Lancaster University Management School
Working Paper
2009/019

Some University Students Are More Equal Than Others: Evidence From England

Ching-Fu Chen and Kwok Tong Soo

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

The LUMS Working Papers series can be accessed at http://www.lums.lancs.ac.uk/publications/
LUMS home page: http://www.lums.lancs.ac.uk/

Some university students are more equal than others: Evidence from England[*]

Ching-Fu Chen[†]
National Cheng Kung University

Kwok Tong Soo[‡]
Lancaster University

October 2008

Abstract

This paper estimates the efficiency of students in English universities using Data Envelopment Analysis (DEA) and a new dataset which is able to capture the behaviour of university students. Taking as the output the classification of a university degree, we use as inputs teaching hours and quality, entry qualifications, and the effort level. We find that university students differ in terms of the efficiency with which they use inputs in producing good degrees. In a second stage, we explore the determinants of the efficiency of university students using a truncated regression model. Higher student efficiency is found to be positively and significantly related to university size, and negatively and significantly related to the proportion of part-time students and the number of academic staff. The quality of a university has no significant impact on the efficiency of its students once endogeneity of university quality is controlled for.

Keywords: Data Envelopment Analysis (DEA); Efficiency; Education.

[*] Thanks to Bahram Bekhradnia for providing the data from HEPI on the student experience in English universities, and to Wendy Beekes, Geraint Johnes and Jill Johnes for useful suggestions. The authors are responsible for any errors and omissions.
[†] Department of Transportation and Communication Management Science, National Cheng Kung University, 1, University Rd., Tainan, 701, Taiwan. Email: cfchen99@mail.ncku.edu.tw
[‡] Department of Economics, Lancaster University Management School, Lancaster LA1 4YX, UK. Email: k.soo@lancaster.ac.uk

Introduction

The university sector in England is large and diverse. As of August 2007 there were 132 universities employing a total of over 110,000 full-time academic staff, with over 1 million full-time undergraduates and a total income of over £21 billion (data from the Higher Education Statistical Agency (HESA)). Universities range from the long-established universities of Oxford and Cambridge, to new universities that have only been recently granted university status as a result of the Further and Higher Education Act of 1992. The subjects taught by universities are also diverse, from the traditional Politics, Philosophy and Economics, to the modern Computer Game Design.

Such diversity of institutions and subjects may be assumed to attract a diverse group of students, who may be expected to be diverse in terms of their abilities. This paper addresses this diversity in student abilities. Specifically, we investigate the efficiency of students in terms of the degree class obtained, given the inputs that they put into their studies, and we explore the determinants of student efficiency. We do so by means of a two-step procedure which first uses Data Envelopment Analysis (DEA) to obtain the efficiency of students. This measure of efficiency is then used as the dependent variable in a truncated regression to identify the factors that influence efficiency. Our analysis is performed for a new dataset of 78 English universities for which consistent data was available for 2006 and 2007.

Our main results are the following. We find that there is substantial variation in student efficiency across universities; university students are not the same in different universities. There is evidence of technological improvement, but also of reduction in efficiency between the two years. Student efficiency is positively related to the size of the university, but negatively related to the percentage of part-time students and the number of academic staff. The quality of a university has no significant impact on the efficiency of its students once the endogeneity of university quality is controlled for.

Previous work on the efficiency of university students in the production of their degrees includes (Johnes 2006a, b). In these papers Johnes uses DEA to estimate the efficiency of students in UK universities using individual-level data. The use of individual-level data allows Johnes to investigate the role of individual-level variables such as age and gender on students' efficiency which we are unable to replicate with our university-level dataset. However, the advantage of our new dataset is that we have direct measures of student effort levels and teaching quality and quantity, which are unavailable in Johnes's data. This allows us to more directly capture the determinants of university degree performance.

In addition, this paper relates to three strands of literature. First, there has been much work on the determinants of educational success in higher education and of dropping out of higher education. This relates to the literature on educational production such as (Lazear 2001) and (Todd and Wolpin 2003) and primarily adopts a regression-based approach, using data at either the individual or institutional level. However, this approach does not (rather, is unable to) address the question of whether students are efficient in terms of producing degree performance. (Naylor and Smith 2004) survey this literature; more recent work includes (Martins and Walker 2005), (Stanca 2006), and (Arulampalam *et. al.* 2007).

A second strand of literature is that on the efficiency of universities. This literature focuses on universities as economic entities and whether they are efficient at producing output in terms of student degrees or research, using as inputs the financial and human resources available to the university. Methods used include DEA and stochastic frontier analysis. This literature nevertheless differs from the present paper in its focus on the performance of the university rather than the performance of students in university. (J. Johnes 2004) surveys this literature; more recent examples include (Johnes *et. al.* 2005) and (Johnes 2006c, 2008).

A third strand of related literature (which is closely related to the second strand) is the literature on the estimation of multi-product cost functions of universities. This literature explores the relationship between the inputs and outputs of universities by estimating the cost function using regression analysis, and is surveyed by (Cohn and Cooper 2004); see also (Johnes *et. al.* 2005).

Methods

There are two primary methods of estimating efficiency. Data Envelopment Analysis (DEA) is a non-parametric mathematical programming approach to frontier estimation, whilst Stochastic Frontier Analysis (SFA) uses a parametric econometric model to estimate the production frontier. This paper uses DEA to explore the relative efficiency of students in different English universities. The exposition in this section follows that of (Coelli 1996) and (Coelli *et. al.* 2005).

We use the input-orientated DEA model, where the objective of the Decision-Making Unit (DMU) is to minimise the inputs required to achieve a given level of output. In this paper students are assumed to have the objective of minimising the effort level required to obtain a given standard in their university degrees.

First consider the constant-returns-to-scale (CRS) model. Let there be K inputs and 1 output on each of N DMUs. For the i^{th} DMU these are represented by the vector x_i and the scalar y_i respectively. The K x N input matrix X and the 1 x N output vector Y represent the data of all N DMUs. The purpose of DEA is to construct a non-parametric envelopment frontier over the data points such that all observed points lie on or above the cost frontier.

The mathematical form of this problem is:

$$\begin{aligned} & \min_{\theta,\lambda} \theta \\ & \text{s.t.} \quad -y_i + Y\lambda \geq 0 \\ & \qquad \theta x_i - X\lambda \geq 0 \\ & \qquad \lambda \geq 0 \end{aligned} \tag{1}$$

Where θ is a scalar and λ is a N x 1 vector of constants. The value of θ obtained will be the efficiency score for the i^{th} DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient DMU; that is, a DMU where the inputs cannot be reduced without a reduction in output. The linear programming problem must be solved for each DMU in the sample and a value of θ obtained for each DMU.

However, the CRS assumption is only appropriate when all DMUs are operating at an optimal scale. The use of the CRS specification when not all DMUs are operating at the optimal scale will result in measures of technical efficiency which are confounded by scale efficiencies. The use of the variable-returns-to-scale (VRS) model will permit the calculation of technical efficiency excluding these scale effects.

The CRS linear programming problem can be modified to account for VRS by adding the convexity constraint N1’ λ = 1 to equation (1) to provide:

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta \\
&\text{s.t.} \quad -y_i + Y\lambda \geq 0 \\
&\qquad \theta x_i - X\lambda \geq 0 \\
&\qquad N1'\lambda = 1 \\
&\qquad \lambda \geq 0
\end{aligned}
\tag{2}
$$

Where N1 is an N x 1 vector of ones. This approach forms a convex hull of intersecting planes which envelop the data points more tightly than the CRS hull and thus provides technical efficiency scores which are greater than or equal to those obtained using the CRS model. If the technical efficiency scores for a DMU are different between CRS and VRS models, this indicates that the DMU has scale inefficiency, and the scale inefficiency can be calculated from the ratio of the CRS and VRS technical efficiency scores.

Since we have two years of data (2006 and 2007), we can use DEA and a Malmquist TFP index to measure productivity change, and to decompose this productivity change into technical change and efficiency change. Efficiency change can in turn be decomposed into scale efficiency and pure efficiency components. Define $d^s(x_t,y_t)$ as the distance from the period t observation to the period s technology which can be calculated using the DEA approach above. The Malmquist productivity change index between period t and t+1 is:

$$
m_0(y_{t+1}, x_{t+1}, y_t, x_t) = \left[\frac{d^t(x_{t+1}, y_{t+1})}{d^t(x_t, y_t)} \times \frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \tag{3}
$$

This represents the productivity of the production point (x_{t+1}, y_{t+1}) relative to the production point (x_t, y_t). A value greater than one will indicate positive TFP growth from period t to period t+1. Equation (3) can be rewritten as:

$$
m_0(y_{t+1}, x_{t+1}, y_t, x_t) = \frac{d^{t+1}(x_{t+1}, y_{t+1})}{d^t(x_t, y_t)} \left[\frac{d^t(x_{t+1}, y_{t+1})}{d^{t+1}(x_{t+1}, y_{t+1})} \times \frac{d^t(x_t, y_t)}{d^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \tag{4}
$$

The first term on the RHS of equation (4) is a measure of efficiency change (movements relative to the efficient frontier), while the second term (in square brackets) is a measure of technical change (movements of the frontier). Following (Fare *et. al.* 1994) efficiency change can in turn be further decomposed as the product of pure efficiency change and scale efficiency change, so that:

$$m_0\left(y_{t+1}, x_{t+1}, y_t, x_t\right) = \frac{d_{VRS}^{t+1}\left(x_{t+1}, y_{t+1}\right)}{d_{VRS}^{t}\left(x_t, y_t\right)} \left[\frac{d_{CRS}^{t+1}\left(x_{t+1}, y_{t+1}\right)}{d_{VRS}^{t+1}\left(x_{t+1}, y_{t+1}\right)} \Bigg/ \frac{d_{CRS}^{t}\left(x_t, y_t\right)}{d_{VRS}^{t}\left(x_t, y_t\right)} \right]^{\frac{1}{2}} \times \left[\frac{d_{CRS}^{t}\left(x_{t+1}, y_{t+1}\right)}{d_{CRS}^{t+1}\left(x_{t+1}, y_{t+1}\right)} \times \frac{d_{CRS}^{t}\left(x_t, y_t\right)}{d_{CRS}^{t+1}\left(x_t, y_t\right)} \right]^{\frac{1}{2}} \tag{5}$$

Therefore the change in productivity is the product of pure efficiency change (the first term on the RHS of equation (5)), scale efficiency change (the second term) and technical change (the third term). Note that as a result of this decomposition, the pure efficiency change is measured relative to the VRS technology, while the technical change is estimated relative to the CRS technology (but see (Ray and Desli 1997) and (Fare *et. al.* 1997) for a discussion of alternative ways of decomposing technical efficiency change).

Data

The data used in this paper comes from two primary sources. For data on the student experience in English universities, we use data from the two Higher Education Policy Institute (HEPI) reports by (Bekhradnia *et. al.* 2006) and (Sastry and Bekhradnia 2007). In these studies, the authors conducted surveys of first and second year students in English universities. In each year there were over 14,000 respondents from a sample of over 23,000. These respondents are distributed across 169 universities and all subject areas; see (Bekhradnia *et. al.* 2006) and (Sastry and Bekhradnia 2007) for details of the sample.

The surveys ask students questions regarding the workload that they experience, including the number of teaching hours, private study, outside employment, use of specialist equipment, and the level of satisfaction. Most questions (and all of those used in the present paper) were repeated in both surveys. Due to the changes in some questions and to a different weighting system for constructing descriptive statistics, (Sastry and Bekhradnia 2007) caution against making comparisons between the results of the two surveys. They do however report that the results of the two surveys reveals only very small differences which they attribute to random variation or changes in the approach.

In the present study we use the results of both surveys, exploiting the similarity of results between them. We aggregate the individual responses to the university level. As a result of this aggregation and allowing for missing observations from our other data sources, our final sample consists of a balanced panel of 78 universities for two years (2006 and 2007). From these HEPI reports we obtain the following input variables. First, we obtain the average number of teaching hours, given by the average number of hours attended. Second, we obtain the average number of hours of private study.

Our second main data source is the National Student Survey (NSS), conducted by HEFCE (Higher Education Funding Council for England) in collaboration with the NUS (National Union of Students). This annual survey, conducted since 2005, asks students a set of questions relating to teaching, assessment and feedback, academic support, organisation and management, learning resources, and personal development. The question we use from the NSS is Question 22: "Overall, I am satisfied with the quality of my course". The response is on a five-point scale, with higher values representing better quality. We use the average of this as a summary measure of the quality of teaching provided by the institution.

The NSS data on the HEFCE website (http://www.hefce.ac.uk/) includes information on the median entry scores of students by university. English students entering English universities almost always take the GCE A-level exam, taking three or four subjects. These exams are graded from A to E, with an A being worth 120 points, and each lower grade being worth 20 points less than the grade above, so that the lowest grade E is worth 40 points. Students with different entry qualifications (e.g. overseas students) have their qualifications converted into points on this scale. We use this median entry score as the measure of student entry grades.

Finally, the NSS data also includes information on the final degree outcomes by university and subject. In England, almost all degrees are classified as first class honours, upper second class honours, lower second class honours, third class honours, or ordinary or unclassified degrees. The NSS data gives information on the percentage of students that achieve each classification level. From this data we calculate the percentage of students who achieve a "good degree", by which is meant upper second class honours or first class honours. This percentage is used as our output measure.

Universities in the UK are prevented from giving good degrees to students who do not deserve them, by a system of external examiners who moderate university degrees. As a result of this moderation, degree results are not marked according to any distributional requirements. Also, whilst there is concern over grade inflation over time (see the survey in

(G. Johnes 2004)), it may be argued that this is much less of a problem for the two year sample used here than for one with a longer time dimension.

Our data uses average values as inputs and the percentage of good degrees as the output. This poses no difficulties of the type discussed in (Dyson *et. al.* 2001) provided the number of entrants and graduates are highly correlated, since in this case the number of students on the input and output sides cancel each other out. This is indeed the case: the correlation between the number of graduates and the number of entrants is greater than 0.9. That we use average values does however change the interpretation of our results. When we refer to scale economies, we mean for example that a doubling of average inputs would lead to a greater than double increase in the percentage of good degrees obtained.

A potential variation on our model would be to model the efficiency of university students in moving into employment, since it may be argued that this represents the true output of a university. However, graduate employment is as much a result of university effort and reputation as it is of students' effort which is the focus of the present paper. This does not preclude the development of a model to address university efficiency in securing graduate employment, but this is beyond the scope of the present paper.

Table 1 presents the descriptive statistics of the dataset, for all universities in the sample, and for pre-1992 and post-1992 universities. Pre-1992 universities are institutions that had university status prior to 1992. Post-1992 universities are institutions that were awarded university status as a result of the Further and Higher Education Act of 1992; these are primarily former polytechnics. In our sample of 78 universities we have 32 pre-1992 universities and 46 post-1992 universities; Appendix A lists the universities included in the sample.

/Table 1 about here/

Over half of all students obtained a good degree, with pre-1992 universities having a significantly higher percentage of students with good degrees. Pre-1992 universities also offered significantly more classroom hours, and their students spent significantly more hours on private study. Students at pre-1992 universities also reported higher levels of satisfaction (the difference is small but statistically significant), and had much higher A-level entry scores as well.

Table 2 reports the simple correlations between the variables of interest, again reported for all universities, and for pre-1992 and post-1992 universities. It is interesting to note that the correlations between the variables are different for the two groups of universities. In pre-1992 universities entry scores are highly positively correlated with degree performance, whereas this correlation is less strong for post-1992 universities. In post-1992 universities there is a positive correlation between the number of classroom hours, the hours of private study and student satisfaction, but in pre-1992 universities there is a negative correlation between the number of classroom and private hours. In pre-1992 universities entry scores are positively correlated with classroom hours and hours of private study, but this relationship is negative or non-existent for post-1992 universities. The results of Tables 1 and 2 suggest that there are important differences between pre-1992 and post-1992 universities and hence possibly in terms of the efficiency of their students as well. This difference between the two groups of universities is one of the aspects we will investigate in this paper.

/Table 2 about here/

Results

Efficiency and productivity change

In this paper we calculate the efficiency of students in English universities in 2006 and 2007 using the method of DEA as outlined above, using as the output the percentage of students graduating with good degrees as defined above. We estimate two models of efficiency. In the first model (the three-input model), we use as inputs the number of hours of private study and classroom hours attended from HEPI, and the quality of teaching from the NSS. In the second model (the four-input model), in addition to these three inputs, we also include the A-level entry scores as a fourth input. We then calculate the change in productivity and its decomposition in both three- and four-input models using the Malmquist index as outlined above. We perform the analysis for both the full sample of universities, and for the subsamples of pre-1992 and post-1992 universities separately.

Table 3 reports the means of the results for the DEA (results for individual universities are available from the authors upon request). Going from the three-input to the four-input model increases both CRS and VRS measures of technical efficiency; this is as expected, since the four-input model includes an additional explanatory variable hence should capture more of the variation in efficiency. Nevertheless the difference between the three-input and four-input models is not always statistically significant.

Average VRS technical efficiency is much higher than average CRS technical efficiency; this results in strong evidence of increasing returns to scale in most of the universities in the sample. There is strong evidence that pre-1992 universities are more scale-efficient and CRS-technical-efficient than post-1992 universities, whereas the difference in VRS technical efficiency between the two groups of universities is much smaller.

Comparing the results of Panel A and Panel B of Table 3, going from applying DEA to all universities together, to DEA for pre-1992 and post-1992 universities separately, does not significantly change the results for the pre-1992 universities. For post-1992 universities, CRS technical efficiency and scale efficiency are significantly higher when evaluated against post-1992 universities than when evaluated against all universities together. This result is perhaps expected given the relative inefficiency of the post-1992 universities in the full sample.

/Table 3 about here/

Figure 1 shows the histograms of each of the four measures of efficiency for 2006 and 2007 where DEA has been applied to the full sample of universities. From this figure it can be seen that there is considerable variation in efficiency across universities, and that the efficiency distribution has changed between the two years. In all cases the distribution has shifted leftwards relative to the frontier in 2007; as confirmed by Table 3, relative student efficiency has decreased between the two years. Also, efficiency in the constant returns models is much more dispersed than in the variable returns models.

/Figure 1 about here/

Figure 2 shows the histograms for CRS technical efficiency using the four-input all-universities model, dividing the sample into pre-1992 and post-1992 universities. From this figure it can be seen that, although post-1992 universities had on average lower CRS technical efficiency than pre-1992 universities (the difference is larger for the CRS models than for the VRS models), there is also significant overlap in efficiency. Therefore, knowing that a university is a pre-1992 university is not sufficient to identify it as a university with highly-efficient students.

/Figure 2 about here/

Table 4 shows the decomposition of the change in productivity between 2006 and 2007 using the Malmquist index. Overall there has been an average of between 2 and 4 percent increase in productivity between the two years depending on the model. When all universities are combined in the analysis (panel A in Table 4), this increase in productivity can be attributed to an improvement in technology of 9 percent using the three-input model, or 10 percent using the four-input model. This apparently large improvement in technology is partially offset by decreases in efficiency, by about 5 percent in the three-input model, or 7 percent in the four-input model. There are no significant differences in results between pre-1992 and post-1992 universities when all universities are combined.

/Table 4 about here/

The decrease in efficiency can be further decomposed into changes in pure efficiency and changes in scale efficiency. The decrease in pure efficiency is quite small (in the order of 1 to 2 percent), so that there is between a 4 and 6 percent decrease in scale economies depending on the model and universities. The results combining all universities is very similar to those obtained by comparing universities within each subsample of pre-1992 and post-1992 universities (panel B in Table 4).

The determinants of efficiency

In the previous subsection we established that university students in England differ in terms of their efficiency. This subsection develops an econometric model to explain the determinants of this difference in efficiency. This two-step procedure is proposed by (Coelli *et. al.* 2005); our approach here follows that of (Simar and Wilson 2007). We estimate a truncated regression model of the following form:

$$\begin{aligned}\theta_{it} \;=\; & \alpha_0 + \beta_1 \text{ Year} + \beta_2 \text{ Rank}_{it} + \beta_3 \text{ Post-92} + \beta_4 \text{ Size}_{it} + \beta_5 \text{ Staff}_{it} \\ & + \beta_6 \text{ \%Postgraduate}_{it} + \beta_7 \text{ \%Female}_{it} \\ & + \beta_8 \text{ \%Overseas}_{it} + \beta_9 \text{ \%Part time}_{it} + \varepsilon_{it} \qquad (6)\end{aligned}$$

where θ_{it} is the measure of efficiency. Year is a dummy for 2007. Rank is the rank of the university as measured by the Sunday Times University Guide and is a measure of the quality of the university. Post-92 is a dummy for whether or not the university is a post-1992 university. Size is the total number of students in the university, which captures the diversity of the student population. Staff is the number of academic staff in the university; by including this variable and the number of students we control for the staff-student ratio in the university. The remaining four variables capture the nature of the student population and possible peer-group effects. Here we have the percentage of postgraduate students (%Postgraduate), the percentage of female undergraduate students (%Female), the percentage of overseas undergraduate students (%Overseas), and the percentage of part-time undergraduate students (%Part time). Data for this second stage has been obtained from various sources including the Sunday Times University Guide and the Higher Education Statistics Agency (HESA).

As (Simar and Wilson 2007) note, a truncated regression is the appropriate method to use in this case since only the part of the distribution of the dependent variable not exceeding 1 is relevant to our computations. A Tobit regression is not appropriate here as the universities with efficiency equal to 1 do in fact have this efficiency level and are not censored; see (Davidson and MacKinnon 2004) for additional discussion. In addition, since the estimate of efficiency using DEA is biased and serially correlated, we use a nonparametric bootstrap (with 1000 replications) to calculate the standard errors, and we also use the bootstrap results to correct for the bias generated by the DEA. Finally, the variables used in the second stage regression (which are to do with university characteristics) are independent of the variables used in the first stage DEA (which are measures of the effort level of students). This reduces the bias in the second-stage regression.

Our reasoning for this division of variables is as follows. The outcome of a university degree depends on student effort, prior education and the teaching that he receives. Other influences for example the percentage of part-time students should impact on degree results only insofar as it influences student effort or the teaching received. Therefore in estimating efficiency we use only the direct influences on degree results, and in our second stage we use variables that may be considered to be environmental variables, or variables that are not under the control of students.

A final econometric issue is that the rank of a university may be endogenous in this model, since how efficient are students may influence degree results and hence university rankings (which are constructed from a composite measure which includes degree performance and research performance amongst other measures). We therefore also perform a two-stage-least-squares (2SLS) regression with university rank being instrumented by a measure of the research performance of the university obtained from the Research Assessment Exercise (RAE). This variable satisfies the properties of being a good instrument, since it is highly correlated with the rank of a university, yet should not directly influence the efficiency of university students beyond its impact on university rank.

Table 5 presents the results of the second-stage regression for the four-input VRS model relative to all universities, since this model is perhaps the closest to the true model of student output; results for the other models are similar and are available from the authors upon request. The table reports both standard truncated regression results and results with the university rank being instrumented using the 2SLS approach, with the observed and bias-corrected coefficients reported side-by-side. The overall fit is very good in both cases, with both regressions being jointly significant at 1 percent or better. The results are broadly similar between both models with one important exception. In columns (1) and (2), the rank of the university is positively related to the efficiency of students; that is, students at better universities (lower rank) are less efficient than those in lower-ranked universities. However, once we take into account the possible endogeneity of university rank in columns (3) and (4), this effect becomes no longer significant.

/ Table 5 about here/

The other results are quite consistent across specifications. The percentages of postgraduate and overseas students have no significant impact on the efficiency of students. Whether or not a university is a pre-1992 university has no significant impact on student efficiency once other factors have been controlled for. However, the higher the percentage of part-time students, the lower the efficiency. This is what may be expected, since part-time students often have to combine their studies with work or family commitments and hence may be less efficient than full-time students. The higher the percentage of female students, the higher the efficiency; this is significant at the 10 percent level once the endogeneity of university rank is controlled for, and suggests that female students are more efficient than male students.

The size of the university is positively and significantly related to efficiency in both models. The number of academic staff is significantly and negatively related to student efficiency; more academic staff reduces the efficiency of students. Taking this result together with that on student numbers may indicate that larger class sizes, contrary to popular opinion, may actually improve student efficiency, perhaps by providing students with more incentive for independent study and reducing their dependence on teaching. There is also evidence that students are becoming less efficient relative to the frontier, as the 2007 dummy is negative and highly significant in all specifications; this confirms the observations in Table 3 and Figure 1. Finally, correcting the regression estimates for the bias of the DEA does not materially change any of the results.

Conclusions

In this paper we estimate the efficiency of university students in England in producing degree results. From our sample of 78 universities in 2006 and 2007 using the method of Data Envelopment Analysis (DEA), we find that students have different levels of efficiency across universities. Technology has improved between 2006 and 2007, but technical efficiency has decreased. Pre-1992 and post-1992 universities exhibited differences in efficiency, with post-1992 universities having lower CRS technical efficiency and scale efficiency. However, we do not find evidence of differences in efficiency change across the two groups of universities. We also find in a second-stage regression that students in larger universities, in universities with fewer academic staff and fewer part-time students are more efficient. The quality of a university has no significant impact on the efficiency of its students once the endogeneity of university quality is controlled for.

Our results have important policy implications. The Report of the National Committee of Enquiry into Higher Education 1997 (also known as the Dearing Report) recommended amongst other things the rapid expansion of the UK university sector. Over the decade from 1996 to 2006 the total number of higher education students in the UK has increased from 1.75 million to 2.36 million, an increase of one-third, representing a participation rate in higher education of over 45 percent. With such a large percentage of the age-group in higher education it is perhaps unsurprising that we find such diversity in the efficiency of students. This diversity in student efficiency also suggests that heterogeneity in the organisation of university education might be more appropriate than a one-size-fits-all approach. Moreover, our results also indicate that there is sufficient overlap in the efficiency of pre-1992 and post-1992 universities such that the simple binary divide may no longer be adequate.

References

Arulampalam W, Naylor R A and Smith J (2007). Am I missing something? The effects of absence from class on student performance. *Warwick Economic Research Paper* No. 820.

Bekhradnia B, Whitnall C and Sastry T (2006). *The academic experience of students in English universities*. Higher Education Policy Institute Report.

Coelli T J (1996). A guide to DEAP Version 2.1: A Data Envelopment Analysis (Computer) Program. *Centre for Efficiency and Productivity Analysis Working Paper* No. 8/96.

Coelli T J, Rao D S P, O'Donnell C J and Battese G E (2005). *An Introduction to Efficiency and Productivity Analysis* 2nd Edition. New York, Springer.

Cohn E and Cooper S T (2004). Multi-product cost functions for universities: economies of scale and scope. In Johnes G and Johnes J (eds). *International Handbook on the Economics of Education*, Cheltenham, UK, Edward Elgar.

Davidson R and MacKinnon J G (2004). *Econometric Theory and Methods*. Oxford, Oxford University Press.

Dyson R G, Allen R, Camanho A S, Podinovski V V, Sarrico C S and Shale E A (2001). Pitfalls and protocols in DEA. *European Journal of Operational Research* 132: 245-259.

Fare R, Grosskopf S, Norris M and Zhang Z (1994). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries. *American Economic Review* 84(1): 66-83.

Fare R, Grosskopf S and Norris M (1997). Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries: Reply. *American Economic Review* 87(5): 1040-1044.

Johnes G (2004). Standards and grade inflation. In Johnes G and Johnes J (eds). *International Handbook on the Economics of Education*, Cheltenham, UK, Edward Elgar.

Johnes G, Johnes J, Thanassoulis E, Lenton P and Emrouznejad A (2005). An exploratory analysis of the cost structure of higher education in England. *Department for Education and Skills Research Report* No. 641.

Johnes J (2004). Efficiency measurement. In Johnes G and Johnes J (eds). *International Handbook on the Economics of Education*, Cheltenham, UK, Edward Elgar.

Johnes J (2006a). Measuring teaching efficiency in higher education: An application of data envelopment analysis to economics graduates from UK universities 1993. *European Journal of Operational Research* 174: 443-456.

Johnes J (2006b). Measuring efficiency: A comparison of multilevel modelling and data envelopment analysis in the context of higher education. *Bulletin of Economic Research* 58(2): 75-104.

Johnes J (2006c). Data envelopment analysis and its application to the measurement of efficiency in higher education. *Economics of Education Review* 25(3): 273-288.

Johnes J (2008). Efficiency and productivity change in the English higher education sector from 1996/97 to 2002/03. *Manchester School* 76(6): 653-674.

Lazear E P (2001). Educational production. *Quarterly Journal of Economics* 116(3): 777-803.

Martins P and Walker I (2005). Student achievement and education production: A case-study of the effect of class attendance. Mimeo, Queen Mary, University of London.

Naylor R A and Smith J (2004). Determinants of educational success in higher education. In Johnes G and Johnes J (eds). *International Handbook on the Economics of Education*, Cheltenham, UK, Edward Elgar.

Ray S C and Desli E (1997). Productivity Growth, Technical Progress, and Efficiency Change in Industralized Countries: Comment. *American Economic Review* 87(5): 1033-1039.

Sastry T and Bekhradnia B (2007). *The academic experience of students in English universities*. Higher Education Policy Institute Report.

Simar L and Wilson P W (2007). Estimation and inference in two-stage, semi-parametric models of production processes. *Journal of Econometrics* 136(1): 31-64.

Stanca L (2006). The effects of attendance on academic performance: Panel data evidence for Introductory Microeconomics. *Journal of Economic Education* 37(3): 251-266.

Todd P E and Wolpin K I (2003). Towards a unified approach for modelling the production function for cognitive achievement. *Economic Journal* 113(485): 3-33.

Table 1: Descriptive statistics.

Variable	All universities Mean	All universities Std. Dev.	Pre-1992 universities Mean	Pre-1992 universities Std. Dev.	Post-1992 universities Mean	Post-1992 universities Std. Dev.
% good degree	56.092	9.941	64.232**	7.749	50.430	6.910
Attended hours	12.515	1.758	12.906*	2.188	12.244	1.329
Private study	12.257	1.728	12.638*	1.352	11.991	1.910
Satisfaction	3.981	0.161	4.087**	0.138	3.907	0.133
Median A-level	292.82	74.21	364.29**	52.45	243.09	37.19

Notes: This table shows averages across 2006 and 2007. The number of universities N = 78 for all universities, N = 32 for pre-1992 universities, and N = 46 for post-1992 universities. *, ** indicates that the means for pre-1992 and post-1992 universities are significantly different from one another at the 5% and 1% level respectively.

Table 2: Correlations between variables.

All universities

	Good degree	Attended hours	Private study	Satisfaction	Median A-level
Good degree	1.0000				
Attended hours	0.0302	1.0000			
Private study	0.1755	0.0866	1.0000		
Satisfaction	0.4240	0.2077	0.1410	1.0000	
Median A-level	0.7525	0.2330	0.1920	0.5894	1.0000

Pre-1992 universities

	Good degree	Attended hours	Private study	Satisfaction	Median A-level
Good degree	1.0000				
Attended hours	-0.1734	1.0000			
Private study	0.1337	-0.1034	1.0000		
Satisfaction	0.1506	-0.0089	0.0738	1.0000	
Median A-level	0.7173	0.2469	0.2621	0.3206	1.0000

Post-1992 universities

	Good degree	Attended hours	Private study	Satisfaction	Median A-level
Good degree	1.0000				
Attended hours	-0.0927	1.0000			
Private study	0.0349	0.1899	1.0000		
Satisfaction	0.0176	0.2986	0.0358	1.0000	
Median A-level	0.1945	-0.0225	-0.0485	0.2754	1.0000

Table 3: Efficiency over time.

Panel A: DEA applied to all universities										
		CRS technical efficiency			VRS technical efficiency			Scale efficiency		
Year	**Model**	**All**	**Pre-1992**	**Post-1992**	**All**	**Pre-1992**	**Post-1992**	**All**	**Pre-1992**	**Post-1992**
2006	3-input	0.7869	0.8716	0.7280**	0.9527	0.9504	0.9542	0.8247	0.9154	0.7615**
	4-input	0.8517	0.8928	0.8232**	0.9611	0.9512	0.9680	0.8852	0.9372	0.8491**
2007	3-input	0.7478	0.8243	0.6946**	0.9443	0.9389	0.9481	0.7903	0.8759	0.7308**
	4-input	0.7917	0.8367	0.7604**	0.9471	0.9400	0.9520	0.8342	0.8884	0.7966**

Panel B: DEA applied to pre-1992 and post-1992 universities separately										
		CRS technical efficiency			VRS technical efficiency			Scale efficiency		
Year	**Model**	**All**	**Pre-1992**	**Post-1992**	**All**	**Pre-1992**	**Post-1992**	**All**	**Pre-1992**	**Post-1992**
2006	3-input	0.8269	0.8716	0.7958**	0.9588	0.9640	0.9551	0.8612	0.9032	0.8319**
	4-input	0.8626	0.9086	0.8306**	0.9679	0.9673	0.9683	0.8901	0.9386	0.8564**
2007	3-input	0.7843	0.8248	0.7562*	0.9566	0.9628	0.9522	0.8181	0.8558	0.7919*
	4-input	0.8197	0.8769	0.7799**	0.9593	0.9673	0.9538	0.8527	0.9061	0.8155**

Notes: ** indicates that the pre-1992 and post-1992 averages are significantly different from each other at the 1% level. N = 32 for pre-1992 universities, and N = 46 for post-1992 universities.

Table 4: Productivity change.

Panel A: Malmquist index applied to all universities							
	Model	**Productivity change**	**Efficiency change**	**Technical change**	**Pure efficiency change**	**Scale change**
3-input	All	1.0413	0.9538	1.0928	0.9919	0.9610
	Pre-1992	1.0383	0.9459	1.0978	0.9889	0.9563
	Post-1992	1.0434	0.9593	1.0893	0.9940	0.9643
4-input	All	1.0243	0.9318	1.1004	0.9859	0.9444
	Pre-1992	1.0312	0.9373	1.1011	0.9891	0.9476
	Post-1992	1.0194	0.9279	1.0999	0.9837	0.9421

Panel B: Malmquist index applied to pre-1992 and post-1992 universities separately						
	Model	**Productivity change**	**Efficiency change**	**Technical change**	**Pure efficiency change**	**Scale change**
3-input	All	1.0297	0.9507	1.0844	0.9982	0.9522
	Pre-1992	1.0381	0.9465	1.0967	0.9995	0.9469
	Post-1992	1.0238	0.9537	1.0758*	0.9973	0.9558
4-input	All	1.0211	0.9533	1.0727	0.9916	0.9607
	Pre-1992	1.0236	0.9669	1.0590	1.0008	0.9662
	Post-1992	1.0193	0.9438	1.0823*	0.9853*	0.9569

Note: *, ** indicates that the pre-1992 and post-1992 averages are significantly different from each other at the 5% and 1% level, respectively. N = 32 for pre-1992 universities, and N = 46 for post-1992 universities.

Table 5: Second-stage results.

Dependent variable: Technical efficiency as measured by DEA applied to all universities using a 4-input variable returns to scale model.				
	Truncated regression		Truncated regression with 2SLS	
	Observed	Bias-corrected	Observed	Bias-corrected
	(1)	(2)	(3)	(4)
Rank	0.051	0.051	-0.016	-0.018
	(2.34)**	(2.34)**	(0.42)	(0.45)
Post-1992 dummy	-0.011	-0.012	0.012	0.012
	(1.00)	(1.02)	(0.66)	(0.67)
Size (000)	0.004	0.004	0.004	0.004
	(4.40)***	(4.44)***	(4.50)***	(4.59)***
Staff (000)	-0.060	-0.061	-0.075	-0.077
	(2.96)***	(2.99)***	(3.50)***	(3.59)***
% Overseas	0.086	0.077	0.095	0.090
	(1.03)	(0.92)	(1.09)	(1.04)
% Postgraduate	-0.020	-0.015	-0.054	-0.051
	(0.30)	(0.23)	(0.82)	(0.77)
% Part-time	-0.087	-0.087	-0.078	-0.078
	(2.80)***	(2.80)***	(2.40)**	(2.42)**
% Female	0.068	0.069	0.084	0.086
	(1.53)	(1.53)	(1.75)*	(1.79)*
Year = 2007	-0.012	-0.013	-0.011	-0.011
	(2.21)**	(2.23)**	(2.03)**	(2.03)**
Constant	0.882	0.881	0.903	0.902
	(29.46)***	(29.42)**	(29.51)***	(29.46)***
Observations	121		121	
Log-likelihood	275.68		273.39	
Chi-squared	32.91		29.07	
p-value	0.00		0.00	

Notes: z statistics in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%. Estimation method is truncated regression with standard errors obtained from 1000 bootstrap replications. In the 2SLS results in columns (3) and (4) the Sunday Times rank is assumed to be endogenous and is instrumented using a measure of research quality based on the Research Assessment Exercise. The number of observations is fewer than in the first stage DEA because the truncated regression omits observations where the technical efficiency is equal to 1, and there are several observations with missing values for some variables. Chi-squared is the chi-squared test of the joint significance of all variables included in the regression, and p-value is the p-value of this test.

Figure 1: Histograms of CRS and VRS efficiency relative to full sample.

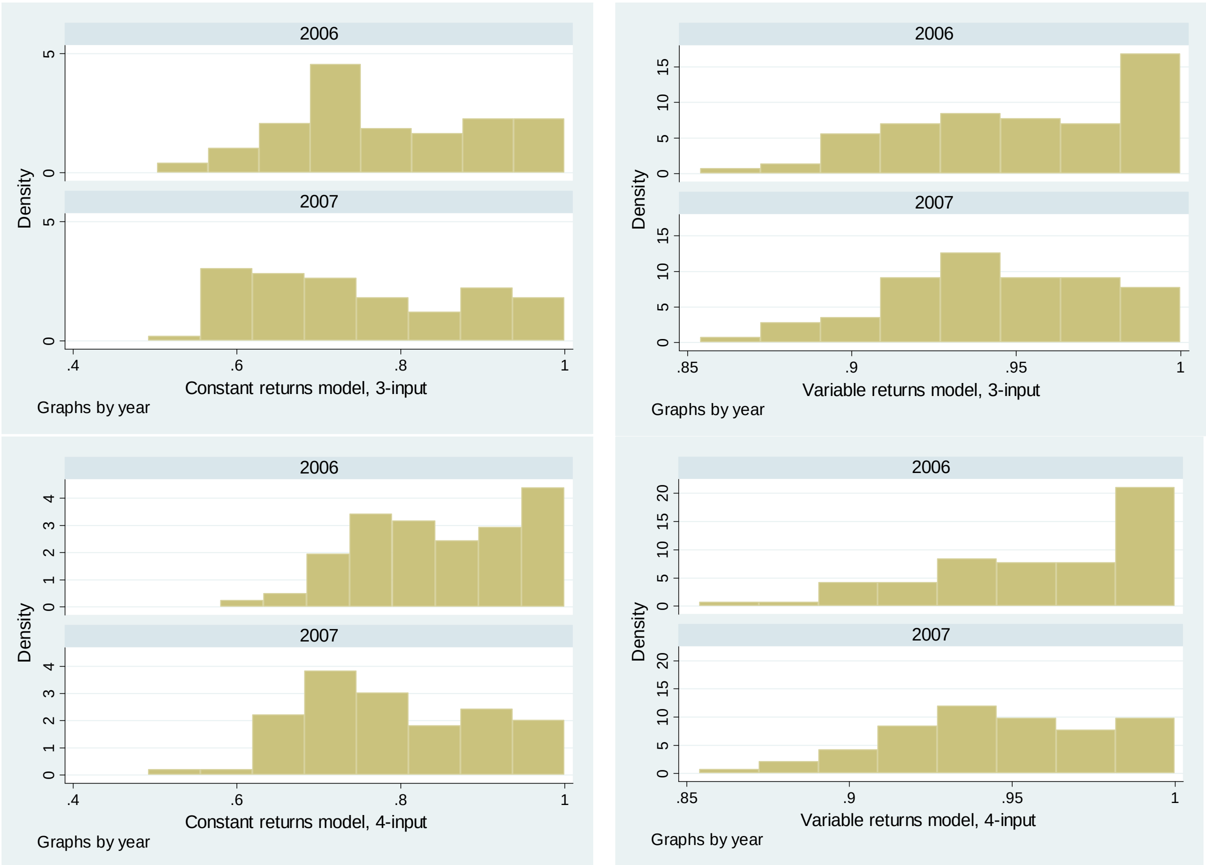
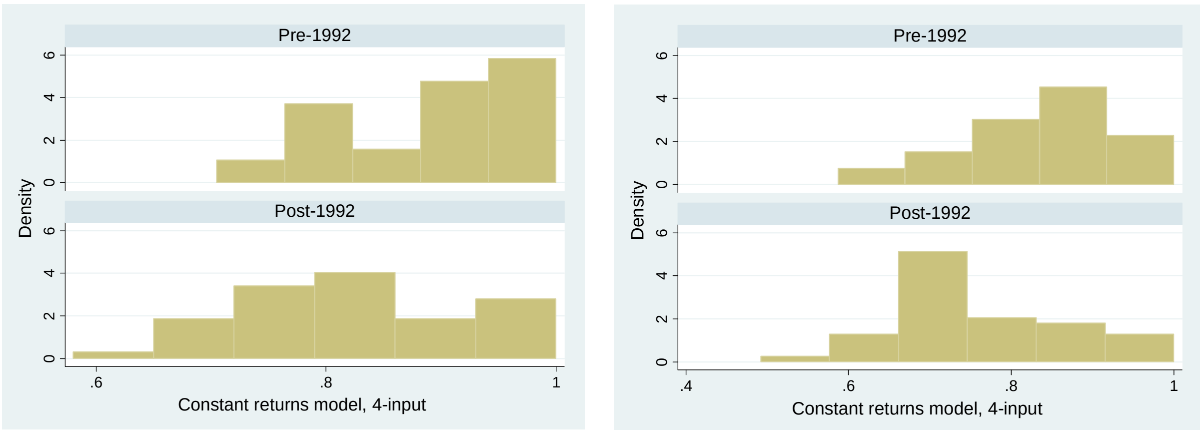


Figure 2: Histograms of CRS four-input efficiency relative to full sample.

2006 2007



Appendix A: List of universities in the sample.

Pre-1992 Universities	Post-1992 Universities
Aston University	Bishop Grosseteste
University of Bath	Buckinghamshire Chilterns
University of Bradford	University of Chester
University of Bristol	Canterbury Christ Church
Brunel University	York St John University College
City University	Edge Hill University
University of Durham	University College Falmouth
University of East Anglia	University of Winchester
University of Essex	Liverpool Hope University
University of Exeter	University of Northampton
University of Hull	Newman College
Keele University	Roehampton University
University of Kent	Southampton Solent University
Lancaster University	University of Worcester
University of Leeds	Anglia Ruskin University
University of Leicester	Bath Spa University
University of Liverpool	University of Bolton
Goldsmiths College	Bournemouth University
Imperial College	University of Brighton
King's College	UCE
Queen Mary	University of Central Lancashire
SOAS	University of Gloucestershire
Loughborough University	Coventry University
University of Newcastle	University of Derby
University of Nottingham	University of Greenwich
University of Reading	University of Hertfordshire
University of Salford	University of Huddersfield
University of Sheffield	University of Lincoln
University of Southampton	Kingston University
University of Surrey	Leeds Metropolitan University
University of Sussex	Manchester Metropolitan University
University of York	Middlesex University
	De Montfort University
	Northumbria University
	Nottingham Trent University
	Oxford Brookes University
	University of Plymouth
	University of Portsmouth
	Sheffield Hallam University
	Staffordshire University
	University of Sunderland
	University of Teesside
	UWE
	University of Chichester
	University of Westminster
	University of Wolverhampton

Table and Figure captions

Table 1: Descriptive statistics.

Table 2: Correlations between variables.

Table 3: Efficiency over time.

Table 4: Productivity change.

Table 5: Second-stage results.

Figure 1: Histograms of VRS and CRS efficiency relative to full sample.

Figure 2: Histograms of CRS four-input efficiency relative to full sample.

Appendix A: List of universities in the sample.