Lancaster University Management School Working Paper 2006/017

Efficiency and productivity change in the English higher education sector from 1996/97 to 2002/03

Jill Johnes

The Department of Economics
Lancaster University Management School
Lancaster LA1 4YX
UK

EFFICIENCY AND PRODUCTIVITY CHANGE IN THE ENGLISH HIGHER EDUCATION SECTOR FROM 1996/97 TO 2002/03

Jill Johnes

Department of Economics

Lancaster University Management School

Lancaster University

Lancaster LA1 4YX

United Kingdom

Tel: +44 (0)1524 594224

Fax: +44 (0)1524 594244

Email: j.johnes@lancaster.ac.uk

January 2006

JEL Classification: I21, C14, D24, O3

Keywords: higher education; efficiency measurement; data envelopment analysis; distance functions; productivity change; Malmquist index

Abstract

This study uses data envelopment analysis (DEA) and a distance function approach to derive Malmquist productivity indexes for 113 English higher education institutions (HEIs) over the period 1996/97 to 2002/03. The analysis finds that over the period of the study HEIs have experienced an annual average increase in Malmquist productivity of 1.5%. On investigating the components of this productivity change, however, it becomes apparent that HEIs have enjoyed an annual average of 2.3% increase in technology combined with a decrease in technical efficiency of -0.8%. The finding of the importance of technology change (relative to technical efficiency change) in the Malmquist productivity indexes for HEIs is in line with previous studies (Flegg *et al* 2004; Worthington & Lee 2005), but the finding of negative technical efficiency change is new. Further examination of the indexes reveals differences between the subgroups of HEIs in England. Pre-1992 HEIs have experienced much lower Malmquist productivity (and technology change) than post-1992 and colleges which belong to the Standing Conference of Principals Ltd (SCOP). Further examination reveals that, for pre- and post-1992 institutions, technology change may be related positively to change in the ratio of students to staff, while technical efficiency change may be negatively related to change in the student staff ratio. Thus rapid changes in the higher education sector may have a positive effect on the technology of production but this may be achieved at the cost of lower technical efficiency.

In 2002/03, the English higher education sector received £4838 million in funding council grants, representing 38% of its total income. In the interests of accountability, it is therefore essential to measure the efficiency of the institutions in receipt of this funding. The higher education sector, however, has characteristics which make it difficult to measure efficiency: it is non-profit making; there is an absence of output and input prices; and higher education institutions (HEIs) produce multiple outputs from multiple inputs.

The distance function approach is a particularly attractive method for measuring efficiency in the context of higher education: it does not require a knowledge of input or output prices, nor does it require any specific behavioural assumptions of the firms under consideration, such as cost minimization or profit or revenue maximization (Coelli & Perelman 1999; O'Donnell & Coelli 2003; Uri 2003a;b; Rodríguez-Álvarez *et al* 2004). When a panel of data is available, moreover, changes in productivity growth over the period under consideration can also be calculated using the Malmquist productivity change index. This index is composed of distance functions, and is therefore superior to alternative indexes of productivity growth (such as the Törnqvist index and the Fisher Ideal index) because it is based only on quantity data and makes no assumptions regarding the firm's behaviour (Grifell-Tatjé & Lovell 1996). The Malmquist productivity index can provide additional insights since it can be decomposed into two additional components, one which measures changes in technical efficiency (i.e. whether firms are getting closer to the production frontier over time), and one which measures changes in technology (i.e. whether the production frontier is moving outwards over time).

There is now a considerable literature on efficiency measurement in the higher education sector, including numerous empirical studies (see, for example, Johnes 2005 for a survey). Few studies examine changing productivity in the higher education sector. There are two exceptions: Worthington & Lee (2005) examine the change in productivity in the Australian universities sector between 1998 and 2003, while Flegg *et al* (2004) examine the change in productivity in the British universities sector over the period 1980/81 to 1992/93. Both studies find an annual average increase in productivity of around 3.5% over the period, and in both cases, the positive productivity change is found to have been caused largely by positive technological change (i.e. an outwardly shifting production frontier) rather than by changes in technical efficiency.

The data which form the basis of the Flegg *et al* (2004) study are no longer representative of the higher education sector which prevails in Britain today. Since 1992, the sector has expanded to around 170 institutions (compared to the 45 included in the Flegg *et al* (2004) study), most of which (around 80%) are in England, and which are highly diverse. Three main groups can be defined. Pre-1992 universities had the status of a university before the provisions of the Further and Higher Education Act of 1992 came into force. Prior to 1992, they were largely funded by the Universities Funding Council. Post-1992 universities are mostly former polytechnics which, prior to 1992, were funded by the Polytechnics and Colleges Funding Councils. The Further and Higher Education Act of 1992 allowed these HEIs to award their own degrees and to use the title of university. The third group of institutions are the colleges which belong to the Standing Conference of Principals Ltd (SCOP). These colleges are part of the higher education sector, but differ from other HEIs in that they are often specialist institutions concentrating on a particular discipline such as music, drama, performing arts, education or agriculture. There is not only diversity between groups, but also within groups. The pre-1992 group, for example, includes old universities, such as Oxford and Cambridge, together with the redbricks founded in the nineteenth and early twentieth century, the former colleges of advanced technology, and the new universities created in the 1960s.

It is of interest to investigate whether the enlarged sector of higher education (including all types of HEIs) has enjoyed similar productivity increases to those found by Flegg *et al* (2004) for an earlier period and a smaller sector. Of particular interest is whether the diverse sub-groups of the UK higher education sector have experienced different productivity changes. To this end, a panel of data from 1996/97 to 2002/03 will form the basis from which to estimate various distance functions which will allow the technical efficiency, technology and productivity change of the sector to be assessed over this period.

The rest of the paper is in 4 sections. Section 1 describes how distance functions can be used to measure the various types of efficiency, and estimation methods are presented in section 2. The data set is described in section 3 which also presents the results of the analysis. Finally, conclusions are drawn in section 4.

1. Technical efficiency, scale efficiency and productivity growth

Three aspects of the efficiency of higher education institutions (HEIs) will be considered: technical efficiency, i.e. the efficiency with which inputs are converted into outputs; scale efficiency, i.e. how close an HEI is to its most efficient scale size; and productivity growth, i.e. the change in output which is not a consequence of growth in input quantities.

1.1 Technical efficiency

Let us assume time periods $t = 1,...,T$, and define the production technology of a firm or decision making unit (DMU), in time *t*, as P^t , and this represents the transformation of the inputs $x^t \in \Re_+^K$ into the outputs $y^t \in \Re_+^M$. Hence

$$P^t = \{(x^t, y^t) : x^t \text{ can produce } y^t\}$$

The output distance function (Shepherd 1970; Färe 1988; Färe *et al* 1994) is defined at time *t* as:

$$D_o^t(x^t, y^t) = \min_\theta \{\theta : (x^t, y^t / \theta) \in P^t\} = \left(\max\{\theta : (x^t, \theta y^t)\} \in P^t\right)^{-1} \qquad (1)$$

If $(x^t, y^t) \in P^t$ then $D_o^t(x^t, y^t) \le 1$, and $D_o^t(x^t, y^t) = 1$ if and only if (x^t, y^t) is on the boundary. The distance function is the reciprocal of Farrell's (1957) output-oriented measure of efficiency and so $D_o^t(x^t, y^t)$ can be used to measure efficiency at time period *t*. A similarly defined distance function, denoted by $D_o^{t+1}(x^{t+1}, y^{t+1})$, can be used to measure efficiency in time period *t*+1.

1.2 Productivity changes over time

In order to assess changes in productivity over time, mixed-period distance functions need to be defined as follows:

$$D_O^t(x^{t+1}, y^{t+1}) = \min\{\theta : x^{t+1}, y^{t+1} / \theta) \in P^t\} \qquad (2)$$

$$D_O^{t+1}(x^t, y^t) = \min\{\theta : x^t, y^t / \theta) \in P^{t+1}\} \qquad (3)$$

Productivity change could be measured relative to period *t* (M_O^t) or relative to period *t*+1 (M_O^{t+1}) (Caves *et al* 1982a; 1982b), where $M_O^t = \left(\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)}\right)$ and $M_O^{t+1} = \frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^t, y^t)}$. While these two measures are the same in a simple one output one input case, they will not necessarily be the same in the context of multiple outputs and multiple inputs. Hence the Malmquist productivity change index is defined as the geometric mean of these two indexes (Färe *et al* 1994):

$$M_O(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\left(\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \right) \left(\frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^t, y^t)} \right) \right]^{1/2} \qquad (4)$$

If this index exceeds unity, there has been an improvement in productivity between periods t and t+1. Values less than 1 suggest the converse. The Malmquist productivity change can be further decomposed into two components as follows (Färe *et al* 1989, 1992):

$$M_O(x^{t+1}, y^{t+1}, x^t, y^t) = \left(\frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \right) \left[\left(\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_O^t(x^t, y^t)}{D_O^{t+1}(x^t, y^t)} \right) \right]^{1/2} \qquad (5)$$

This provides further insights into productivity changes, since the first component, E = $\left(\frac{D_O^{t+1}(x^{t+1}, y^{t+1})}{D_O^t(x^t, y^t)} \right)$, measures the change in technical efficiency over the two periods (i.e. whether or not the unit is getting closer to its efficiency frontier over time), and the second component, T = $\left[\left(\frac{D_O^t(x^{t+1}, y^{t+1})}{D_O^{t+1}(x^{t+1}, y^{t+1})} \right) \left(\frac{D_O^t(x^t, y^t)}{D_O^{t+1}(x^t, y^t)} \right) \right]^{1/2}$, measures the change in technology over the two time periods (i.e. whether or not the frontier is shifting out over time). Values of either of these components of greater than unity suggest improvement, while values of less than 1 suggest the opposite.

1.3 Scale efficiency

In the exposition so far, constant returns to scale (CRS) have been assumed. It is straightforward (see section 2) to relax the CRS assumption and assume variable returns to scale (VRS). Thus we distinguish, for time period t, between the CRS distance function $D_{O,CRS}^t(x^t, y^t) = D_O^t(x^t, y^t)$, as defined earlier, and the VRS distance function $D_{O,VRS}^t(x^t, y^t)$. The ratio $SE^t = D_{O,CRS}^t \big/ D_{O,VRS}^t$ provides an estimate of the scale efficiency of the firms under consideration in period t. If SE^t is equal to 1 then the firm is already at its optimum scale size in period t.

With regard to returns to scale and productivity change, Färe *et al* (1994; 1997) propose a further decomposition of the Malmquist index such that E = PE x S where: E is the efficiency change calculated on the assumption of CRS (defined above); PE = $\frac{D_{O,VRS}^{t+1}(x^{t+1}, y^{t+1})}{D_{O,VRS}^{t}(x^{t}, y^{t})}$ (Färe *et al* 1998); and S = SE^{t+1} / SE^{t} for periods *t* and *t*+1 (Färe *et al* 1997;1998; Coelli *et al* 1998) where SE^{t} and SE^{t+1} are as defined above, and S measures the degree to which a unit gets closer to its most productive scale size over the periods under examination. Any empirical estimation of this decomposition of the Malmquist productivity change index should be treated with caution, since it mixes VRS and CRS efficiencies in the estimation of its components (Ray & Desli 1997).

2. Estimation

The required distance functions can be estimated using parametric or nonparametric techniques. In the former case, stochastic frontier analysis is used to estimate the production frontier, which is assumed to take a specific functional form (translog, for example). The appropriate functional forms for the production frontier and for the estimated efficiencies, however, have no particular grounding in theory and can therefore introduce errors. The nonparametric method makes no assumptions regarding functional form since it derives the distance functions via linear programming (Färe *et al* 1989). In this case, the two distance functions required to evaluate M_O^t are calculated by solving the following linear programs:

$$\left[D_O^t(x^t y^t)\right]^{-1} = \text{Max } \phi_k \qquad (6)$$

Subject to

$$\phi_k y_{rk}^t - \sum_{j=1}^{n} \lambda_j y_{rj}^t \leq 0 \qquad r = 1,\ldots,s$$

$$x_{ik}^t - \sum_{j=1}^{n} \lambda_j x_{ij}^t \geq 0 \qquad i = 1,\ldots,m$$

$$\lambda_j \geq 0 \quad \forall j = 1,\ldots,n$$

$$\left[D_O^t(x^{t+1}, y^{t+1})\right]^{-1} = \text{Max } \phi_k \qquad (7)$$

Subject to

$$\phi_k y_{rk}^{t+1} - \sum_{j=1}^{n} \lambda_j y_{rk}^t \leq 0 \qquad r = 1,\ldots,s$$

$$x_{ik}^{t+1} - \sum_{j=1}^{n} \lambda_j x_{ij}^t \geq 0 \qquad i = 1,\ldots,m$$

$$\lambda_j \geq 0 \quad \forall j = 1,\ldots,n$$

Similarly, the following linear programs need to be solved in order to evaluate the distance functions which constitute M_O^{t+1}:

$$\left[D_O^{t+1}(x^{t+1}y^{t+1})\right]^{-1} = \text{Maximize } \phi_k \qquad (8)$$

Subject to

$$\phi_k y_{rk}^{t+1} - \sum_{j=1}^{n} \lambda_j y_{rj}^{t+1} \le 0 \quad r = 1,\ldots,s$$

$$x_{ik}^{t+1} - \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \ge 0 \quad i = 1,\ldots,m$$

$$\lambda_j \ge 0 \quad \forall j = 1,\ldots,n$$

$$\left[D_O^{t+1}(x^t, y^t)\right]^{-1} = \text{Max } \phi_k \qquad (9)$$

Subject to

$$\phi_k y_{rk}^{t} - \sum_{j=1}^{n} \lambda_j y_{rj}^{t+1} \le 0 \quad r = 1,\ldots,s$$

$$x_{ik}^{t} - \sum_{j=1}^{n} \lambda_j x_{ij}^{t+1} \ge 0 \quad i = 1,\ldots,m$$

$$\lambda_j \ge 0 \quad \forall j = 1,\ldots,n$$

Solution of equations (6) and (8) provides the output-oriented data envelopment analysis (DEA) measures of technical efficiency (under CRS) in periods *t* and *t*+1 respectively. The CRS assumption can be dropped by the inclusion, in each set of equations, of the additional constraint $\sum_{j=1}^{n} \lambda_j$. When VRS are present, however, it has been suggested that estimates of productivity change based on the VRS distance functions are biased. (Grifell-Tatjé & Lovell 1995)[1]. It is generally agreed that the Malmquist productivity index based on CRS distance functions correctly measures productivity change even if the underlying technology exhibits VRS (Coelli *et al* 1998; Casu *et al* 2004). Thus, VRS distance functions will only be estimated for periods *t* and *t*+1 in order to estimate technical efficiency and scale efficiency in each of those periods respectively. The distance functions required to estimate the Malmquist productivity change index will be estimated using CRS assumptions.

[1] This bias is systematic. Productivity change is overstated when there is input growth in the presence of decreasing returns to scale, and understated when there is input growth in the presence of increasing returns to scale. The converse is the case in the context of input contraction.

There are two approaches to calculating the Malmquist productivity change index (Grifell-Tatjé & Lovell 1996). First, it can be calculated for each pair of adjacent years from t, t+1to T-1, T (for t=1,…,T). Alternatively, it can be calculated for each year relative to the same fixed base, i.e. for t relative to s, t+1 relative to s, and so on to T relative to s. The value of the Malmquist productivity change index can vary according to method used, particularly if production frontiers in adjacent periods overlap (Grifell-Tatjé & Lovell 1996). Both methods will therefore be used and compared in the ensuing analysis.

3. Data and Results

3.1 Inputs and Outputs

The Higher Education Statistics Agency (HESA) produces detailed annual statistics for all HEIs in England, covering resources, students and staff, and the first destinations of graduates. Four measures of inputs are constructed from the data. Expenditure on capital (CAPITAL) measures the capital input, the number of full-time equivalent (FTE) academic staff (STAFF) measures labour input, and the number of FTE postgraduate students (PG) and the number of FTE first degree and other undergraduates (UG) measure the raw material input. As in previous studies (Ahn & Seiford 1993; Abbot & Doucouliagos 2003; Flegg *et al* 2004; Worthington & Lee 2005), no attempt is made to take into account inter-institution differences in quality of inputs (quality may vary substantially by institution in the context of the raw material and labour inputs), mainly because of a lack of published data in this area, and this should be borne in mind when interpreting the results.

Three measures of output are constructed. The number of first and other undergraduate degree graduates (UGOUTPUT) and the number of higher and other postgraduate degree graduates (PGOUTPUT) measure the teaching output of HEIs. As with student input, these measures are not adjusted at all for quality, and this is consistent with the approaches taken in previous studies (Ahn & Seiford 1993; Athanassopoulos & Shale 1997; Madden *et al* 1997; Worthington & Lee 2005). While it would be possible to make some adjustment for quality of undergraduate output (such as using only the number of first class graduates, as in Flegg *et al* 2004), this has not been done for two reasons. First, counting only the number of first class graduates assumes that the remaining graduates are of no value; and second, it seems appropriate to make no attempt to adjust for quality on the output side given that no such adjustment has been made on the input side.

The third output, research, is measured by income received for research purposes (RESEARCH). The use of income to measure research output is now firmly rooted in the literature because of its ease of availability and because it measures, to some extent, the quality of research (Ahn *et al* 1989; Ahn & Seiford 1993; Avkiran 2001; Abbott & Doucouliagos 2003; Flegg *et al* 2004; Worthington & Lee 2005). No attempt is made to construct a separate measure of the social outputs of HEIs.

Detailed definitions of the input and output measures can be found in table 1. It was possible to collect the data required and to construct these variables for seven years (1996/97 to 2002/03, which, in order to avoid confusion when considering productivity changes over time, will be referred to as 1996 to 2002)[2], and for a total of 113 HEIs[3]. Descriptive statistics are presented for all measures in table 2. While there is a general upward trend in mean input and output levels over the period under consideration, staff input and research output measures show a slight fall in 1997, while undergraduate inputs fall in 2000. The final two years, however, have seen a particularly sharp increase in input measures. With regard to differences between subgroups, it is clear from table 2 that the post-92 group of HEIs have the largest average number of undergraduates, while pre-92 HEIs have the largest average number of postgraduates and research output. The SCOPs and SCOP-type institutions are the smallest in size, on the basis of mean score on all of the input and output measures.

Tables 1 & 2

3.2 Technical and Scale Efficiency

There are clearly considerable differences between the different types of HEIs in terms of their input and output structure. It has previously been found that the efficiency with which these inputs are converted into outputs does not differ significantly across the subgroups of HEIs (Johnes 2006). It is therefore appropriate to apply DEA across the entire sample of HEIs. The resulting efficiency scores across the sector and over time are summarised in table 3[4]. Average technical efficiency over the period for the sector as a whole is 85%; this has varied from a low of 80% in 1997

[2] Variables measured in monetary terms are standardised to January 1996 values.
[3] Data for HEIs which merged during the study period are amalgamated for years prior to the merger; HEIs which entered the sector during the study period are not included. HEIs for which a full set of data were not available, or which produced zero of any output (thereby being outliers and affecting the DEA results) have been removed. Open University has also been removed because of its large size and its unique nature of teaching provision.
[4] Full results are available from the author on request.

to a high of 89% in 1998. Scale and pure technical efficiency display a similar pattern (with a drop in 1997) but at slightly higher overall levels of 92% and 93% respectively. These average figures are a little lower than the ones reported by Flegg *et al* (2004) who find that technical efficiency varies from 85% to 92%, while scale and pure technical efficiency have ranges of 93% to 97% and 95% to 99% respectively. The difference in results is entirely understandable as this study has a much wider coverage of HEIs.

Table 3

The figures for the overall sector conceal some large differences between the subgroups. Generally, while pre-1992 HEIs experience a similar pattern of efficiencies to the sector as a whole, post-92 HEIs have lower levels, while the SCOP and SCOP-type colleges have much higher efficiency levels. All subgroups, however, experience a fall in efficiency (of all types) in 1997. A further interesting observation is that, while SCOPs have a higher overall average score for all types of efficiency, scale efficiency is particularly high in this subgroup at 96%. This compares with 91% for pre-92 HEIs and 88% for post-92 institutions.

3.3 Productivity Changes

Changes in productivity over the period of study are summarised in table 4. The Malmquist productivity change experienced by the sector as a whole has averaged 1.5% per year, with a low of 0% and a high of 3.5%. From an examination of the components of the Malmquist productivity index, it emerges that technology change has averaged 2.3% per annum, and that the Malmquist index has been brought down by a negative technical efficiency change of -0.8% on average per year. Thus productivity increases are largely a consequence of technology change rather that technical efficiency change, and this is consistent with previous studies, although the value of the Malmquist productivity change index is much lower here than in similar studies (Flegg *et al* 2004; Worthington & Lee 2005).

Table 4

The figures on productivity change for the whole sector conceal differences between the subgroups. Pre-92 HEIs have experienced a Malmquist productivity change of only 0.1% because the increase in technology efficiency (0.5%) is almost outweighed by the decrease in technical efficiency (-0.4%). Post-92 institutions and SCOPs have seen much greater Malmquist productivity changes at around 2.5%. In both case this has been caused by high technology change (3.8% and 3.4% respectively) combined with negative technical efficiency change.

It is possible to break down the technical efficiency change component into two further components, namely pure technical efficiency change and scale efficiency change. For the sector as a whole, technical efficiency change is evenly split between the components (annual averages of -0.4% pure technical efficiency change and -0.4% scale efficiency change), but this varies by type of HEI. For post-92 institutions, their negative technical efficiency change is more a consequence of pure technical efficiency change (-0.8%) than scale efficiency change (-0.4%); whereas for pre-92 HEIs and SCOP colleges experience scale efficiency is the larger component, in absolute terms (see table 4).

Finally, rather than look at an annual average over the period, each year can be compared with the base year (1996 in this case) to see cumulative productivity change over time. The findings confirm the results of the previous analysis namely that productivity change over the entire period is caused by strong positive technology change combined with negative technical efficiency change. Specifically, between 1996 and 2002 (see table 6), the increase, across the entire sector, in Malmquist productivity is 9.4% which comprises -4.7% technical efficiency change and 14.8% technological change. But there are vast differences between the subgroups. Pre-92 HEIs have seen only a 3% increase in technology change and a -2.2% change in technical efficiency. In contrast, post-92 HEIs and SCOP colleges have experienced huge increases in technology change (26.6% and 22.5% respectively) combined with technical efficiency changes of -7.6% and -5.4% respectively. Thus post-92 institutions and SCOP colleges have experienced an overall productivity change of 17% and 16% (respectively) compared with only 0.7% for the pre-92 sector.

Technology change is clearly important in driving productivity change in English higher education over the period 1996-2003, but we are left with the question of why this is this case? The most obvious source of change in production activity in universities is the increased use of information technology and e-learning. The Department for Education and Skills has highlighted the improvements introduced by increased use of technology: information is more accessible to users, causing changes in teaching, and increasing the efficiency of administrators (DFES 2005). Improved communications have also increased the ease with which collaborative research can be undertaken. Thus all aspects of a university's activities are affected by increasing use and application of technology.

What reasons can then be offered for the observed negative changes in technical efficiency over the period? These are more easily observed from a plot of the year by year cumulative changes (see figure 1), from which it is clear that influences in the period around 1996 to 1997 had severe effects on productivity: there was a relatively large increase in technology change but this was accompanied by a severe drop in technical efficiency. This is observed, moreover, in all sub-sectors of the higher education sector. Factors pushing out the production frontier (such as he introduction of e-learning into universities) may have a detrimental effect on, or may be accompanied by a fall in, technical efficiency. For example increased use of e-technology in teaching may allow class sizes to increase, or might have been adopted in response to class sizes. Yet an increasing ratio of students to staff may have an adverse effect on technical efficiency (for example, retention rates may be affected). The index of change in the ratio of students to staff is also displayed in figure 1 and reveals that decreases in the technical efficiency change index occur simultaneously with increases in the student staff ratio change index. This pattern is marked for the sector as a whole, and for the pre- and post-1992 subgroups of HEIs. However, it is not the case for the SCOP colleges where changes in the ratio of students to staff have been less than in the other two subgroups. Thus the changing student staff ratio can only offer a partial explanation for the observed increase in the technology change index (and decrease in the technical efficiency change index), and further research is necessary to examine this issue.

4. Conclusion

This study has used DEA and distance functions to derive Malmquist productivity indexes for the English Higher education sector over the period 1996/97 to 2002/03. The Malmquist productivity indexes have been decomposed into technical efficiency change indexes (which reveal whether HEIs are getting closer to the production frontier) and technology change indexes (which reveal whether the production frontier is moving outwards). It differs from an earlier study by Flegg *et al* (2004) in that it includes most of the HEIs of the expanded higher education sector in existence in England today (113 HEIs), and covers a smaller and more recent time period.

Over the period of the study, Malmquist productivity has risen by an annual average of 1.5%, and this has been caused by a combination of positive annual average technology change (2.3%) and negative annual average technical efficiency change (around -0.8%). While technology change has been found to be an important component of Malmquist productivity change in higher education (Flegg *et al* 2004; Worthington & Lee 2005), the finding of negative technical efficiency change is new. This is a worrying finding since it suggests that while HEIs have attempted to respond to the Government's desire for expansion in the higher education sector by changing their technology, they are doing so at the price of technical efficiency.

It is perhaps of more concern that the factors influencing the sector and its productivity have affected the various subgroups of the English higher education sector differentially. Pre-1992 HEIs have experienced much lower Malmquist productivity change than the other two sectors (at an annual average of 0.1%). SCOP colleges and post-1992 HEIs have both had higher Malmquist productivity changes (each with an annual average of 2.5%). All three subgroups have experienced negative technical efficiency change, but this has been largest in the post-1992 sector and smallest in the pre-1992 HEIs. For post-1992 HEIs, the negative technical efficiency change is a consequence of poor pure technical efficiency change rather than scale efficiency change. The converse is the case for pre-1992 HEIs and the SCOP colleges.

A further examination of the cumulative change in productivity over time reveals that the technology change index moves in a similar pattern to the index of change in the student staff ratio for the sector as a whole. This is also the case for pre- and post-1992 HEIs, but is not so for the SCOP colleges. So, while changes in teaching practices to accommodate increasing student numbers in the pre- and post-1992 HEIs may partially account for the increase in technology change (i.e. the pushing out of the production frontier), this is clearly not the case for all institutions. Moreover, the decrease in technical efficiency occurring simultaneously with the increasing technology is a worrying observation, and suggests that institutions need time to adapt to the changing technology.

Figure 1: Technical efficiency change, technology change, Malmquist productivity change and student staff ratio change indexes

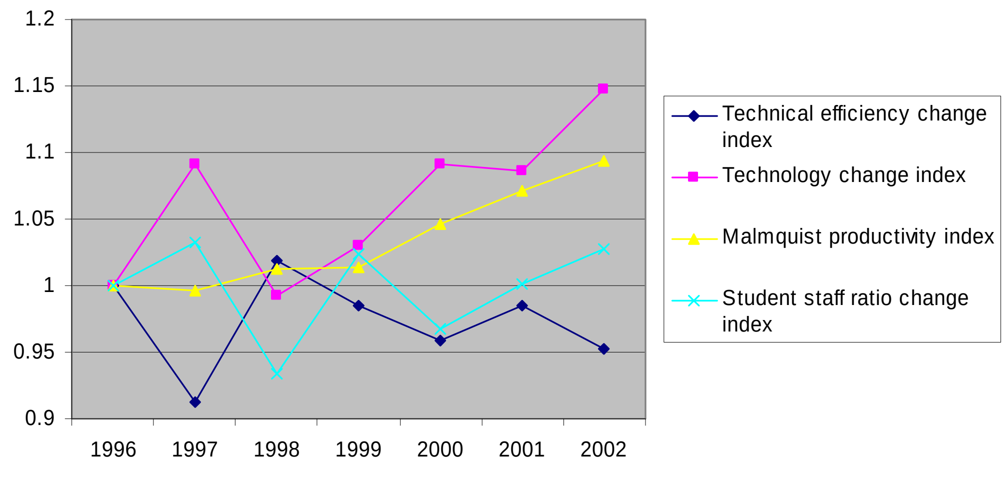

Table 1: Definitions of inputs and outputs

Variable name	Definition
Inputs:	
STAFF	The number of full-time academic staff plus 0.5 times the number of part-time academic staff
CAPITAL[1]	Depreciation costs and interest payable (in thousands)
UG	The total number of FTE first degree and other undergraduates
PG	The total number of FTE postgraduate students
Outputs	
UGOUTPUT	The number of first degree and other undergraduate degrees awarded
PGOUTPUT	The number of higher degrees plus total other postgraduate qualifications awarded (including doctorate, other higher degrees, PGCEs and other postgraduate qualifications)
RESEARCH[1]	Income received in funding council grants plus income received in research grants and contracts (in thousands)

Note:
1. These variables are deflated to January 1996 values using the higher education pay and prices index (http://www.universitiesuk.ac.uk/statistics/heppi/default.asp).

Table 2: Descriptive statistics for the inputs and outputs

	ALL	n=791	Pre-92	n=343	Post-92	n=238	SCOPs	n=210
Variable	Mean	sd	Mean	sd	Mean	sd	Mean	sd
STAFF	883.19	877.36	1313.37	1114.77	861.05	277.45	205.64	152.44
CAPITAL	5993.81	5175.00	7824.26	6317.43	7243.34	2535.14	1587.95	1360.80
UG	8262.92	5408.31	7638.27	4754.29	13400.61	3349.67	3460.48	2641.63
PG	1762.28	1334.32	2415.71	1455.81	1921.05	809.38	515.08	475.87
UGOUTPUT	2374.35	1605.18	2087.26	1341.04	3953.66	1078.88	1053.37	864.73
PGOUTPUT	904.24	738.15	1245.69	799.01	964.14	552.72	278.64	282.44
RESEARCH	53260.71	55564.19	81407.41	71058.80	48765.83	16538.55	12381.99	9746.92

Table 3: Technical efficiency over time

Technical Efficiency (CRS efficiency)

	All HEIs				Pre-92 HEIs				Post-92 HEIs				SCOP & SCOP-type colleges			
	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geo Mean	Min	SD	Arith Mean	Geo Mean
1996	0.62	0.105	0.88	0.87	0.64	0.099	0.86	0.86	0.64	0.100	0.85	0.84	0.62	0.100	0.94	0.94
1997	0.56	0.125	0.81	0.80	0.61	0.135	0.80	0.79	0.60	0.089	0.77	0.77	0.56	0.133	0.85	0.84
1998	0.69	0.090	0.89	0.89	0.71	0.089	0.88	0.87	0.69	0.085	0.87	0.86	0.72	0.075	0.95	0.95
1999	0.52	0.106	0.87	0.86	0.69	0.091	0.88	0.87	0.65	0.086	0.80	0.80	0.52	0.117	0.91	0.91
2000	0.49	0.116	0.84	0.84	0.58	0.116	0.83	0.82	0.64	0.104	0.83	0.83	0.49	0.126	0.88	0.87
2001	0.61	0.107	0.87	0.86	0.65	0.108	0.87	0.86	0.61	0.093	0.82	0.82	0.69	0.105	0.91	0.90
2002	0.59	0.125	0.84	0.83	0.59	0.124	0.85	0.84	0.61	0.115	0.79	0.78	0.64	0.117	0.89	0.89
All years	0.49	0.114	0.86	0.85	0.58	0.112	0.85	0.84	0.60	0.100	0.82	0.81	0.49	0.115	0.91	0.90

Table 3 (continued):

Pure Technical Efficiency (VRS efficiency)

	All HEIs				Pre-92 HEIs				Post-92 HEIs				SCOP & SCOP-type colleges			
	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geo Mean	Min	SD	Arith Mean	Geo Mean
1996	0.64	0.079	0.94	0.94	0.77	0.074	0.94	0.94	0.72	0.080	0.93	0.93	0.64	0.087	0.96	0.96
1997	0.70	0.089	0.92	0.92	0.75	0.085	0.92	0.92	0.70	0.083	0.93	0.93	0.73	0.104	0.91	0.91
1998	0.72	0.066	0.95	0.95	0.79	0.067	0.94	0.94	0.82	0.057	0.96	0.96	0.72	0.072	0.96	0.96
1999	0.53	0.093	0.92	0.92	0.75	0.080	0.93	0.93	0.71	0.088	0.92	0.91	0.53	0.115	0.92	0.91
2000	0.67	0.093	0.92	0.91	0.68	0.090	0.91	0.91	0.67	0.104	0.90	0.89	0.76	0.082	0.94	0.93
2001	0.72	0.072	0.94	0.94	0.77	0.064	0.94	0.94	0.72	0.075	0.94	0.94	0.76	0.082	0.94	0.94
2002	0.70	0.091	0.92	0.92	0.75	0.080	0.94	0.93	0.70	0.099	0.89	0.88	0.74	0.091	0.93	0.93
All years	0.53	0.084	0.93	0.93	0.68	0.078	0.93	0.93	0.67	0.087	0.92	0.92	0.53	0.092	0.94	0.93

Scale Efficiency

	All HEIs				Pre-92 HEIs				Post-92 HEIs				SCOP & SCOP-type colleges			
	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geom Mean	Min	SD	Arith Mean	Geo Mean	Min	SD	Arith Mean	Geo Mean
1996	0.76	0.067	0.93	0.93	0.76	0.071	0.92	0.91	0.79	0.061	0.91	0.91	0.88	0.032	0.99	0.99
1997	0.66	0.093	0.87	0.87	0.66	0.097	0.86	0.86	0.71	0.062	0.83	0.83	0.71	0.085	0.93	0.93
1998	0.78	0.064	0.94	0.94	0.78	0.060	0.93	0.93	0.78	0.066	0.90	0.90	0.94	0.016	0.99	0.99
1999	0.78	0.064	0.94	0.93	0.79	0.054	0.94	0.94	0.78	0.056	0.88	0.88	0.93	0.016	0.99	0.99
2000	0.49	0.084	0.92	0.92	0.58	0.079	0.91	0.91	0.82	0.059	0.93	0.93	0.49	0.111	0.94	0.93
2001	0.75	0.072	0.92	0.92	0.77	0.072	0.92	0.92	0.75	0.065	0.87	0.87	0.83	0.050	0.96	0.96
2002	0.71	0.072	0.91	0.91	0.71	0.078	0.90	0.90	0.78	0.059	0.89	0.88	0.84	0.052	0.96	0.96
All years	0.49	0.077	0.92	0.92	0.58	0.077	0.91	0.91	0.71	0.067	0.89	0.88	0.49	0.065	0.97	0.96

Table 4: Geometric mean changes in technical efficiency, technology, Malmquist productivity, pure efficiency and scale efficiency

	Technical efficiency change index	Technology change index	Malmquist productivity change index	Pure efficiency change index	Scale efficiency change index
ALL HEIs					
1996/97	**0.913**	**1.091**	**0.996**	**0.978**	**0.930**
1997/98	**1.117**	**0.912**	**1.018**	**1.035**	**1.079**
1998/99	**0.966**	**1.039**	**1.003**	**0.970**	**0.998**
1999/00	**0.973**	**1.063**	**1.035**	**0.990**	**0.984**
2000/01	**1.028**	**0.987**	**1.014**	**1.031**	**0.997**
2001/02	**0.968**	**1.055**	**1.021**	**0.976**	**0.992**
All years	**0.992**	**1.023**	**1.015**	**0.996**	**0.996**
Pre-92 HEIs					
1996/97	0.921	1.054	0.972	0.981	0.939
1997/98	1.106	0.919	1.016	1.022	1.083
1998/99	1.002	1.006	1.008	0.990	1.012
1999/00	0.941	1.102	1.037	0.976	0.964
2000/01	1.051	0.937	0.984	1.037	1.013
2001/02	0.968	1.027	0.994	0.991	0.976
All years	0.996	1.005	1.001	0.999	0.997
Post-92 HEIs					
1996/97	0.911	1.122	1.022	0.999	0.911
1997/98	1.127	0.898	1.012	1.036	1.087
1998/99	0.925	1.072	0.991	0.948	0.975
1999/00	1.032	1.028	1.061	0.980	1.053
2000/01	0.989	1.035	1.023	1.048	0.944
2001/02	0.955	1.091	1.043	0.942	1.014
All years	0.987	1.038	1.025	0.991	0.996
SCOP and SCOP type colleges					
1996/97	0.901	1.120	1.008	0.951	0.936
1997/98	1.123	0.917	1.029	1.054	1.065
1998/99	0.956	1.057	1.011	0.955	1.001
1999/00	0.962	1.043	1.003	1.022	0.942
2000/01	1.035	1.019	1.056	1.003	1.032
2001/02	0.982	1.060	1.040	0.989	0.993
All years	0.991	1.034	1.024	0.995	0.994

Table 5: Geometric means of changes in technical efficiency, technology, Malmquist productivity, pure efficiency and scale efficiency relative to the base year (1996)

	Technical efficiency change	Technology change	Malmquist productivity change	Pure efficiency change	Scale efficiency change
ALL HEIs					
1996/97	0.913	1.091	0.996	0.978	0.933
1996/98	1.019	0.993	1.012	1.012	1.007
1996/99	0.985	1.030	1.014	0.980	1.005
1996/00	0.959	1.091	1.046	0.970	0.989
1996/01	0.985	1.086	1.071	1.000	0.985
1996/02	0.953	1.148	1.094	0.975	0.977
All years	0.968	1.072	1.038	0.986	0.982
Pre-92 HEIs					
1996/97	0.921	1.054	0.972	0.981	0.939
1996/98	1.020	0.970	0.988	1.002	1.017
1996/99	1.021	0.980	1.000	0.992	1.029
1996/00	0.962	1.065	1.024	0.969	0.993
1996/01	1.010	0.997	1.001	1.005	1.005
1996/02	0.978	1.030	1.007	0.996	0.981
All years	0.985	1.015	1.000	0.991	0.994
Post-92 HEIs					
1996/97	0.911	1.122	1.022	0.999	0.911
1996/98	1.026	1.006	1.033	1.035	0.991
1996/99	0.949	1.075	1.019	0.982	0.966
1996/00	0.980	1.110	1.087	0.963	1.017
1996/01	0.968	1.157	1.121	1.008	0.961
1996/02	0.924	1.266	1.170	0.950	0.974
All years	0.959	1.120	1.074	0.989	0.970
SCOP and SCOP-type colleges					
1996/97	0.901	1.120	1.008	0.951	0.947
1996/98	1.010	1.017	1.028	1.002	1.008
1996/99	0.967	1.065	1.029	0.957	1.010
1996/00	0.931	1.114	1.036	0.979	0.951
1996/01	0.963	1.162	1.120	0.982	0.981
1996/02	0.946	1.225	1.158	0.971	0.974
All years	0.953	1.115	1.062	0.973	0.978

References

Abbott, M & Doucouliagos, C (2003) ‘The efficiency of Australian universities: a data envelopment analysis’ *Economics of Education Review*, 22(1) pp89-97

Ahn, T, Arnold, V, Charnes, A & Cooper, W W (1989) 'DEA and ratio efficiency analyses for public institutions of higher learning in Texas' *Research in Governmental and Nonprofit Accounting*, 5 pp165-185

Ahn, T & Seiford, L M (1993) ‘Sensitivity of data envelopment analysis to models and variable sets in a hypothesis test setting: the efficiency of university operations’ in Y Ijiri (ed*) Creative and Innovative Approaches to the Science of Management* Quorum Books, Westport, Connecticut, pp191-208

Athanassopoulos, A D & Shale, E (1997) ‘Assessing the comparative efficiency of higher education institutions in the UK by means of data envelopment analysis’ *Education Economics*, 5 (2) pp117-134

Avkiran, N K (2001) ‘Investigating technical and scale efficiencies of Australian universities through data envelopment analysis’ *Socio-Economic Planning Sciences*, 35(1) pp57-80

Casu, B, Girardone, C & Molyneux, P (2004) ‘Productivity change in European banking: a comparison of parametric and non-parametric approaches’ Essex Finance Centre Discussion Paper 04-01

Caves, D W, Christensen, L R & Diewert, W E (1982) ‘The econometric theory of index numbers and the measurement of input, output and productivity’ *Econometrica*, 50 pp1393-1414

Coelli, T and Perelman, S (1999) ‘A comparison of parametric and non-parametric distance functions: with application to European railways’, *European Journal of Operational Research*, **117**, 326-339.

Coelli, T, Rao, D S P & Battese, G E (1998) *An Introduction to Efficiency and Productivity Analysis*, Kluwer Academic, Norwell, MA

DFES (2005) *Harnessing Technology: Transforming Learning and Children’s Services*

Färe, R (1988) *Fundamentals of Production Theory*, Berlin: Springer-Verlag.

Färe, R, Grosskopf, S, Lindgren, B and Roos, P (1992) ‘Productivity changes in Swedish pharmacies 1980-1989: a non-parametric Malmquist approach’, *Journal of productivity Analysis*, **3** (1/2), 85-101.

Färe, R, Grosskopf, S & Norris, M (1997) ‘Productivity growth, technical progress and efficiency change in industrialized countries: reply’ *American Economic Review* 87(5) pp1040-1043

Färe, R, Grosskopf, S & Roos, P (1998) ‘Malmquist productivity indexes: a survey of theory and practice’ in Färe, R, Grosskopf, S & Russell, R R (eds) *Index Numbers: Essays in Honour of Sten Malmquist* Kluwer Academic Publishers, Norwell, MA

Färe, R, Grosskopf, S, Norris, M & Zhang, Z (1994) ‘Productivity growth, technical progress and efficiency change in industrialized countries’ *American Economic Review* 84(1) pp66-83

Färe, R, Grosskopf, S & Weber, W L (1989) 'Measuring school district performance' *Public Finance Quarterly*, 17(4) pp409-428

Farrell, M (1957) ‘The measurement of productive efficiency’ *Journal of the Royal Statistical Society Series A* 120 pp253-281

Flegg, A T, Allen, D O, Field, K & Thurlow, T W (2004) ‘Measuring the efficiency of British universities: a multi-period data envelopment analysis’ *Education Economics* 12(3) pp231-249

Grifell-Tatjé, E & Lovell, C A K (1995) ‘A note on the Malmquist productivity index’ *Economics Letters* pp169-175

Grifell-Tatjé, E & Lovell, C A K (1996) ‘Deregulation and productivity decline: the case of Spansih savings banks, *European Economic Review* 40 pp1281-1303

Johnes, J (2006) ‘Data envelopment analysis and its application to the measurement of efficiency in higher education’ *Economics of Education Review*, forthcoming

Madden, G, Savage, S & Kemp, S (1997) ‘Measuring public sector efficiency: a study of economics departments at Australian Universities’ *Education Economics*, pp153-167

O’Donnell, C & Coelli, T (2003) ‘A Bayesian approach to imposing curvature on distance functions’ Centre for Efficiency and Productivity Analysis Working Paper 03/2003, School of Economics, University of Queensland

Ray, S C & Desli, E (1997) ‘Productivity growth, technical progress and efficiency change in industrialized countries: comment’ *American Economic Review* 87(5) pp1033-1039

Rodriguez-Alvarez, A, Fernandez-Blanco, V & Lovell, C A K (2004) ‘Allocative inefficiency and its costs: the case of Spanish public hospitals’ *International Journal of Production Economics* 92 pp99-111

Shepherd, R W (1970) Theory of Cost and Production Frontiers Princeton University Press, New Jersey

Uri, N D (2003a) ‘The adoption of incentive regulation and its effect on technical efficiency in telecommunications in the United States’ *International Journal of Production Economics* 86 pp21-34

Uri, N D (2003b) ‘Technical efficiency in telecommunication in the United States and the impact of incentive regulation’ *Applied Mathematical Modelling* 27 pp53-67

Worthington, A C & Lee, B L (2005) ‘Efficiency, technology and productivity change in Australian universities 1998-2003’ Working Paper 05/01, University of Wollongong, School of Accounting and finance