at a point in time is simply obtained by looking at the deviation from the best practice frontier. However, due to technology advancement, this frontier may shift from one year to the next. In Figure 1 we show how a hospital may have a change in productivity but that this may totally attributed to technical inefficiency. If a hospital produces at point x in time period 1, the red lines describes the inefficiency at time 1. In time 2, they may still produce at this point, but now the best practice frontier has moved upwards. This means that the production at point x is now further away from frontier. This gives a lower level of production compared to the new frontier, but because the frontier has shifted, this productivity change is mainly due to technological change rather than efficiency change.



Following Fare, Grosskopf, Norris and Zhang (1994), we use the Malmquist Productivity Index (initially introduced by Malmquist (1953)) to measure changes in productivity over time. Fare et al (1994) illustrate how component distance functions can be estimated using DEA-like methods and then calculate the Malmquist TFP change indices. They also show how the resulting TFP indices can be decomposed into technical efficiency change and technical change components.

The Malmquist index is defined using distance functions. We consider an output distance function and this characterises the production technology by looking at a maximal proportional expansion of the output vector (P(x)), given an input vector:

$d_0{}^t(x,y) = \min\{\delta : (y/\delta) \in P^t(x)\}$. The distance here represents the smallest factor δ by which output needs to be deflated so as to be feasible or producible with a given input vector x, under period t technology. This distance function will take a value of 1 or less if the output vector is an element of the feasible production set, P(x). It takes a value of 1 if y is located on the outer boundary of the feasible set, or a value greater than 1 if y is located outside the feasible production set. The Malmquist output index based on technology in period t is then defined as $Q_0^t(y_s, y_t, x) = \dfrac{d_0^t(x, y_t)}{d_0^t(x, y_s)}$.

A similar Malmquist index can be defined using period s technology. These output indices simply measure growth in output but do not distinguish between the contribution due to growth in inputs and the contribution due to technical change or changes in efficiency. Real output may grow between period s and t but this may be due to growth in the use of inputs. We now construct a measure of growth in outputs net of input growth. The approach followed here is discussed in Cave, Christensen and Diewert (1982) and this formed the basis for what became known as the Malmquist Productivity Index number approach. This allows us to measure how much more output has been produced using a given level of inputs and technology, relative to what could have been produced under a given reference technology using the same level of inputs. This is referred to as the output-orientated measure of change in productivity.

Fare et al (1994) takes the Malmquist index of TFP growth, defined in Caves et al (1982) and using non-parametric methods they show how the component distance functions can be estimated using DEA like methods. They also show how the resulting TFP indices could be decomposed into technical efficiency and technical change components. The Malmquist TFP index measures TFP change between two points, by calculating the ratio of the distances of each data point relative to a common technology.

The Malmquist TFP change index between period s (base year) and t as:

$$m_0(y_s, x_s, y_t x_t) = [\frac{d_0^s(y_t, x_t)}{d_0^s(y_s, x_s)} x \frac{d_0^t(y_t, x_t)}{d_0^t(y_s x_s)}]^{\frac{1}{2}}$$

where $d_0^s(x_t, y_t)$ is the distance from period t observation to period s technology. A value of M_0 greater than one will indicate positive TFP growth from period s to period t. This equation is equivalent to the geometric mean of two TFP indices, first with respect to period s technology and second with respect to period t technology.

An equivalent way to express this is:

$$m_0(y_s, x_s, y_t, x_t) = \frac{d_0^t(y_t, x_t)}{d_0^s(y_s x_s)} [\frac{d_0^s(y_t, x_t)}{d_0^t(y_t, x_t)} * \frac{d_0^s(y_s, x_s)}{d_0^t(y_s, x_s)}]^{\frac{1}{2}} .$$

The first part of this index is a measure of efficiency change, that is ratio of technical efficiency in period t to technical efficiency in period s. The second part is a measure of technical change. It is the geometric mean of the shift in technology between two periods, evaluated at xt and xs. In order to evaluate the MPI we must calculate the four distance functions and this can be done using mathematical programming or econometric techniques. In this paper we focus on the non-parametric method. We use the output orientated approach, meaning that we compare the level of output produced by a given level of input and present state of technology, relative to what could have been produced under a given reference technology using the same level of inputs. The reference technology is the best practice frontier as used previously in the DEA analysis.

The Malmquist Productivity Index allows us to distinguish between shifts in the production frontier (technological change), and movement of hospitals nearer the frontier (efficiency change). Each index is evaluated with respect to the reference technology in each year and we then report the geometric mean of the TFP indices for each year. For example, for regional hospitals between 1995 and 1996, we derive the reference best practice frontier for 1995 and calculate the growth from 1995 to 1996 compared to best practice in 1995. We then derive a best practice frontier based on 1996 output and compare the output growth between 1995 and 1996 with reference to this frontier. Finally, the geometric mean for all growth indices is given as the measure of efficiency change.

3. Estimation

Following Fare et al (1994) for the with hospital, we must calculate four distance functions to measure TFP change between two periods. The required linear programs are:

$$
\begin{aligned}
&[d_0^t(y_t, x_t)]^{-1} = \max_{\phi,\lambda} \phi \\
&st\ -\phi y_{it} + Y_t\lambda \geq 0, \\
&x_{it} - X_t\lambda \geq 0, \\
&\lambda \geq 0
\end{aligned}
$$

$$
\begin{aligned}
&[d_0^s(y_s, x_s)]^{-1} = \max_{\phi,\lambda} \phi \\
&st - \phi y_{is} + Y_s\lambda \geq 0, \\
&x_{is} - X_s\lambda \geq 0, \\
&\lambda \geq 0
\end{aligned}
$$

$$
\begin{aligned}
&[d_0^t(y_s, x_s)]^{-1} = \max_{\phi,\lambda} \phi \\
&st - \phi y_{is} + Y_t\lambda \geq 0, \\
&x_{is} - X_t\lambda \geq 0, \\
&\lambda \geq 0
\end{aligned}
$$

$$
\begin{aligned}
&[d_0^s(y_t, x_t)]^{-1} = \max_{\phi,\lambda} \phi \\
&st - \phi y_{it} + Y_s\lambda \geq 0, \\
&x_{it} - X_s\lambda \geq 0, \\
&\lambda \geq 0
\end{aligned}
$$

These four linear programs must be solved for each hospital. To decompose technical efficiency into scale efficiency and pure technical efficiency we add two linear programs for each hospital as follows:

$$
\begin{aligned}
&[d_0^t(y_t, x_t)]^{-1} = \max_{\phi,\lambda} \phi \\
&st - \phi y_{it} + Y_t\lambda \geq 0, \\
&x_{it} - X_t\lambda \geq 0, \\
&\lambda \geq 0 \\
&N1'\lambda = 1
\end{aligned}
$$

$$
\begin{aligned}
&[d_0^s(y_s, x_s)]^{-1} = \max_{\phi,\lambda} \phi \\
&st - \phi y_{is} + Y_s\lambda \geq 0, \\
&x_{is} - X_s\lambda \geq 0, \\
&\lambda \geq 0 \\
&N1'\lambda = 1
\end{aligned}
$$

This convexity constraint is added to allow for variable returns to scale, when measuring efficiency. This forms a convex hull of intersecting planes which envelope the data points more tightly than the CRS conical hull and provides efficiency scores greater than or equal to those of the CRS model. An efficient firm is now only benchmarked against firms of similar size. This approach allows us to calculate distance functions relative to VRS technology. We can then get a measure of scale efficiency.

In summary an analysis using DEA methods gives us estimates of Technical Change and Technological Change. We can also derive pure technical efficiency change by measuring a distance function relative to VRS technology. This allows us to measure scale efficiency. TFP change is technical change * technological change.

4. Data on Acute Irish Hospitals

In this paper we analyse the development of technical efficiency in acute hospitals during the period 1995 to 1998, selected on the basis of most recently available comparable data. By looking at all hospitals together and comparing the efficiency of one to the production frontier of all hospitals combined, we are ignoring the fact that there is much variation in size in terms of bed capacity and types of procedures carried out. For this reason, we split the sample into groups based on the type of hospital. Before we specify the numbers in each group, it is important to know how the hospital sector is split and what distinguishes these different groups. The groups we use is a conventional categorisation in Irish terms, reflecting ownership as well as complexity. There may be a more appropriate categorisation for the purposes of efficiency analysis, where voluntary hospitals are not treated as a homogenous group and we will investigate this later in our programme of research.

Regional hospitals, owned and funded by the Health Boards, provide the most comprehensive range of services and most of them are teaching hospitals. County hospitals, owned by the Health Boards, have consultant-staffed units of general medicine, general surgery, obstetrics and gynaecology, and separate children's wards. Voluntary public hospitals, supported but not owned by the Health Boards, are general hospitals which often function as teaching hospitals and are located mainly in Dublin and other large centres of population.

The next two groups of hospitals are self-explanatory providing maternity and orthopaedic services respectively. Finally we group all other types of hospitals together and different services are provided by each, i.e. cancer, long stay, and infectious diseases.

The variables we use consist of inputs to hospital production in the form of capital and labour, and outputs from production. In terms of capital we use the average number of beds in the year in each hospital and this data is available in the Health Statistics publications. Labour inputs are measured by the number of people employed in each hospital and is counted in December of each year. We use full time equivalent staff to measure labour input. Given the shift work nature of hospitals and prevalence of part-time employment this will give a more accurate indication of the amount of labour used to provide services than does a simple count of the number of staff employed or the overall cost of labour. The employment figures are obtained from the Department of Children and Health Personnel Census and are categorised by General Support Staff, Health and Social Care Professionals, Management/Administration, Medical/Dental and Nursing. Table A1 provides an example of the breakdown of employment categories into grades of employees.

The outputs of hospital production consist of in-patients, out-patients and daycases. To measure in-patients we look at the total number of discharges and deaths within a year. Discharges are used instead of length of stay as there may be huge differences across hospitals in efficiency in terms of occupancy rates. Out-patients are counted as total yearly number of attendances at consultant-controlled out-patient clinics in each hospital. Previous authors for example (McKillop et al., 1999) and Gregan and Bruce (1997) have questioned reliance on the number of discharged patients per hospital in measuring efficiency. They argue that the complexity of the casemix measured for example by employing Diagnostic Related Groups (DRG) should be taken into account. We have shown in the previous paper, the importance of using data adjusted for casemix in county hospitals. We now use data adjusted for casemix for county, regional and general hospitals. The number of inpatients and daycases is adjusted for their respective DRGS. A relative value reflecting cost of procedures is applied to each DRG, and we obtain an aggregate output adjusted for casemix. In some cases, reporting of discharges to HIPE was not accurate, so in order to provide comparability across years and hospitals, we exclude any hospitals that have less than 80% coverage of records.

The classifications of hospitals not only allow us to distinguish between different services provided but also compare hospitals of similar sizes. For example across all hospitals the average number of beds in each hospital in each year is 194. But the range in terms of beds varies substantially, from 31 to 667. When we classify the hospitals into different groups we find that regional hospitals are the largest by far in terms of bed numbers. The next highest group is 'general', but the minimum value is quite low at 55. The reason for such a low number is because we include paediatric hospitals into the general category, as there are only three such hospitals. When we break down the years we will see that after 1997 when the National Childrens Hospital became part of Tallaght hospital, this minimum value will increase.

4. Results

The first table shows the mean TFP change for each set of hospitals, during the three different time periods.

Table 1: Malmquist Total Factor Productivity Index (DRG output)

	Regional	General	County
1995-1996	**1.048**	**0.99**	**1.005**
1996-1997	1.073	0.99	1.029
1997-1998	0.966	1.046	0.96
Average	1.028	1.012	0.997
N	6	8	22

Table 1 shows that in regional hospitals, between 1995 and 1998 average productivity growth was 2.8%. In general hospitals, during the same time, average productivity growth was 1.2%. County hospitals had a negative growth change of 0.03%. County hospitals experienced a decline in productivity growth over the years, compared to best practice. For regional hospitals, the highest growth was between 1996 and 1997, whereas for general hospitals the biggest growth rate was from 1997-1998. County hospitals experienced a decline in growth from 1997 to 1998, even though the growth rate between 1996 and 1997 was 2.9%. The dynamics of total factor productivity growth as there appears to be no set pattern in one direction. In regional and county hospitals the highest total factor productivity change is between 1996 and 1997, perhaps due to increased expenditure at this time. The previous paper on hospital efficiency suggests that hospitals are not totally efficient, so perhaps there were some technological improvements and these are reflected here in total factor productivity changes. The next table shows the breakdown of this index into technological change and efficiency change.

Table 2: Decomposition of Malmquist TFP Index into technological change and efficiency change.

	Regional	General	County
1995-1996			
Efficiency Change	0.992	0.985	1.020
Technological Change	1.057	1.006	0.985
1996-1997			
Efficiency Change	0.996	1.000	0.980
Technological Change	1.078	0.999	1.05
1997-1998			
Efficiency Change	0.994	1.011	1.016
Technological Change	0.971	1.035	0.945
Average			
Efficiency Change	0.994	0.999	1.005
Technological Change	1.034	1.013	0.992

This shows that average efficiency change between 1995 and 1998 is 0.5% for county hospitals, and –0.01% for general hospitals. Average technical progress is 1.3% for general hospitals and 0.08% for county hospitals. The highest level of technological change is in regional hospitals, where average technical progress is 3.4%. From 1995 to 1997 total factor productivity growth for regional hospitals was due moreso to technical progress than efficiency change, but the negative growth in 1997-1998 was a result of both efficiency and technological decline.

Looking at year on year changes, we see that high growth between 1996 and 1997 for regional hospitals is mainly due to technological advancement. However, this seems to have declined form 1997 to 1998. In general hospitals, technological change was greatest from 1997-1998. Efficiency had also increased throughout all years, increasing to 1.1% in 1997-1998. In county hospitals, the positive technical progress only took place between 1996 and 1997, when the efficiency change was negative. In 1995-1996, efficiency change dominated improvements in technology. The overall decline in efficiency by 1998 may be attributed to lack of technological change rather then declines in efficiency.

As mentioned in Section 3, the figure for efficiency change may be obtained while assuming CRS, but in reality hospitals could face scale inefficiencies due to DRS or IRS. Using the VRS assumption, we decompose the efficiency change index into pure efficiency change and scale efficiency change. The pure efficiency change measures changes in proximity of hospitals to the frontier, devoid of scale effects. Table 3 shows the decomposition of the measure of efficiency change into pure efficiency change and scale efficiency change components. For example, between 1995 and 1997, in county hospitals, average pure efficiency change is –1.1% (pure technical inefficiency), and average scale efficiency change (scale inefficiency) is 0.1% production levels, if there are increasing returns to scale. The main source of decreases in regional hospital technical efficiency between 1992 and 1994 appears to be in terms of pure technical inefficiency (otherwise known as managerial inefficiency). This has changed slightly by 1995 and up to 1997, these hospitals show less pure technical inefficiency. But in 1998-2000, we see that the main source of inefficiency is in terms of scale.

Table 3: Decomposition of Efficiency Change

	Regional	General	County
1995-1996			
Pure efficiency change	0.994	1.002	1.006

Scale efficiency change	0.998	0.982	1.014
1996-1997			
Pure efficiency change	1.002	0.995	0.989
Scale efficiency change	0.994	1.005	0.990
1997-1998			
Pure efficiency change	0.993	1.006	1.000
Scale efficiency change	1.001	1.005	1.016
Average			
Pure efficiency change	0.996	1.001	0.998
Scale efficiency change	0.998	0.997	1.007

These results are generally consistent with the findings for a similar study in Northern Ireland between 1986 and 1992. McCallion et al (2000) show that larger hospitals increase productivity by 2.31% and smaller ones by 22.53%. Technological increase is outweighed by a decline in efficiency change for small hospitals and scale efficiency falls over this time period. Maniadakis et al (1999) apply Malmquist indices to estimate productivity changes in Scottish hospitals and found that there was a productivity slowdown in the first year following NHS reforms, but found progress in subsequent years. Sommersguter-Reichmann (2000) analysed hospitals in Austria from 1994 to 1998 and found an increase in productivity of 3.8% due to technology improvements based on a new financing system.

5. Conclusion

This paper analyses Total Factor Productivity change in acute hospitals in Ireland between 1995 and 1998. Using DEA like methods we calculated the Malmquist Total Factor Productivity Index and decomposed this into levels of average efficiency change and average technological change. Controlling for VRS technology, we then decomposed the efficiency change further into pure efficiency and scale efficiency change.

The results show that the average total factor productivity change is highest in regional hospitals. General and county hospitals experienced a decline in total factor productivity. In regional hospitals the main contributor to this result is in terms of technological progress, as opposed to efficiency change. In general and county hospitals, the main contributor is a reduction in efficiency change.

Using parametric distance functions we could also check the robustness of these findings to the choice of methodology.

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