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Best-practice benchmarking in UK higher education: New nonparametric approaches using financial ratios and profit efficiency methodologies

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Abstract

The neglected issue of using profit efficiency for the best-practice benchmarking of UK universities is explored to see whether this supports the policy stance of encouraging more specialised university production. The paper also investigates whether nonparametric modelling with financial ratios, in contrast to nonparametric modelling based on the prices and quantities of each university's inputs and outputs, can yield ready insights into this profit efficiency issue. The empirical results, using two new approaches, confirm that more specialised university production yields relatively higher performance on average than less specialised production. The results also highlight certain advantages of financial ratios modelling.

Keywords: Profit efficiency; Financial ratios; DEA-based best-practice benchmarking; Universities; Specialisation.

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INTRODUCTION

The goals of best-practice performance and increased specialisation in UK higher education

The last two decades of policy making, with respect to the largely publicly funded UK universities, have been characterised by the long-standing objective that universities should strive for best-practice performance. Thus, as far back as the mid-1980s, we find major policy directives (see the UK Government Green Paper, Cm 9524 (1985) and the UK Government White Paper, Cm 114 (1987)) introducing selective research funding and the use of performance indicators in UK higher education as spurs to attaining both higher quality and greater efficiency in this sector.

Also, to help to ensure that the policy goal of increased efficiency is achieved, the last two decades have witnessed substantial enforced expansion in university outputs without a commensurate expansion of inputs. Moreover, to try to ensure that this relentless policy drive towards greater efficiency did not result in lower quality outputs, regulatory teaching quality and research quality assessment systems were also implemented. The latter research assessment system has been particularly important to universities as the public funding of research has become increasingly weighted, over time, in favour of higher quality research. (For more detail on UK higher education policy and the regulatory quality assessment systems, see Glass et al (2006a).)

The inevitable outcome of this long-standing policy stance, and its supporting mandates, is that each UK university has been increasingly forced to carefully consider where its relative efficiency strengths or comparative advantages are located. Thus, while researchers have long highlighted this aspect of UK higher education policy (see the Johnes (1990), Glass et al (1995) and Johnes (1996a, 1996b, 1997) studies), the explicit policy statements encouraging universities to concentrate on their comparative research and teaching strengths only emerged in 2003 (see the UK Government White Paper, Cm 5735 (2003) and the Higher Education Funding Council for England (2003) statements). An important feature of these recent policy statements is that UK universities are now explicitly encouraged to become more specialised. With the latter increased specialisation to be based on the principle of comparative advantage, the policy view is that UK higher education can become more efficient without compromising output quality.

Given the long-standing policy emphasis on securing comparative advantage gains in university production, it is to be expected that the UK higher education sector should *already* be manifesting evidence of such relative efficiency strengths. To see what form such evidence might take, let us first characterise the UK higher education sector as consisting of three divisions, as given by (i) universities with very evident research strength and a strong research-emphasis, complemented by a strong postgraduate research student provision, (ii) universities with very little research capability and a strong teaching-emphasis that is focused primarily on undergraduate student provision, and (iii) universities with an 'in-between' research and teaching emphasis.

With such a three-fold division of UK higher education, the principle of comparative advantage would suggest that the more-specialised universities in divisions (i) and (ii) should be relatively more efficient, on average, than the less-specialised universities in division (iii). Indeed, over time, the relentless drive for increased efficiency in UK higher education could well result in the sector being eventually characterised by a two-fold division as a result of universities currently operating in division (iii) being gradually forced to opt for more-specialised production in either division (i) or division (ii). Initially, each university in division (iii) may try to resist such absorption into other divisions by an internal reallocation of its resources towards its comparative research and teaching strengths. Eventually, however, if the pressure for efficiency gains is sustained, increased specialisation towards division (i) or division (ii) seems inevitable.

The current empirical evidence supports the policy goal of increased specialisation

The Johnes (1997) study of the structure of UK higher education, based on mid-1990s data, contends that there is *already* ample evidence that universities in the more-specialised divisions (i) and (ii) are relatively more efficient that those in the less-specialised division (iii). Consequently, using an econometric cost function analysis together with a heuristic tabu-search methodology, the Johnes (1997) findings suggest that substantial cost savings would be secured if UK higher education moved towards a more-specialised two-fold division consisting of universities operating in either division (i) or division (ii).

Initially the Johnes (1997) findings were challenged as 'not proven' by Appa et al (1998). However, subsequent research (see the Glass et al (2006a) study), using a data envelopment analysis (DEA) methodology, has provided strong support for Johnes' findings across a wide variety of models employing similar mid-1990's data. Also, although it is not a major aspect of the present paper, the empirics below record stochastic cost frontier evidence, for the same mid-1990's period, which supports Johnes' findings. Thus the currently-available empirical evidence, using both parametric and nonparametric methodologies, supports the policy-makers' view that increased specialisation in UK higher education yields efficiency gains and, therefore, should be overtly encouraged. (For a recent survey of empirical work on UK higher education, see the Glass et al (2006a) study.)

The need to investigate the relative profit efficiencies of UK universities

While the above-noted research has provided important insights into relative efficiencies in UK higher education, it has however important shortcomings. For example, the parametric cost function analyses focus only on the relative cost efficiencies of UK universities. Similarly, while the nonparametric DEA analyses do link with cost-minimisation, revenue-maximisation, and profit-maximisation goals (via the input-oriented, output-oriented, and non-oriented approaches, respectively), they mainly use quantity data, which means they do not explicitly incorporate prices, with the result that relative cost, revenue, and profit efficiencies are not fully addressed.

These shortcomings immediately give rise to an important question: would a focus on the relative *profit* efficiencies of UK universities reveal the same pattern of comparative strengths? Just as the above research suggests that the more-specialised divisions (i) and (ii) are more *cost* efficient, on average, than the less-specialised division (iii), would a similar pattern pertain for the *profit* efficiencies of UK universities?

This is a particularly relevant question for UK universities. Given the relentless pressure, since the mid-1980s, towards securing efficiency gains, it has been long recognised that each UK university must pay rigorous attention to its profit efficiency. This means that each university must constantly evaluate how the levels and mixes of its research and teaching outputs, over its academic subjects, affects its research and teaching revenues relative to its research and teaching costs. To do otherwise, would be to jeopardise its viability, given the intensely competitive environment in which UK universities operate.

Can the accounting tool of financial ratios help to provide ready answers?

In attempting to answer the important question about the relative profit efficiencies of UK universities, a further interesting question emerges: can a ready answer be found by using the accounting tool of financial ratios to evaluate the relative performance of UK universities? If we focus on finding a *ready* answer, the answer to this further question seems to depend on whether we are referring to the parametric statistics-based, or to the nonparametric DEA-based, analysis of financial ratios.

For example, Fernandez-Castro and Smith (1994) have examined whether the use of statistical-based techniques can be employed with financial ratios to yield ready measures of best-practice-benchmarked performance for organisations. In their extensive survey of such methods, the authors highlight how the many difficulties in such an approach make the obtaining of ready, reliable measures very problematic. Among these difficulties, they list the lack of theory underlying the statistical formulations, the inapplicability of the assumption of multivariate normality, the appropriate specification of functional forms and error distributions, the choice of comparison group, the choice of financial ratios, the weights to be used in combining ratios, and the choice of appropriate benchmarks.

Given these difficulties Fernandez-Castro and Smith (1994) propose that a nonparametric, DEA-based analysis of financial ratios could be used to obtain a ready, complementary insight into the issue of best-practice-benchmarked performance. In making this proposal, they of course recognise that both the statistical-based and the DEA-based approaches have advantages and disadvantages. As summarised by Lovell (1993), the former is stochastic and attempts to distinguish the effects of statistical noise from the effects of inefficiency, while the latter is nonstochastic and lumps noise and inefficiency together in its measure of inefficiency. Also the former is parametric and confounds the effects of misspecification errors with its measure of inefficiency, while the latter is nonparametric and less prone to these types of specification error. Moreover, while more recent research is attempting to address the disadvantages associated with each approach (see the Lovell (2001) survey), the two approaches survive to provide useful complementary insights into the issue of assessing the relative performance of organisations.

New methodologies for evaluating the relative profit efficiencies of UK universities

In this paper, we utilise two recently-developed, nonparametric, DEA-based methodologies to provide empirical investigations of the relative profit efficiencies of UK universities. These investigations deliberately relate to the mid-1990s so as to complement the Johnes (1997) and other findings for this period. (It should be noted that decisive findings for this period is vital, for the policy-makers' and universities' views of relative university performance in the mid-1990s were pivotal in formalising the subsequent policy stance of explicitly encouraging increased specialisation.)

One methodology investigates relative profit efficiency in terms of a set of financial ratios which gives particular emphasis to the profitability of universities. The latter emphasis, unfortunately, means that the raw ratios data is characterised by a substantial number of negative values. Consequently, to cope with the major problem of adequately handling this substantial amount of negative data in DEA modelling, the analysis employs the recently-developed directional distance function approach of Portela et al (2004). This important advance in DEA modelling has substantial advantages over earlier approaches to the problem of negative data, as will be explained in the methodology section below.

The second methodology uses the recently-developed, DEA-based profit efficiency analysis of Chambers et al (1998), which models organisations in terms of the prices and quantities of their outputs and inputs. This additional methodology is employed to explore whether it yields similar findings to that of the nonparametric ratios-based analysis.

(We had hoped to also explore the profit efficiency findings yielded by a parametric econometrics-based profit function analysis. Unfortunately, despite trying a wide range of specifications, the empirical results could not be regarded as reliable due to the substantial breaking of the regularity conditions necessary for meaningful profit functions. This problem persisted even when we used the alternative profit function specification (which is suited to situations where output quality differences influence revenues) with its less demanding regularity conditions (see Khumbakar and Lovell (2000), chapter 5). Due to this problem, the paper focuses on the two nonparametric approaches noted above. However, the results for a parametric stochastic cost frontier approach (which satisfied the necessary regularity conditions) are recorded below, so as to confirm that the paper's data yields a similar pattern of cost efficiencies for UK universities as found in the Johnes (1997) study.)

The structure of the paper is as follows. The next section explains the methodologies for the two nonparametric approaches. After this, a section discusses the data used, followed by the empirical results section. This results section uses the Atkinson and Wilson (1995) bootstrap methodology, for constructing confidence intervals in small sample groupings, to ensure statistically meaningful comparisons of mean profit efficiency scores for various university groups. The final section provides brief conclusions.

METHODOLOGY

Best-practice benchmarking via financial-ratios-based nonparametric analysis

In principle, it appears that financial ratios can be readily employed to evaluate the relative performance of a university. In practice, however, this evaluation is not straightforward due to the very large number of different financial ratios that can be derived from the financial statements of universities. The latter reality means that any attempt to assess the extent to which a university is achieving best-practice performance must justify (i) the particular selection of ratios used, (ii) the pre-assigned weights used in combining the selected ratios, and (iii) the notion of best-practice benchmarking, as expressed in financial ratios, being used. Clearly, even if a research consensus about (i) has emerged, justifying (ii) and (iii) are problematic.

Faced with these problems, and aware of the many difficulties associated with statistically-based solutions, Fernandez-Castro and Smith (1994) have proposed the use of a nonparametric mathematical programming methodology for evaluating relative performance via ratios. An important advantage of this methodology is that, given a selected set of financial ratios, it does not require any pre-assigned judgement about the relative importance of these ratios as indicators of performance. Rather, it only requires that these ratios are all valid indicators of performance and, other things being equal, a high value of an indicator (ratio) is better than a low value. This means that no pre-assigned judgement on the relative importance of the performance objectives of (here) universities, as expressed in financial ratios, is therefore being enforced when assessing the relative performance of UK universities. The Fernandez-Castro and Smith (1994) modelling approach thus responds to (ii) above by deliberately taking an essentially agnostic (and hence conservative) stance on the relative importance of performance objectives.

In responding to (iii) above, this modelling approach evaluates the performance of a university by deliberately comparing it only with those universities emulating the pattern of performance demonstrated by the university being assessed. As detailed further below, if this comparison group of peer universities outperforms the university under scrutiny, then they can be viewed as best-practice peers for the latter non-best-practice university to emulate. Hence, by evaluating each university against a different, but appropriate, benchmark the approach avoids the problem of finding an appropriate, universal measure of best-practice performance.

To implement the above benchmarking, this nonparametric approach constructs a best-practice frontier as a piecewise linear envelopment of the data for the set of universities in the empirical model. Note, by employing a data envelopment analysis (DEA) methodology, this empirical construction avoids having to specify a functional form for the best-practice frontier of performance possibilities. The performance of the university under scrutiny is then evaluated relative to the appropriate part of the empirically constructed frontier. This evaluation yields a single (percentage) measure of relative performance for the given university.

More formally, the Fernandez-Castro and Smith (1994) model assesses the relative performance of university j via a linear programme. Thus, given $j=1,\ldots,J$ universities which are appraised on $m=1,\ldots,M$ financial ratios r_{jm}, the efficiency of each university j's performance, as expressed in financial ratios, can be evaluated as the solution to the linear programming problem:

$$\max_{\theta,z} \quad \theta$$

$$\text{subject to} \quad \sum_{j=1}^{J} z_j r_{jm} \;\geq\; \theta r_{jm}, \;\; m = 1,\ldots, M,$$

$$z_j \;\geq\; 0, \quad j = 1,\ldots, J, \quad \sum_{j=1}^{J} z_j \;=1, \qquad (1)$$

where $1 \;\leq\; \theta \;<\; +\infty$ indicates the scale factor by which all j's ratios can be increased. When $\theta = 1$, university j attains efficient (best-practice) performance in the sense that each of its ratios would not be improved if its performance was the same as the best performing universities in the empirical set. Contrariwise, when $\theta > 1$, university j is failing to attain best-practice performance (as all its ratios need to be scaled up by $\theta > 1$ to achieve such best-practice performance, thus indicating that j is only operating at $(1/\theta)(100)$ percent efficiency).

In the latter case, the inefficient performance of j is measured relative to the efficient or best-practice frontier. This frontier is constructed as a piecewise linear envelopment of the data for the set of all universities in the empirical model. As shown in (1) z_j, where $j = 1,\ldots, J$, indicates the weight placed on (the ratios of) each of the universities when constructing the efficient frontier. The non-zero optimal z values thus identify the particular universities which make up the 'best performance' composite university relative to which j is being evaluated. These universities can therefore be interpreted as best-practice peers for the given inefficient j to emulate, with the latter peers being chosen by the model as opposed to being pre-assigned.

It is important to note that the optimal weights used in (1) to obtain a university's efficiency score, and its best-practice peers, generally differ from university to university. Hence, provided that universities with obvious outlier ratio values are not included in the reference group, this flexibility in the choice of weights serves as a useful counter to the claim that inappropriate weights are to blame for j being deemed inefficient. Since (1) ensures that a university being assessed is given a weighting structure that emphasizes the particular financial ratios which show it in the best possible light, then its computed inefficiency cannot be blamed on inappropriate, unfavourable weights.

It is also important to note that the convexity constraint $\sum_{j=1}^{J} z_j \;=1$ in (1) ensures that, in searching for an optimal solution, the composite university incorporates only interpolation of university observations. The solution to (1) thus avoids using a best practice composite university that has been obtained by an extrapolation of observed university (ratio) behaviour outside the observed domain. Finally, note that in (1) the r_{jm} are defined so as to permit comparison of universities of different size.

The problem of negative data for DEA modelling

The practical implementation of the Fernandez-Castro and Smith (1994) modelling approach can, however, be problematic if some of the financial ratios have negative values. As can be seen in (1), the model assesses whether j 's performance could be improved by evaluating the potential for positive radial expansion of its financial ratios. Clearly, if for example, $r_{j1} < 0$, the positive scaling up of this negative ratio (via θr_{j1}) means that it is being made worse. Thus, if $r_{j1} < 0$ denoted the net income to total assets ratio of a university j (which is indeed the case for several UK universities in the empirical set), then the direction of potential movement will be in the opposite to that desired for improved performance.

To cope with the problem of a university exhibiting such a negative ratio, the Fernandez-Castro and Smith (1994) modelling approach proposes that the particular ratio be treated as fixed. The constraint associated with r_{j1} (<0) in (1) would thus be rewritten as $\sum_{j=1}^{J} z_j r_{j1} \geq r_{j1}$, ensuring that the comparison group of universities exhibits performance that is no worse than university j's on the ratio on which j has negative performance. As this amended constraint does not contain θ, this means that r_{j1} is not included in the calculation of the relative efficiency score for j (though the amended constraint limits the comparison set).

Unfortunately, while this way of handling negative data can be viewed as reasonable for the Fernandez-Castro and Smith (1994) study (where there were only a very small number of cases of negative data), it is inappropriate for evaluating the relative performance of UK universities (where a substantial proportion of the universities in the empirical set have negative net income to total assets ratios). Consequentially, the empirical analysis employed in the present study utilizes the recently developed Portela et al (2004) modelling approach which permits meaningful relative efficiency measurement in the presence of negative data.

A new approach to handling negative data in DEA modelling

Prior to the Portela et al (2004) approach, DEA efficiency studies handled negative data by transforming them in some way into positive data (such as by adding an arbitrary positive large number to all values of the relevant variable). These earlier approaches were problematic in that the resulting models either (i) had solutions which were dependent on the way the data was transformed, or (ii) they did not yield an efficiency measure that could be readily interpreted in terms of how a production unit could improve its performance or of how its performance compared with other units. Portela et al (2004) avoid these problems by utilizing a directional distance function approach to coping with negative data in DEA modelling.

The directional distance model (see Chambers et al (1996, 1998) and Färe and Grosskopf (2000)) version of (1) can be written, for university j, as

$$\max_{\beta,z} \quad \beta$$

$$\text{subject to} \quad \sum_{j=1}^{J} z_j r_{jm} \geq r_{jm} + \beta g_r, \quad m = 1,\ldots,M,$$

$$z_j \geq 0, \quad j = 1,\ldots,J, \quad \sum_{j=1}^{J} z_j = 1, \tag{2}$$

where $g_r > 0$ is the directional vector determining the direction in which the r_{jm} are expanded, and $\beta \geq 0$ indicates the scale factor by which all j's ratios can be potentially expanded. For strictly positive data, Chambers et al (1998) suggest setting the direction vector equal to the value of j's observed data values (here the r_{jm} in (2) above). However, when any observed ratio values are negative, this procedure in (2) would move these ratios in the opposite direction to that desired for improved performance.

To avoid this problem the Portela et al (2004) approach replaces (2) with their range directional model (RDM) as given, for each university j, by

$$\max_{\beta,z} \quad \beta$$

$$\text{subject to} \quad \sum_{j=1}^{J} z_j r_{jm} \geq r_{jm} + \beta R_{jm}, \quad m = 1,\ldots,M,$$

$$z_j \geq 0, \quad j = 1,\ldots,J, \quad \sum_{j=1}^{J} z_j = 1, \tag{3}$$

where R_{jm}, the range of possible improvement of university j, is defined as

$$R_{jm} = \max_{J} \{r_{jm}\} - r_{jm} \quad m = 1,\ldots,M. \tag{4}$$

Since this range of possible improvement in (4) can never be negative, then the DEA model in (3) can deal with negative data. Also, as Portela et al (2004) demonstrate, the RDM model yields a relative efficiency measure $(1 - \beta)$ which has a meaningful interpretation (with $(1 - \beta) = 1$ indicating that j is efficient and $(1 - \beta) < 1$ indicating that j is inefficient). In particular, the range of possible improvement used in (3) is determined by the efficient universities' observed ratio values, as is characteristic of traditional DEA radial models like (1) above (with positive data).

It should be noted that while the RDM efficiency measure has a close similarity to the traditional DEA radial efficiency measures, the former uses a different reference point to measure efficiency. Thus while traditional DEA models use the origin, the RDM model uses the 'ideal' point defined by $\max_J\{r_{jm}\},\ m = 1,\ldots, M$ when employing (4). As Portela et al (2004) note, this means that in the RDM model the direction of potential improvement towards the efficient frontier is 'biased' towards the (here) ratios with the largest potential for improvement by (here) university j, relative to other universities. Hence, by requiring an inefficient university to prioritize improvement on those ratios where it does 'worse', rather than where it does 'best', relative to other universities, the RDM model imposes 'demanding' targets on universities when generating its relative efficiency scores. (Portela et al (2004) also propose an inverse RDM model which would prioritize improvement on those ratios where an inefficient university is already doing well. Unfortunately, while the latter model gives certain insights, it generates efficiency measures for universities that are neither comparable to each other nor with the RDM efficiency scores.)

We now outline an alternative nonparametric methodology for the best-practice benchmarking of UK universities.

Best-practice benchmarking via nonparametric profit efficiency analysis

The best-practice benchmarking of UK universities can also be achieved by employing the recently developed DEA-based profit efficiency analysis (Chambers et al (1998)). This analysis uses the prices and quantities of university outputs and inputs rather than financial ratios.

To outline this methodology, let us take a production technology T describing the transformation of university inputs $x = (x_1,\ldots,x_N) \in R^N_+$ into university outputs $y = (y_1,\ldots, y_M) \in R^M_+$ as given by

$$T = \{(x, y) : x \text{ can produce } y\} \tag{5}$$

where T is a convex, closed set and where inputs and outputs are freely disposable. Chambers et al (1998) then define a directional technology distance function on T as

$$\vec{D}_T\ (x, y; -g_x, g_y) = \sup\{\beta : (x - \beta g_x, y + \beta g_y) \in T\}, \tag{6}$$

where $g = (-g_x, g_y) \neq 0$ is a non-zero directional vector determining the direction in which inputs are contracted and outputs are expanded. The largest simultaneous (potential) contraction/expansion will thus project (x, y) onto the boundary of T at $(x - \vec{D}_T g_x, y + \vec{D}_T g_y)$ where $\vec{D}_T$ is given by (6). This means that (6) provides a technical efficiency measure of how far the realised input-output vector (x, y) must be projected along $(-g_x, g_y)$ to reach the frontier of T. As proved by Chambers et al (1998), $\vec{D}_T$ is a complete characterisation of technology.

Following Chambers et al (1998), the profit function can then be defined as

$$\pi(p, w) = \sup\{py - wx : (x, y) \in T\}, \qquad (7)$$

where $p = (p_1, ..., p_M) \in R_+^M$ and $w = (w_1, ..., w_N) \in R_+^N$ denote the vectors of output and input prices, respectively. Since (7) states that $\pi(p, w)$ is greater than or equal to the value of any feasible input-output vector, including $(x - \vec{D}_T g_x, y + \vec{D}_T g_y)$, then

$$\pi(p, w) \geq p(y + \vec{D}_T g_y) - w(x - \vec{D}_T g_x)$$

$$\text{or} \quad \pi(p, w) \geq py - wx + \vec{D}_T(x, y; -g_x, g_y)(pg_y + wg_x). \qquad (8)$$

The inequality in (8) indicates the relationship between the profit function and the directional distance function. Chambers et al (1998) use this to define their profit efficiency measure (πE) by rearranging (8) as

$$\frac{\pi(p, w) - (py - wx)}{pg_y + wg_x} \geq \vec{D}_T(x, y; -g_x, g_y) \qquad (9)$$

and then making this into an equality by adding a residual term (AE_π) as follows

$$\frac{\pi(p, w) - (py - wx)}{pg_y + wg_x} = \vec{D}_T(x, y; -g_x, g_y) + AE_\pi$$

$$\text{or} \quad \pi E = TE_\pi + AE_\pi, \qquad (10)$$

where a value of $\pi E = 0$ indicates that the university concerned has attained efficient (best-practice) performance, while $\pi E > 0$ indicates that the university is failing to attain best-practice performance. (Note that while our focus is on the overall profit efficiency measure πE, expression (10) states that πE can be decomposed into a technical efficiency measure $TE_\pi = \vec{D}_T(x, y; -g_x, g_y)$ and a (residual) allocative efficiency measure AE_π.)

As defined in (10), profit efficiency is measured as the difference between maximal profit $\pi(p,w)$ and realised profit $(py - wx)$ normalised by the value of the directional vector $(pg_y + wg_x)$. Chambers et al (1998) suggest setting the latter value equal to the value of the realised input-output vector so that the difference between maximal potential profit and realised profit is normalised by $pg_y + wg_x = py + wx$, or by the sum of realised revenues and costs. Färe *et al* (2004) suggest that this normalisation can be regarded as a proxy for the size of the production unit (here university). Note that this normalisation is important as it is well-defined even when observed profit is negative or zero. It also ensures that πE is independent of the unit of measurement. Also note, from (10), that the maximal profit component $\pi(p,w)$ in the numerator of πE needs to be empirically computed for each university.

Computing the profit efficiency measure πE

The maximal profit for each university j, relative to the technology T, is computed via the linear programme

$$\pi(p^j,w^j) = \max_{(x,y,z)} \; p^j y - w^j x$$

$$\text{subject to} \quad \sum_{j=1}^{J} z_j y_{jm} \geq \mathrm{y}_m, \quad m = 1,\ldots,M,$$

$$\sum_{j=1}^{J} z_j x_{jn} \leq x_n, \quad n = 1,\ldots,N,$$

$$z_j \geq 0, \quad j = 1,\ldots,J, \; \sum_{j=1}^{J} z_j = 1, \tag{11}$$

where p^j and w^j are j's output and input price vectors, and where the last three lines of (11) indicate how T is constructed from the observed data. Note, in (11), that $\sum_{j=1}^{J} z_j = 1$ permits increasing, decreasing or constant returns to scale and thus, in turn, positive, negative and zero maximal profit. This is important as some of the universities in the observed data set are operating at a loss whereas others are making a profit. From (10) and (11), the profit efficiency measure for university j is thus denoted πE^j and is given by

$$\pi E^j = [\pi(p^j,w^j) - (p^j y^j - w^j x^j)]/[p^j g_y^j + w^j g_x^j], \tag{12}$$

where the difference between j's maximal and observed profit is normalised by the sum of j's observed revenues and costs as given by $p^j g_y^j + w^j g_x^j = p^j y^j + w^j x^j$.

(It should be noted that, as the empirical analysis is concerned with evaluating profit efficiency relative to the point at which a research assessment exercise (RAE) occurs, further constraints are added to (11) to incorporate a fixed input per university and the cost implications of different output mixes across universities. This is to ensure that the empirically constructed best-practice frontier contains truly best-practice universities for benchmarking purposes. More detailed discussion of these further constraints is provided in the data section below.)

DATA DESCRIPTION

The data used relates to the population of 98 non-specialist universities in 1996. Very specialised university institutions were excluded in order to avoid outlier problems when employing the nonparametric DEA-based methodologies. The 1996 date is important as it permits (a) the DEA results to be compared with those yielded by the mid-1990's econometrics study of Johnes (1997), and (b) the research and the teaching quality results for UK universities in 1996 to be incorporated as a way of taking account of output quality in the profit efficiency analysis, which uses the prices and quantities of university outputs and inputs rather than financial ratios (the Johnes (1997) study did not explicitly incorporate this quality aspect). The mid-1990's date is also important as the regulators view of university performance in this period led to the explicit policy directive encouraging increased specialisation in university production.

The selection of financial ratios used in the empirical analysis

In employing the nonparametric analysis based on financial ratios, to assess the relative performance of UK universities, the selection of ratios follows that of Fernandez-Castro and Smith (1994), but with additional emphasis being given to the profitability of universities. Fernandez-Castro and Smith (1994) use a (non-definitive) selection of six financial ratios to reflect the important dimensions of corporate performance that commonly feature in ratio-based studies of relative performance. Their selected ratios are thus cash/total assets; current assets/current liabilities; working capital/total assets; long term liabilities/total assets; net income/total assets; and sales/total assets. These ratios reflect, respectively: cash position; liquidity; working capital position; leverage; profitability; and turnover. In the current universities case, 'sales' in the turnover ratio was taken as the revenue from the 'sale' of research and teaching outputs. (As explained below, this revenue dimension is widened by the use of further ratios).

With the possible exception of the leverage ratio, a high ranking in the chosen ratios is considered, ceteris paribus, to reflect a strong financial position. As Fernandez-Castro and Smith

(1994) recognise, high leverage can be ambiguous in that while it may convey good corporate health and managerial confidence about future corporate health, it could alternatively indicate excessive risk which should therefore be reduced, ceteris paribus. Consequently, to check whether the leverage ratio could be overly dominant in determining the relative efficiency scores of some companies, Fernandez-Castro and Smith (1994) ran models which both excluded and included this ratio. Their check revealed that the exclusion of this ratio gave a more appropriate efficiency assessment of bankrupt companies in their data set. As noted in the empirics below, we also implemented this check, but found that the results were not overly sensitive to the exclusion/inclusion of the leverage ratio in the UK universities case.

To get a richer characterisation of the profitability dimension of UK universities, we also employed ratios reflecting the earnings to expenditure situation of universities. Thus, in one model, we used a revenue to expenditure ratio, with revenue being restricted to that generated by both research and teaching activities. In another model, we used an income to expenditure ratio, with income being defined more broadly in the balance sheet sense so as to include earnings arising from sources such as conference, catering and residence-renting activities. Together with the leverage ratio check, these alternative definitions mean that four models will be run for the ratio-based analysis of the relative performance of UK universities.

Table 1 describes the financial ratios data, for the year 1996, used in the empirical analysis, with the data being presented in terms of the mean ratios for various university groupings. Given the emphasis on the relative efficiency of university groups with different research strengths, Table 1 classes university groups by their average research score per member of research-active staff in the 1996 research assessment exercise (RAE). Further details are given in the note below Table 1. In terms of the three-fold characterisation of UK higher education given in the introduction section, the top traditional group corresponds to the strong research-emphasis division (i), the bottom new group corresponds to the strong teaching-emphasis division (ii), and the in-between group to division (iii) with its in-between research and teaching emphasis. The latter group is made up of the bottom traditional and top new groups taken together.

Looking at the mean ratio values per university group, in Table 1, it can be seen that the lowest values for all but one of the ratios are to be found either in the bottom traditional or in the top new university groups making up the in-between group. The single exception is the leverage ratio, with the lowest mean being found in the bottom new group. The empirical analysis below examines the extent to which various combinations of each university's financial ratios influence its efficiency scores relative to corresponding best-practice benchmarks. These are then used to explore whether this generates evidence of lower mean relative efficiency scores in the 'in-between', or in the regulator-termed 'squeezed-middle', university group. The pattern of results are then compared to those yielded by the alternative profit efficiency methodology.

The data used in the profit efficiency analysis

In this analysis, the same set of UK universities are modelled as producers using two variable inputs (academic staff and other non-teaching, non-research staff) and one fixed input (capital expenditure) to produce the two quality-adjusted variable outputs of teaching and research. This level of aggregation of both the variable inputs and the variable outputs is essentially dictated by the availability of reliable data, especially with respect to their prices. The annual data relates to the point in time at which the regulatory 1996 RAE took place. By using this data point, the study is able to incorporate the results of the 1996 RAE and thus obtain a measure of research output which explicitly takes account of both the quality and the quantity of that output. It also permits the measure of teaching output to be adjusted via the average of the 1996 regulatory teaching quality assessment results for each university.

The research output measure for each university uses the 1996 RAE research ratings for each university's units of assessment, with each rating indicating the average number of research points (on a seven-point scale) per member of staff in the given unit. The average points score per unit, times the number of staff per unit, is then aggregated over a university's units to obtain the university's overall research score. The latter score thus provides a measure of research output which explicitly takes account of both the quality and quantity of that output.

The above research output measure forms the basis of the 'quality research' revenue that UK universities receive from the public Funding Councils. It also influences the research revenue that universities receive (via competitive bidding) from Research Councils, government departments, charities, endowments and business. Hence, in computing a university's research output price, all sources of research revenues are taken into account, with this price being measured as the average revenue per unit of quality-adjusted research output.

The quality-adjusted teaching output of each university is measured as its total number of full-time equivalent (FTE) undergraduate and postgraduate students, with quality adjustment via the average of the teaching quality assessment results (which are on a 24-point scale) for the university's taught subjects. The corresponding teaching output price is measured by the average revenue per student (after quality-adjusting the teaching output). Note that it was not possible to disaggregate teaching into two, undergraduate and postgraduate, outputs with distinct prices, as the revenue data was only available for the total number of both types of students.

In making this adjustment for teaching quality, we recognise that the regulatory teaching quality assessment results may not provide an adequate, accurate reflection of teaching quality. For example, it could be argued that its scoring system refers more to processes rather than to teaching per se. However, it is exceedingly difficult to secure a teaching quality measure which *truly* reflects a university's unique 'added value by teaching quality'. Such a measure needs to be distinct from students' prior attainments, students' personal learning abilities, students' socio-economic backgrounds, facilities that are commonly available at other universities, and possible trends in the percentage of (say) first class degrees that it is deemed appropriate to award, etc.

One of the difficulties here is that most 'added value' often comes from a small set of excellent teachers with the very special ability to explain things with remarkable lucidity, to give fascinating, pertinent illustrations, and to motivate a deeper interest in the subject via their own very obvious, contagious enthusiasm for the subject. While student assessments of teaching quality, and awards for excellent teaching, go some way to capturing this extremely valuable contribution, they are still open to criticism (for example, often it is only the best students who can properly gauge this high teaching quality) and very far from providing a comparable metric across universities.

Given these difficulties surrounding teaching quality assessment, our teaching quality adjustment in essentially pragmatic. Despite the low credibility that academics accord to the regulatory teaching quality (no funds attached) assessment, UK universities are nonetheless very sensitive to their 'league-table' scores in this public assessment – not only striving vigorously for high scores, but unashamedly using these to attract students. Consequently, as these scores give a public impression of universities' teaching qualities, we have pragmatically used this public regulatory assessment for teaching quality adjustment.

On the input side, the two variable labour inputs are measured by the number of (FTE) staff in each category, with input price for each category being computed as the ratio of labour expenses to (FTE) staff for that category. The study also recognises that a university's teaching and research outputs depend not only on its inputs of labour but also on supporting capital expenditure that is aimed at improving its teaching and research performances. Consequently, in this methodology, capital expenditure is treated as a fixed input in the short-run modelling situation. This means that (11) computes short-run variable profit in the empirical analysis. (Further detail regarding the profit definition will be given below.)

By defining the fixed input in this way, each university's capital stock is thus also implicitly taken as given, though deliberately not incorporated explicitly in the modelling. Our reason for this was to try to focus on a fixed input contribution that has a more direct influence on teaching and research performances in the short run rather than on sunk costs that do not have this short-run influence. If this distinction is not made, a small-student-number, weak-research university with an inner city location and high-valued properties, but with relatively small capital expenditure, could be erroneously viewed as using a relatively large amount of fixed input due to focusing on its sunk capital stock costs. Indeed the latter fixed input costs could be greater than those of a larger-student-number, strong-research university with a rural 'green-field' campus location, that is using greater capital expenditure to aid its teaching and research performances. Hence, as will be noted below, capital expenditure is incorporated in the modelling by adding an appropriate constraint to the existing three constraints, in (11) above, that are used to construct the production technology (see (5) above) and thus the best-practice frontier from the observed data.

The profit efficiency analysis also recognises that the potential reallocation of resources across universities, implicit in combining activities (universities) to construct best-practice frontiers, must take into account the cost implications of different output mixes across universities. To do this, appropriate constraints incorporating the 'average cost of output mix' faced by each university with respect to its research and teaching outputs, must be added to the existing three constraints in (11) in the same way as the capital expenditure constraint is added.

The data for the (two) 'average cost of output mix' constraints are based on regulatory cost weightings for teaching and research subject areas. For teaching output, the (quality-unadjusted) public funding weights per student area were used to obtain a weighted average cost for (aggregate university-level, quality-adjusted) teaching output. Likewise, given that the 'quality research' funding allocation (which does not include other research funds) implies a regulatory view of cost weightings for research conducted in different subject areas, per quality rating, these weights were used to obtain a weighted average cost for (aggregate university-level, quality-adjusted) research output.

The further constraints, to incorporate the fixed input and the cost implications of different output mixes across universities $j = 1,...,J$, are given by

$$\sum_{j=1}^{J} z_j x_{jf} \leq x_{jf} \quad \text{and} \quad \sum_{j=1}^{J} z_j a_{jm} \leq a_{jm}, \quad m = 1,...,M, \tag{13}$$

where x_{jf} in the first constraint in (13) refers to (fixed) capital expenditure in university j, and the a_{jm} in the other constraints in (13) denote the weighted average cost of (aggregate, quality-adjusted) output m in university j.

Finally, to comment on the profit definition, note that in analysing the profit efficiency of UK universities the study focuses on the main business of universities, namely their production of research and teaching outputs. Thus, in both the objective function of the profit-maximising programme (11) and in the definition of the profit efficiency measure (12), the focus is deliberately put on the (variable) profit arising from these outputs.

The study does, however, recognise that universities also earn 'other' profit from sources such as conference, catering, and residence-renting activities. But, given the policy emphasis on efficiency gains from research and teaching specialisation, and the fact that this 'other' profit is often completely unrelated to a university's comparative research and teaching strengths, each university's 'other' profit is taken as given (and hence non-variable) in the empirical analysis. As can be seen in the definition of the profit efficiency measure (12), this means that when 'other' (non-variable) profit is added to both maximal and observed profit in the numerator of (12) it cancels out, and thus does not affect a university's relative profit efficiency score. To further check that this way of handling 'other' profit does not neglect a link between research and teaching profit efficiency and 'other' profit earning ability, 'other' profit was regressed against the profit efficiency scores. This regression check found no statistically significant relation between these scores and 'other' profit across UK universities for the period under consideration.

A brief summary of the data employed in the profit efficiency methodology is presented in Table 2. For both methodologies, the data was compiled from figures provided by the Higher Education Statistics Agency, Noble's Higher Education Financial Yearbooks and the Mayfield University Consultants

EMPIRICAL RESULTS

The first five columns of figures in Table 3 present the mean relative efficiency results (%), by university group, for the four ratios-based models and the profit efficiency model. These results are generated by the respective nonparametric, DEA-based models. The last column in Table 3 records the mean relative cost efficiency results obtained by estimating a parametric stochastic cost frontier model. As clarified below, the analysis of results is concerned with comparing the mean relative efficiency scores of each university group within a given column (and thus within each model) rather than across the columns of Table 3.

Results for the cost efficiency model

To obtain the cost efficiency results, the empirical analysis employed the Aigner et al (1977) stochastic frontier approach, with the Battese and Coelli (1988) application of the Jondrow et al (1982) decomposition being used to separate noise from cost inefficiencies in the residuals. The cost efficiency results were thus obtained from the maximum likelihood estimation of a cross-section translog (TL) stochastic cost frontier model of form $ln\,C_i = TL(y_i;\beta) + v_i + u_i$ where C_i denotes the total expenditure incurred by university *i* in producing its (positive) outputs y_i, β is the vector of parameters to be estimated, v_i is the normally-distributed random-noise error term, and u_i is the half-normally-distributed error term which captures cost inefficiencies. The v_i are assumed to be distributed as $v_i \sim \text{iid}\, N(0,\sigma_v^2)$, independently distributed of the u_i.

Following the Battese and Coelli (1995) approach, the u_i are assumed to be a function of certain environmental variables z_i, by specifying that the u_i are independently (but not identically) distributed as the truncated (at zero) normal distribution of form $N(m_i,\sigma_u^2)$ where $m_i = \sum_k \delta_k z_k$ with δ_k denoting parameters to be estimated. The estimates of the unknown parameters (the βs, the δs, σ_v^2, and σ_u^2) were obtained simultaneously via maximum likelihood estimation using Frontier.

Given the cost model's output focus (by not explicitly incorporating input prices, though the βs are taken to be unspecified functions of input prices) and format, only cost inefficiency is estimated as the model does not permit this to be decomposed into estimates of technical and input allocative inefficiency. The latter, however, are not necessary for the purpose in hand. Also, with no zero-output cost measures (such as scope economies) being computed, the translog specification suffices for the current purpose. The usual symmetry parameter restrictions were imposed prior to estimation, with the other regularity conditions (nondecreasing in outputs and rightward skew of the residuals) being checked after the estimation (see note below Table 3).

The cost model views universities as producers of three quality-adjusted outputs (research, postgraduates and undergraduates), with quality adjustment via the RAE and the teaching quality assessments as discussed in the previous section. The university-specific z_i used in the empirical analysis constitute a parsimonious, non-definitive attempt to reflect aspects of the student, staff and output environments in which each university operates in the given cross-section (1996 data) situation. The intention here is to recognise that, at given point in time, universities operate in certain 'environments' which are largely the outcome of long-run, historically-established positions. Hence, to the extent that these positions can be viewed as reasonably given in the short run, the z_i can be viewed as approximately exogenous at the point of the cross-section study.

The z_i were taken as: the academic quality of student intake (average A-level score), the percentage of students from lower social classes, the student to academic staff ratio, the percentage of academic staff aged 55 and over, the percentage of academic staff that are research-active, the percentage of total students taking science courses, and the ratio of research grants to all revenue. It is assumed that these z_i are approximately exogenous in the given cross-section analysis (but it is recognised that, to the extent that some endogeneity intrudes, even in short run, this will introduce some degree of simultaneous equation bias to our estimates). It is also recognised that a case can be made for other z_i specifications – however, as a minor part of this paper, our focus was on checking that a reasonable output-focused cost model, using our mid-1990s data, yielded a similar pattern of cost efficiencies for UK universities as found by the Johnes (1997) output-focused cost model for the same mid-1990s period.

Turning to Table 3, we can see that the relative cost efficiency results for the study's data are similar to that found by Johnes (1997) for the same mid-1990s period. Thus, from the last column in Table 3, we can see that the mean relative cost efficiency of the in-between group (82.84%) is less than that found for both the more-specialised (research-emphasis) top traditional (86.59%) and (teaching-emphasis) bottom new (85.00%) groups.

To check whether these mean differences are statistically significant, we used the Atkinson and Wilson (1995) bootstrap methodology for constructing confidence intervals in small sample groupings (with the number of bootstrap replications set at 10,000 each time). This bootstrapping procedure enables us to attach percentile confidence intervals to means of efficiency scores and thus to determine whether (small-sample) university-group mean efficiency scores are significantly different from zero and from other group-mean scores.

The bootstrapping algorithm involves the following steps: (1) Take a given small-sample set of N scores s_i and get its mean $\bar{s}_i$. (2) Apply a small-sample correction factor to get a new set of N scores $\tilde{s}_i$ as given by $\tilde{s}_i = s_i\left(\sqrt{K}\right) + \bar{s}_i\left[1-\left(\sqrt{K}\right)\right]$ where $K = N/(N-1)$. (3) Independently draw N times from the set of $\tilde{s}_i$ scores with replacement, such that each observation has equal probability of selection, to obtain the set of N scores s_i^*. (4) Compute mean $\bar{s}_i^*$. (5) Repeat steps (3) – (4) J times to obtain the set of J values $\bar{s}_i^*$, where J is appropriately large in magnitude (namely, at least equal to N^2).

The set of J bootstrap values $\bar{s}_i^*$ approximate the exact small-sample distribution of $\bar{s}_i$ with mean μ_i, so that these values can be ordered by algebraic value to construct confidence intervals for μ_i via the bootstrap *percentile method* described by Efron (1982). A 95% confidence interval, for example, is obtained by deleting 2.5% of the values from both ends of the ordered array of the J bootstrap values, with the endpoints of the truncated array thus giving the boundaries of the 95% confidence interval. The interval for other levels of confidence is obtained in a similar manner. The Appendix of Atkinson and Wilson (1995) provides a proof that the correction in step (2) above is necessary to avoid type-I errors in small samples and thus to avoid the computed confidence interval being too tight. They also indicate that the number of bootstrap replications J must be at least N^2 to ensure that the simulation noise from step (3) above is of an appropriately small order. For all cases we exceeded this by using J = 10,000.

Applying the bootstrap methodology to the cost efficiency results, this indicated that the mean score of the relatively less-specialised in-between group was significantly lower than that of the more-specialised research-emphasis group at the 97.5% confidence level (using a one-tailed test). However, it is only significantly lower than that of the more-specialised teaching-emphasis group when the confidence level (in the one-tailed test) is reduced to 88%. Although the latter confidence level is lower than one would like, the overall pattern of relative efficiency scores is comparable to that found by Johnes (1997) – namely, that more-specialised UK university production is relatively more cost efficient on average.

Before leaving the column of cost efficiency results, it is interesting to note that the relatively lower mean cost efficiency of the in-between group is largely due to the particularly low mean cost efficiency of the top new group (at 81.14%) rather than to that of the bottom traditional group (at 84.23%). Given this finding for the top new group, together with its relatively low research capability and the current policy stance, this suggests that this university group will come under increasing pressure to move towards a relatively more-specialised teaching-emphasis production. Table 3 indicates the attractiveness of such a move, with the teaching-emphasis bottom new group enjoying a higher mean cost efficiency (of 85.00%) than that of the top new group (at 81.14%). Universities with cost efficiency scores that are ranked low within the bottom traditional group's scores will face similar pressures towards a greater teaching emphasis. In contrast, universities that have scores ranked high within the bottom traditional group's scores may be able to secure a greater research emphasis. These findings accord with those of Johnes (1997).

Results for the financial-ratios-based models

Looking at the results for the four ratios-based models, Table 3 indicates a similar pattern of mean relative efficiency scores as found for the cost efficiency model. Thus for each ratios model, the mean relative efficiency score of the less-specialised in-between group is found to be less than that of both the more-specialised (research-emphasis) top traditional and (teaching-emphasis) bottom new groups. Also, for all four ratios models, the relatively lower mean efficiency score of the in-between group is once more largely due to the particularly low mean efficiency score of the top new group rather than to that of the bottom traditional group. Before using the bootstrapping procedure to check whether these mean differences are statistically significant, let us make some further comments about the ratios models results.

As the ratios Model 1, which excludes the leverage ratio, gave a similar pattern of relative efficiency scores to that yielded by Model 2 which includes this ratio, Models 3 and 4 also retain the leverage ratio. In comparing Models 1 and 2, the similar pattern of relative performance yielded by the efficiency scores for these two models was confirmed by Spearman rank correlation analysis. Thus, in contrast to the Fernandez-Castro and Smith (1994) analysis, we concluded that the inclusion of the leverage ratio is appropriate for measuring the relative efficiency scores of UK universities.

(In comparing the ratios models *across* the columns of results given in Table 3, it must be remembered (see Kerstens and Vanden Eeckaut (1999)) that increasing the number of ratios in successive models may increase but not decrease the relative efficiency score of a university. Thus, in moving from 5 ratios in Model 1 to 6 ratios in Model 2 by adding one new ratio to the existing 5 ratios, Table 3 indicates that the mean scores for all groups have increased. A similar finding holds when comparing Models 2 and 3, and Models 2 and 4, as the number of ratios is increased from 6 to 7 in both comparisons by adding one new ratio. Consequently, given this dimensionality feature of radial efficiency DEA-based models, the essential comparison in Table 3 is concerned with the mean relative efficiency scores of different university groups *within* each column, and thus within each model.)

In terms of the policy emphasis on the comparative research and teaching strengths of UK universities, Model 3 would appear to be the most appropriate specification of the three ratios-based models which include the leverage ratio (namely Models 2, 3 and 4). This is because Model 3 gives greater emphasis to characterising profitability aspects than Model 2, and also uses a narrower definition of earnings (based on research and teaching revenue only) than Model 4. However, while nonparametric Wilcoxon signed-rank tests reject the null hypothesis that Models 3 and 4 (which both give greater emphasis to profitability than Model 2 but differ in their earnings definitions) have identical efficiency score distributions, Spearman rank correlation analysis indicates that Models 3 and 4 have a very similar pattern of *relative* performance.

The detailed bootstrapping results indicate that the mean efficiency score of the more-specialised (research-emphasis) top traditional group is statistically significantly higher than that of the less-specialised in-between group for the ratios Models 1, 2, 3, 4 and the cost efficiency model at the significance levels of 8%, 3%, 3%, 3% and 2.5%, respectively, using a one-tailed test. Thus, at confidence levels of 97% and above, all these models except Model 1 suggest that the in-between group is less efficient than the top traditional one on average. If we are willing to work with a confidence level of 92%, a similar finding holds for Model 1. These results thus suggest that the accounting tool of financial ratios, like the cost efficiency model, can provide evidence that the less-specialised in-between group is less efficient on average than the more-specialised, research-emphasis group. Clearly, with this group being less efficient, on average, than the research-emphasis group, and with a stronger research-emphasis requiring costly investment, it is expected that few universities in the in-between group will be able to realize the goal of a greater research-emphasis.

However, the more-specialised (teaching-emphasis) bottom new group is only significantly more efficient than the less-specialised in-between group on average at lower levels of significance – namely, 19%, 17%, 5%, 8% and 12%, respectively, for Models 1, 2, 3, 4 and the cost efficiency model. It is interesting to note that it is only Model 3, which most characterises the profitability aspects in accordance with the policy emphasis, that suggests that the in-between group is less efficient on average when compared to the teaching-emphasis group at confidence levels over 95% on the one-tailed test. For confidence levels of 92% and 88%, respectively, Model 4 and the cost efficiency model yield a similar finding. From Table 3, however, it is clear that if we focus on the less-specialised top new component of the in-between group, then this top new group is significantly less efficient on average then the more-specialised teaching-emphasis bottom new group (at significance levels of 2%, 4%, 6%, 3% and 1% for the four ratios models and the cost efficiency model, respectively). This finding of lower mean efficiency for the top new group, obtained via both the financial ratios models and the cost efficiency model, suggests that this group needs to consider a greater teaching emphasis so as to secure increased efficiency.

Results for the profit efficiency model

Turning now to the profit efficiency results, Table 3 indicates very similar findings to those just discussed for the four ratios models and the cost efficiency model. Hence, as before, the greater mean efficiency of the more-specialised, research-emphasis top traditional group (at 83.04%), relative to that of the less-specialised in-between group (at 75.04%), is much more pronounced than that of the more-specialised, teaching-emphasis bottom new group (at 78.56%). Thus the bootstrapping indicates that the mean profit efficiency score of the more-specialised (research-emphasis) top traditional group is once more statistically significantly higher than that of the less-specialised in-between group at the 1% significance level. Also, the bootstrapping indicated that the mean profit efficiency score of the in-between group is not significantly lower than that of the more-specialised (teaching-emphasis) bottom new group (except at the unreasonable significance level of 25%). It is interesting to note that this pattern of profit efficiency results, for the mid-1990s, accords with the Johnes (1996a) prediction. In a neat, budget-constrained utility-maximising, empirical analysis of universities' preferences for teaching and research, Johnes (1996a) found that, over the 1985-1992 period, stronger research universities had increased the weight given to research, while in other universities this weight had actually declined. Given this finding, and the continuation of competitive, selective funding of research, Johnes (1996a) predicted a pattern of more-pronounced specialisation in research or teaching in UK universities so as to exploit their relative strengths.

In noting the higher mean profit efficiency of the more-specialised, research-emphasis top traditional group, relative to that of the less-specialised in-between group, it must be remembered that the former group's higher profit efficiency is not *solely* derived from its greater specialisation in research. The top traditional group's teaching situation also contributes to its mean profit efficiency score. As indicated in equation (12), a university's profit efficiency score is essentially a measure of its profit performance in producing *both* its research and teaching outputs, relative to best practice.

This is an important point to remember, as the very large majority of UK universities operate in a situation where each university's respective revenue from teaching accounts for over 50% of its combined revenue from both research and teaching. For example, for the university groups in Table 3's data situation, the respective mean % revenues from teaching are: Top Traditional (52%), Bottom Traditional (69%), In-Between (80%), Top New (93%), Bottom New (95%) and All (68%). These figures indicate that while the more-specialised, teaching-emphasis bottom new group is very heavily specialised towards teaching in revenue-generating terms, the more-specialised, research-emphasis top traditional group is by no means as heavily specialised towards research in revenue-generating terms. However, for all cases, profit efficiency is measured with respect to each university's performance in producing both research and teaching.

A sub-section of the recent Glass et al (2006b) study, of 'level playing-field' profit efficiency measures for UK universities, provides estimates of the decomposition of profit efficiency into technical efficiency and allocative efficiency measures as defined in equation (10) above. These estimates indicate that the more-specialised, research-emphasis top traditional group enjoys relatively higher (mean) profit, technical and allocative efficiencies than the less-specialised in-between group. The Glass et al (2006b) study also generates further insights by investigating the extent of (mean) output-specific and input-specific misallocations that obtains for different university groups, relative to the best-practice profit-maximising outputs-inputs mixes scenario.

Returning to the profit efficiency findings in Table 3, it is interesting to note that the profit efficiency results for the component parts of the in-between group differs from that yielded by the four ratios models and the cost efficiency model. In the latter models, the bottom traditional group consistently manifested greater mean efficiency than the top new group. For the profit efficiency model, this pattern is reversed with the mean profit efficiency score of the bottom traditional group (at 73.34%) being lower than that of the top new group (at 77.34%). This finding seems to be highlighting an important aspect of the pressures faced by the bottom traditional group in its attempt to emulate the research success of the top traditional group.

To explain what we mean, note that the profit efficiency model focuses very specifically on the research and teaching revenues of universities. In doing this, the profit efficiency model does not reflect the broader dimensions of university strength and performance that are explicitly incorporated in the ratios models. For example, even though the ratios Model 3 does incorporate a specific characterisation of the profitability aspect linked to research and teaching revenues that accords with the policy emphasis, it also incorporates other dimensions of financial strength. Consequently, if the bottom traditional group has relatively good performance on these other dimensions (as the results for the four ratios models in Table 3 would suggest is the case), but is experiencing difficulty in achieving relatively good performance in securing revenues (as the comparison of the profit and cost efficiency results in Table 3 would suggest), then the results for this group would be as found in Table 3.

These profit efficiency findings for the bottom traditional group are not unexpected. Historically this group has had a much broader research base than the top new group and, despite the continuous policy pressures for efficiency gains since the mid-1980s, it has tried to maintain this broad base into the mid-1990s. But, even though the bottom traditional group has achieved reasonable success in relative cost efficiency terms and in maintaining teaching revenues, it has inevitably faced problems in securing research revenues across this broad research base. With research funding being increasingly weighted, over time since the mid-1980s towards higher quality research output, the mid 1990's profit efficiency consequences of trying to maintain a broad research base in the bottom traditional group is very obvious as reflected in the findings of Table 3. Indeed it was these very consequences that led both the regulators and the universities concerned to pursue a policy of increased specialisation in research production. Thus, in a very real sense, the regulators' term 'the squeezed middle' accurately describes the difficult situation of the bottom traditional group.

In contrast, the relative research revenue efficiency of the top traditional group, due to its higher quality research output, has helped to produce its relatively high profit efficiency score shown in Table 3. Also, in contrast to the bottom traditional group, as the top new group had both a much narrower research base and a much lower research capability to start with, the top new group did not experience the same research revenues pressures as the bottom traditional group. Moreover, with its greater teaching emphasis, the top new group has been able to significantly expand its teaching revenues by becoming more specialised in producing taught postgraduate courses. This feature, which began to emerge in the mid-1990s, has since become a major success story for these universities. However, as Table 3 highlights, while the top new group has achieved reasonable mean profit efficiency, relative to other groups, its performance in broader terms (as reflected by its ratios models results) and in terms of its cost efficiency is relatively weak.

The above profit efficiency findings thus indicate how the ratios models and the profit efficiency model can provide useful, complementary insights. The ratios models have the advantage of addressing more dimensions of financial strength than the profit efficiency model. Also, they have the advantage of not having to wait several years until the relevant regulatory research and teaching quality assessments yield measures for making appropriate quality adjustments of university outputs. This, however, does not mean that the ratios models completely neglect the output qualities issue. Rather, it can be argued that this issue is already addressed since the financial ratios incorporate the financial implications of output qualities at the given time of ratios measurement.

In contrast, while the profit efficiency model has the timing problem of quality-adjusting outputs, it does have the advantage of focusing very specifically on the key policy issue of the research and teaching revenues of universities. Given that the latter has driven the policy stance towards increased specialisation in UK universities, it is essential that this profit efficiency emphasis is used to complement the broader emphasis given by the ratios models.

Pulling the above results together, the overall picture suggests that nonparametric DEA-based models employing the accounting tool of financial ratios can indeed provide a ready demonstration that the relatively less-specialised in-between university group is less efficient, on average, than other more-specialised groups. While the greater mean efficiency of the research-emphasis group is more pronounced than that of the teaching-emphasis group, relevant to the in-between group's mean efficiency in this demonstration, the overall picture nonetheless stands. As shown above, in providing this demonstration, the ratios models yield very similar results to the profit and cost efficiency models.

CONCLUSIONS

The current policy stance for UK higher education encourages universities to become more specialised according to their comparative research and teaching strengths in order to achieve efficiency gains. The currently-available empirical evidence, based on econometric cost functions and DEA models employing quantity data only, suggests that there are indeed efficiency gains from such specialisation in the UK university sector.

In this paper, the neglected issue of the profit efficiency of UK universities is explored. In particular, the paper explores whether the accounting tool of financial ratios can be utilised to reveal that more specialised university production yields relatively higher performance on average than less specialised production. The empirical results, obtained from nonparametric DEA-based models incorporating financial ratios, and using a new methodology for handling the problem of negative data, confirmed that more specialised university production is more efficient than less specialised production on average. However, this finding was much more pronounced for more-specialised, research-emphasis university production than for more-specialised, teaching-emphasis production. The statistical significance of these findings was confirmed by a bootstrapping procedure.

A recently-developed nonparametric DEA-based profit efficiency methodology was also used to provide an alternative approach to measuring the relative performance of UK universities. This methodology yielded similar results to the ratios-based models.

The results of the two new nonparametric approaches thus suggest that the current policy stance, of encouraging increased specialisation in UK university production, is not only supported by empirical evidence from cost efficiency modelling but also by evidence from profit efficiency modelling. Also, the finding of higher mean profit efficiency for the more-specialised, research-emphasis group, relative to all other groups, suggests that a two-fold division of UK higher education into research-emphasis and teaching-emphasis universities will become increasingly likely over time. Given the very evident comparative research advantage of the research-emphasis group, which translates into greater mean profit efficiency, plus the policy stance of biasing research funding towards higher quality research output, it is unlikely that other groups will be able to overcome the pressures towards this two-fold division.

The finding that the models employing financial ratios yield similar results to the profit and cost efficiency models is important. In particular, unlike the latter models, the ratios models don't have to focus on university outputs data. Consequently, they don't have to wait several years for the relevant regulatory quality assessments to yield the measures required for quality-adjusting these outputs. Rather, the financial ratios already incorporate the financial implications of output qualities at the given time of ratios measurement. Hence they have the advantage of being able to provide ready, comparable evaluations of relative university performance. While this is so, the results of the above analysis indicate that there are good reasons for also using the profit efficiency model to complement the ratios model approach. By doing this, useful insights into both the narrower and the broader aspects of university performance can be obtained.

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Table 1

Mean Values of Financial Ratios by University Group

University Group	*Cash / Total Assets*	*Current Assets / Current Liabilities*	*Working Capital / Total Assets*	*Long Term Liabilities / Total Assets*	*Net Income / Total Assets*	*T & R Revenue / Total Assets*	*T & R Revenue / Expend-iture*	*Income / Expend-iture*
Top Traditional	0.0542	1.6481	0.0937	0.4204	0.0082	0.6440	0.7595	1.0069
Bottom Traditional	0.0471	1.7441	0.0960	0.3859	0.0007	0.6638	0.7238	0.9983
In-Between	0.0471	1.6124	0.0733	0.3776	0.0041	0.6287	0.7596	1.0038
Top New	0.0470	1.4337	0.0424	0.3663	0.0087	0.5811	0.8083	1.0111
Bottom New	0.0527	1.7154	0.0548	0.3596	0.0099	0.5900	0.7971	1.0179
All	0.0514	1.6553	0.0757	0.3886	0.0073	0.6234	0.7703	1.0090

Note: T & R in columns 7 and 8 denotes Teaching and Research. University groups are classed by ARS (average research score per member of research-active staff in the 1996 RAE), where $1.0 \leq ARS \leq 7.0$. Traditional or pre-1992 universities $(n = 56;\ 2.15 \leq ARS \leq 6.64)$ are grouped into Top Traditional $(n = 37;\ ARS > 4.5)$ and Bottom Traditional $(n = 19;\ ARS < 4.5)$. New or post-1991 universities $(n = 42;\ 1.6 \leq ARS \leq 3.58)$ are grouped into Top New $(n = 14;\ ARS > 3.0)$ and Bottom New $(n = 28;\ ARS < 3.0)$. The figures in Table 1 relate to the population of 98 non-specialist UK universities in 1996.

Table 2

Mean Values of Data used in the Profit Efficiency Analysis

	Outputs		*Inputs*	
	Research	*Teaching*	*Academic Staff*	*Other Staff*
Quantities	1974	7394	1057	1325
Prices (£s)	8421	6608	28887	18515

Weighted average cost of research output (£s) = 2898

Weighted average cost of teaching output (£s) = 4203

Mean profit from research, teaching and other activities (£'000) = 8749

Mean capital expenditure (£'000) = 14171

Note: Research output quantity is the quality-adjusted research score. Teaching output quantity is the quality-adjusted (scaled-down) number of (FTE) students. Output prices correspond to these quality-adjusted output quantities. Staff inputs are in FTE terms. The figures in Table 2 relate to the population of 98 non-specialist UK universities in 1996.

Table 3

Mean Relative Efficiency Scores (%) for the Ratios, Profit and Cost Models

University Group	*Ratios Model 1*	*Ratios Model 2*	*Ratios Model 3*	*Ratios Model 4*	*Profit Efficiency*	*Cost Efficiency*
Top Traditional	76.49*	81.29**	83.66**	81.31**	83.04**	86.59**
Bottom Traditional	76.35	79.30	80.30	79.40	73.34	84.23
In-Between	73.57	77.17	79.58	77.26	75.04	82.84
Top New	69.80[a]	74.20[a]	78.60[b]	74.40[a]	77.34	81.14[a]
Bottom New	75.34	79.18	82.83[††]	80.18[†]	78.56	85.00
All	75.18	79.30	82.05	79.62	79.07	84.90

Note: Ratios Model 1 uses 5 ratios: Cash/Total Assets; Current Assets/Current Liabilities; Working Capital/Total Assets; Net Income/Total Assets; and Teaching and Research Revenue/Total Assets. Model 2 uses the 5 ratios of Model 1 plus the leverage ratio, Long Term Liabilities/Total Assets. Model 3 uses the 6 ratios of Model 2 plus the ratio Teaching and Research Revenue/Expenditure. Model 4 uses the 6 ratios of Model 2 plus the ratio Income/Expenditure. The cost efficiency scores were obtained from a stochastic cost frontier analysis which, like Johnes (1997), uses an output-focus approach (but with quality-adjusted outputs). As required, the estimated cost function is monotonically nondecreasing in outputs and the residuals are positively skewed thus ensuring meaningful cost efficiency estimates (also the null hypothesis of no cost inefficiency was rejected and the null hypothesis of homoskedastic disturbances was not rejected).

[**(*)] indicates that the more-specialised top traditional (research-emphasis) group has a significantly higher mean efficiency score than that of the less-specialised in-between group at the 5% (10%) significance level (on a one-tailed test via bootstrapping).

[††(†)] indicates that the more-specialised bottom new (teaching-emphasis) group has a significantly higher mean efficiency score than the in-between group at the 5%(10%) significance level.

[a(b)] indicates that the top new group has significantly lower mean efficiency than the (more-specialised) bottom new group at the 5%(10%) significance level.