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MEASURING TEACHING EFFICIENCY IN HIGHER EDUCATION: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS TO GRADUATES FROM UK UNIVERSITIES 1993

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ABSTRACT

Data envelopment analysis (DEA) is applied to 2568 graduates from UK universities in 1993 in order to assess teaching efficiency. Following a methodology developed by Thanassoulis & Portela (2002), each individual's efficiency is decomposed into two components: one attributable to the university at which the student studied, and the other attributable to the student himself. From the former component, a measure of each institution's teaching efficiency is derived and compared to efficiency scores derived from a conventional DEA applied using each institution as a decision making unit (DMU). The results suggest that efficiencies derived from DEAs performed at an aggregate level include both institution *and* individual components, and are therefore misleading. Thus the unit of analysis in a DEA is highly important. Moreover, an analysis at the individual level can give institutions insight into whether it is the students' own efforts or the institution's efficiency which are a constraint on increased efficiency.

JEL Classification: I21, C14
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1. INTRODUCTION

Studies of university efficiency have largely taken three distinct approaches: a university level approach, where the unit of observation is the institute of higher education itself (J. Johnes, 1996; Avkiran 2001); a subject level approach, where the unit of observation is a department within the institution (Beasley, 1990, 1995; Johnes & Johnes, 1992, 1993); and an individual level approach, where the unit of observation is the individual student (Smith *et al*, 2000; Rodgers & Ghosh, 2001; Bratti, 2002). Various technical approaches have also been applied to measuring university efficiency, the main distinction being between a parametric approach and a non-parametric approach. Parametric techniques which have commonly been applied include regression methods and limited dependent variable models. The former have been applied at both the level of the institution of higher education (J. Johnes & Taylor, 1990) and at the level of subject area within the higher education institution (J. Johnes, 1997). Logit and probit models have been used both when analysing the outcomes of individual students (Smith & Naylor, 2001; Bratti, 2002) and also when investigating variations in research performance of cost centres within universities (J. Johnes *et al*, 1993). Non-parametric techniques such as data envelopment analysis (DEA) have also been applied successfully at both the level of institutions of higher education and the level of departments or subject areas within the higher education institutions (Athanassopoulos & Shale, 1997; Avkiran, 2001; Abbott & Doucouliagos, 2002; Tomkins & Green, 1988; Beasley, 1990; 1995; Johnes & Johnes, 1992; 1993). The latter approach, however, has not yet been applied to evaluate the efficiency of *individuals* within higher education.

Ideally, a method applied to individual level data should allow for variation in student outcome by university as well as by individual. Multilevel modelling is a parametric approach which allows for just such variation, and has typically been applied to primary and secondary school pupils to determine school efficiency (Aitken & Longford, 1986; Goldstein & Thomas, 1996; Goldstein & Sammons, 1997; Yang & Woodhouse, 2001). An alternative to multilevel modelling exists in the form of the non-parametric technique, namely DEA. Typically DEA has been applied to data sets where the DMUs can be seen as 'firms' converting inputs into outputs, for example banks (Sherman & Ladino, 1995), health service (Giuffrida & Gravelle, 2001), and farms (Wadud & White, 2000). In education, DEA has increasingly been used to measure efficiency, in primary schools (Mancebon & Mar Molinero, 2000), secondary schools (Bonesrønning & Rattsø 1994; Kirjavainen & Loikkanen, 1998; Mante, 2001; Ramanathan, 2001; Bradley *et al*, 2001) and universities or other institutions of higher education (Athanassopoulos & Shale, 1997; Sarrico & Dyson, 2000; Avkiran, 2001). More recently, DEA has been used to measure the efficiency of school *pupils* in secondary school examination performance. These *individual* efficiencies have then been used to ascertain the contribution of each pupil's *school* to his efficiency level (Portela & Thanassoulis, 2001; Thanassoulis & Portela, 2002). Thus, the application of DEA to individual pupils can offer insights into the efficiency of the institution at which they study.

The purpose of the present paper is to apply the DEA methodology to *individual students* who graduated from the traditional university sector in 1993. The results will then be used to assess what insights, if any, can be offered into the teaching efficiency of the institutions from which the students graduated. Particular interest will be shown in how the results of a DEA of individuals compare with the results of DEAs applied to aggregate data in order to ascertain whether the unit of analysis affects the results of DEA. The paper comprises 5 sections of which this is the first. The next section gives a general overview of the DEA methodology and describes how it can be applied at the level of the individual student. Section 3 reviews the literature on the determinants of teaching output, while the results of applying DEA to a dataset of 1993 graduates are reported in section 4. Conclusions are drawn in section 5.

2. METHODOLOGY

DEA has developed considerably since its first inception by Farrell in 1957, and a full bibliography of these developments and applications can be found in Seiford (1994) and Tavares (2002). Although an input-oriented approach is more commonly used in empirical applications, it is more appropriate in the present context to use an output-oriented approach: in a given year, once an individual student is at university, his characteristics (both social and academic) are fixed, and therefore his efficiency (in terms of academic achievement at university) is maximized by maximizing outputs subject to his given level of inputs. In an output-oriented framework with variable returns to scale (VRS) the DEA dual[1] is:

$$\text{Maximize} \qquad \phi_k - \varepsilon \sum_{r=1}^{s} s_r - \varepsilon \sum_{i=1}^{m} s_i \tag{1}$$

$$\text{Subject to} \qquad \phi_k y_{rk} - \sum_{j=1}^{n} \lambda_j y_{rj} + s_r = 0 \qquad r = 1,\ldots,s \tag{2}$$

$$x_{ik} - \sum_{r=1}^{n} \lambda_j x_{ij} - s_i = 0 \qquad i = 1,\ldots,m \tag{3}$$

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{4}$$

$$\lambda_r, s_r, s_i \geq 0 \qquad \forall r = 1,\ldots,s; i = 1,\ldots,m$$

where there are s outputs and m inputs; y_{rk} is the amount of output r used by DMU k; x_{ik} is the amount of input i used by DMU k; and s_r, s_i are the output and input slacks respectively. Technical efficiency of DMU k is measured by $1/\phi_k$. The VRS dual differs from the constant returns to scale (CRS) dual only by the inclusion of the constraint in equation (4). Comparison of the efficiencies derived from the above with the CRS efficiencies allows the derivation of measures of pure technical efficiency and scale efficiency.

In the context of measuring teaching efficiency in higher education, a number of options exist for the definition of DMUs: the institutions of higher education; the departments within the institutions; or the individual students in the higher education sector. If the individual students are treated as DMUs, then applying DEA to all students across the higher education sector means that allowance should be made for the likely variation in output level by *university* as well as by *individual*. Thus, each student's efficiency score obtained from applying DEA to all students in the higher education sector would incorporate a component which was a consequence of the student's own efforts and a component which was a consequence of the efficiency in teaching of the university attended by the student. In order to assess the efficiency of the institutions of higher education, it would therefore be necessary as a first step to

[1] The dual terminology is consistent with Charnes, Cooper and Rhodes, 1978. But note that output maximization from given inputs (i.e. an output-oriented approach) is achieved through a primal which minimizes the objective function (Norman & Stoker, 1991).

decompose the students' efficiency scores into these two components. Consider a hypothetical data set of students from two universities. Each university produces the 'output' of graduates with degrees, the quality of which is measured by degree results, using the 'input' of initial student quality, measured by entry qualification. The output and input data can be plotted for all students (see Figure 1).

The boundary EFCD envelops all students and is (in line with the terminology of Thanassoulis & Portela, 2002) the student-within-all-universities efficiency boundary, students lying on segments EF and CD being boundary but not efficient. Thus, using the traditional DEA definition of efficiency, student F, who lies on the student-within-all-universities efficiency frontier, has an efficiency score of 1, whereas student Y, who lies inside the student-within-all-universities efficiency frontier, has an overall efficiency level of OY/OY" which is less than 1[2]. In other words, OY/OY" represents the proportion of degree achievement obtained by student Y relative to the best achievement obtained by students from all universities, *and* given student Y's initial qualifications.

This student-within-all-universities efficiency score, however, ignores the effect that the university has on the student's level of achievement. Students from university T, for example, have their own efficiency boundary (termed the student-within-own-university efficiency boundary), defined by ABCD. Similarly, the student-within-own-university efficiency boundary for university S is EFGH. Thus student Y (from university T) has a student-within-own-university efficiency score of OY/OY', which represents the proportion of degree achievement obtained by student Y relative to the best achievement obtained by students from university T only *and* given student Y's initial qualifications. The distance Y'Y" gives a measure of the impact of student Y's university on his degree result. The university-within-universities efficiency score, specific to student Y, is defined as the ratio OY'/OY".

In summary, student Y has a student-within-all-universities efficiency of OY/OY", of which OY/OY' is due to the student's own efforts, and OY'/OY" is due to the efficiency of the university attended by student Y. This can be contrasted with student G from university S who has a student-within-own-university efficiency score

[2] Note that the efficiency score is derived using the vertical distance from the frontier in the output-oriented framework; this contrasts with the input-oriented approach where the efficiency score is derived using the horizontal distance from the frontier. Under VRS the measures may differ for inefficient universities.

of 1 (this student is achieving the best degree that he can relative to students within the same university and given his entry qualification), but a university-within-all-universities efficiency score of OG'/OG" = OG/OG" (i.e. less than 1) because of the university's inefficiency.

3. POSSIBLE OUTPUTS FROM AND INPUTS TO THE HIGHER EDUCATION TEACHING PROCESS

The correct specification of the student inputs and outputs in the higher education teaching process is crucial in the derivation of the DEA efficiency score for each DMU. The more inputs and outputs that are included in the DEA, the greater will be the expected proportion of efficient DMUs and the higher will be the expected overall average efficiency (Chalos 1997). There is not, however, a method for determining the inputs and outputs which ought to be included in a DEA. As a consequence, this section looks at evidence from previous statistical studies on the measurement and determinants of teaching output, as an aid to specifying and defining an appropriate set of inputs and outputs for the higher education teaching process in the following section.

The possible outputs from the teaching process are numerous (J Johnes & Taylor, 1990; G Johnes, 1992; J Johnes, 1996), but actual measures of teaching output for which data are available are fewer. Common measures of teaching output are based on graduation and completion rates (J Johnes & Taylor, 1990; J Johnes, 1996). Measures based on the actual degree results obtained by graduates are used to capture an element of both quantity and quality of teaching output, and this approach will be used in this paper.

Turning to possible inputs, the most obvious is the quality of the student on arrival at university, and there is strong evidence of a positive relationship between previous academic achievement and degree results (Freeman 1970; Kapur 1972; Tarsh 1982; Crum & Parikh 1983; Sear 1983; Rudd 1984; Montague & Odds 1990; J Johnes 1992; Chapman 1994; Rodgers & Ghosh 2001; Smith & Naylor 2001; Bratti 2002), although there is a suggestion that the association is weaker than expected a priori (Bligh *et al* 1979; Tarsh 1982; Sear 1983; Rudd 1984; Smith 1990). One explanation for this is that the analysis of graduates from a variety of subjects conceals variations between subjects in the strength of the relationship between school qualifications and degree results. Evidence suggests that it is strongest amongst science graduates and weakest amongst arts and social sciences graduates (Entwistle & Wilson 1977; Sear 1983).

Degree results appear to differ between male and female graduates with males achieving worse degree results than females (Rudd 1984; Rodgers & Ghosh 2001; Smith & Naylor 2001). Other personal characteristics which appear to have a clear effect on degree performance include marital status and country of origin. Married students and students who are not from abroad perform better in their degrees than, respectively, unmarried students and those from abroad (Smith & Naylor, 2001).

Type of degree and subject of study could be expected to affect degree performance. There is limited evidence that part-time students perform less well than full-time students (Smith & Naylor 2001) while there is substantial evidence that degree performance varies by subject (Higher Education Quality Council, 1996; Rodgers & Ghosh 2001). The latter result suggests a need for comparing students within a subject of study rather than across the spectrum of subjects. This approach is taken in numerous statistical studies of the relationship between student inputs and student outputs (Smith 1990; Jenkins & Smith 1993; Bratti 2002).

Other possible characteristics which have been tested for their effect on degree achievement include age, socio-economic status and living accommodation whilst at university, but the evidence is mixed. The relationship between a graduate's age and his degree classification has been found to be significantly negative (Barnett & Lewis 1963; Barnett *et al* 1968; Kapur 1972; Entwistle & Wilson 1977), significantly positive (Walker 1975; Eaton & West 1980; Smith & Naylor 2001) and zero (Nisbett & Welsh 1972; Smith 1990). Further examination reveals the possibility that the relationship may vary according to degree subject (Woodley 1984; Smithers & Griffin 1986; J Johnes 1992): in one study, mature students were shown to perform particularly well in arts subjects and least well in the sciences (Walker 1975). Similarly, when type of school attended by graduates is used as a proxy for socio-economic status, there is evidence that attending a grammar or independent school has a positive effect on degree results (Barnett & Lewis, 1963), but this contrasts with more recent results which suggest that attending an independent school has a negative effect on degree results (Smith & Naylor, 2001), or that type of secondary school attended has no relationship with degree results (Rodgers and Ghosh, 2001). When the effect of parental occupation is tested, the recent finding of a positive relationship between social class and degree results (Smith & Naylor 2001) is at odds with an earlier finding of no relationship between the two (J Johnes 1992). The effect of living accommodation whilst at university on degree results is also unclear: in a study at university level, the percentage of student living at home is negatively related to degree performance (J Johnes & Taylor, 1987), but in a more recent study using individual graduates, the opposite is found (Smith & Naylor 2001). The mixed nature of the results regarding these characteristics suggests that particular care should be taken if including in a DEA analysis.

All the findings reported above concern the role which a graduate's personal characteristics play in determining his degree result. The quality of the institution attended has also been demonstrated to be an important determinant of degree achievement, although less so than personal characteristics (Astin 1968). There is evidence, however, that degree results vary according to institution or broad category of institution (Bligh *et al* 1979; Bee & Dolton 1985; J Johnes & Taylor 1987; 1990). Differences between institutions in the personal characteristics of the students recruited no doubt accounts for some of the inter-institutional variation in degree results. That variation which cannot be accounted for by the students' personal characteristics must therefore be attributed to the university's own characteristics and quality of teaching. The extent to which each student's efficiency in achieving their degree result is a consequence of the student's own characteristics and how much is a consequence of the institution's quality of teaching is the subject of the ensuing analysis.

4. DATA AND RESULTS

The analysis requires a full data set of the performance and personal characteristics of individuals leaving their institution of higher education in a given year. Such a data set, compiled by the Universities Statistical Record (USR)[3] of more than 117000 students (from pre-1992 universities) leaving university in 1993 fulfils the criteria required and therefore forms the basis of the analysis[4].

[3] The data set was made available by the USR and the UK Data Archive.

[4] Students who failed, were classed as aegrotat or enhanced first degree, or left university for non-academic reasons have been deleted. In addition, students from Scottish universities or whose main entry qualification was Scottish Certificate of Education have been deleted in order to avoid problems which may arise from the inclusion of individuals who are from a system of education which differs from that in the rest of the UK.

Section 3 reports a body of evidence suggesting a substantial difference between subjects in the pattern of degree results, and in the determinants of degree achievement. Therefore, in order to avoid potential problems arising from a cross-subject comparison, the methodology is applied and assessed using a subset of 2568 graduates whose major or joint major subject was coded as economics. Two possible (and alternative) measures of degree performance have been constructed, DEGMARK and DEGVALUE. It was also possible to construct a number of input measures reflecting both academic and personal characteristics. Academic ability on arrival at university is measured by total A level score (ASCORE). Variables reflecting gender, marital status, nationality, type of degree course, type of accommodation and type of school attended have also been constructed. A full definition of all output and input measures used in the analysis is provided in the appendix[5]. The spread of graduates by degree class and various characteristics is illustrated in table 1. The relationship between degree results and, respectively, previous academic attainment, gender and nationality is as expected from previous studies (reported in section 3). Marital status shows little relationship with degree results, while type of degree course (part-time or not part-time) shows the opposite relationship from that expected (see section 3). Of the variables for which previous studies indicated mixed results with regard to their relationship with degree results, living at home while a student and attending a school other than an independent school have a positive relationship with degree results here.

As pointed out earlier, DEA can be sensitive to the number and definition of inputs and outputs included in the analysis. Thus, several DEA runs have been tried, and these are described in the appendix. The specification of inputs has been determined by both previous evidence and the findings in table 1. A summary of efficiencies across all students for each model is presented in table 2, from which it is clear that the variation in all measures of efficiency is quite small compared with the variation found when applying a similar methodology to school pupils (Thanassoulis & Portela, 2002). The small level of variation here is consistent with the smaller degree of variation in the academic ability of the individuals in the study, compared to the much wider spread of ability in school pupils. Table 2 shows a similar pattern of mean, median and maximum efficiencies across all runs, but the value of minimum efficiency is consistently lower when DEGMARK rather than DEGVALUE is the

[5] There was little variability in age of the students retained in the study and so this variable was not included in the analysis.

measure of output. The correlations of efficiencies derived from different DEA runs shown in table 3 suggest that the efficiencies are insensitive to whether DEGMARK or DEGVALUE is used as the measure of degree performance, since all correlations are highly significant.

The summary across all students conceals some potentially interesting variations in efficiencies between students from different universities. Thus table 4 shows a summary of efficiencies by department. Several points of interest emerge from this table. First, when initial academic ability (as measured by ASCORE) is the only input, the mean university-within-all-universities efficiency measure varies from 0.85 to 1, with 11 departments (of the 37 under consideration) achieving a score of 1. When additional inputs are included in the model, the spread of mean university-within-all-universities efficiencies remains the same, but only 2 departments achieve a score of 1. Second, a small number of departments are particularly sensitive to the specification of inputs in the DEA run. Consider, for example, department 21 which is a top performer in terms of mean university-within-all-universities efficiency score when initial academic ability is the only input, but which falls to the middle third of the table, with a mean university-within-all-universities efficiency score of 0.95, when additional inputs are included. A similar picture emerges for department 13, whereas department 37 experiences and even bigger drop in position and mean university-within-all-universities efficiency score (from 1 to 0.90).

Two obvious questions arise from examining the individual level efficiencies by department. First, do the mean university-within-all-universities efficiency scores derived for each department give a different picture of the performance of departments than that derived from a DEA performed at department level (i.e. with each department as a DMU)? Second, do the results from this individual level analysis offer insights into each department's performance which cannot be derived from a higher level DEA?

In order to answer the first question, the same individual data is aggregated to the level of departments, which are then treated as DMUs. The results of various possible DEA runs on this department level data are shown in table 5. It is clear that most of the runs give a similar picture of department efficiency; correlations of these efficiencies are all significant at the 5% significance level apart from correlations between the efficiencies of run 8 and the efficiencies of six other runs. Thus only run

8, where the outputs are number of graduates and number of first and upper second degrees, and the only input is average A level score, stands out as different from the other DEA runs.

Table 6, which shows the correlations between the department level and individual level efficiencies, reveals interesting differences between the approaches. When the department level DEA runs are compared with the mean university-within-all-universities efficiencies derived from the individual DEA runs, the correlations vary from an insignificant 0.098 to a highly significant (but not particularly high) 0.571. Generally, the department level runs which include only ACSORE as an input are significantly correlated with the mean university-within-all-universities efficiencies derived from the individual DEA runs, whereas runs which include all possible input measures are not.

An examination of the department level DEA runs and the mean *student*-within-all-universities efficiency scores derived from the individual level DEA runs, however, reveals that virtually all correlations are highly significant. Department level runs 7, 9, 10, 12, 13 and 15 in particular are highly correlated with the mean student-within-all-universities efficiency scores derived from the individual level DEA runs[66]. These results suggest that DEA runs at an aggregate rather than individual level reflect the efforts and characteristics of the students rather than the departments to which they belong.

An answer to the second question posed above requires a more detailed examination of the individual level DEAs. Consider the results of table 4b (the ensuing points are not dependent on DEA model chosen but could equally well be made from table 4a, or from the efficiencies derived from runs where DEGMARK is used as the output measure). Department 26 is a relatively poor performer in terms of university efficiency, as its mean university-within-all-universities efficiency score is 0.85. A closer look reveals that the student-within-own-university efficiency measure is very high compared with the student-within-all-universities efficiency measure (see figure 2a). Thus, the students of department 26 are performing well *within that department* (i.e. they are performing on or close to the department's own efficiency frontier), but are constrained from performing better because of the *department's relative inefficiency* (i.e. the department's own efficiency frontier is well inside the

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[6] The results in table 6 are confirmed when department median (rather than mean) efficiencies are used.

overall efficiency frontier). Consider now department 1, which has a very similar measure for mean student-within-all-universities efficiency and is a similar size to department 26, but its overall efficiency as measured by mean university-within-all-universities efficiency score, is 0.97. A closer examination reveals that the student-within-own-university efficiency and student-within-all-universities efficiency measures for department 1 are similar (see figure 2b). Thus the students of department 1 are not performing particularly well *within that department* (i.e. many of the students are performing well inside the department's own efficiency frontier) and the only constraint on achieving higher efficiency is their own efforts, since the department's efficiency frontier is close to the overall efficiency frontier.

Even among the departments which are relatively efficient, differences can be seen between the departments in terms of student effort. In table 4a, the departments achieving a mean university-within-all-universities efficiency score of 1 vary in terms of their mean student-within-all-universities and mean student-within-own-university efficiency scores: departments 3 and 21 have a mean university-within-all-universities efficiency score of 1 and mean student-within-all-universities and mean student-within-own-university efficiency scores of 0.87, compared with department 13 which also has a mean university-within-all-universities efficiency score of 1, but has mean student-within-all-universities and mean student-within-own-university efficiency scores of 0.83. Such information is surely of interest to students and potential students: conscientious students could be disadvantaged by attending a university where their performance could be constrained by the university's own inefficiency.

The departments can also obtain useful information from these individual level results. Consider again departments 26 and 1: the former department needs to find ways of increasing its own efficiency (i.e. moving its own efficiency frontier out) in order to increase measured efficiency, while the latter needs to find ways of stimulating students' efforts in order to increase both student-within-own-university and student-within-all-universities efficiency (i.e. getting its students performing closer to its own and the overall efficiency frontiers). Department 35 appears to be similar to department 1, in terms of the mean university-within-all-universities efficiency. A closer look at the two measures (see figure 2c), however, shows that in the case of this department, a different strategy for improving efficiency may be required depending on the individual. For students who are at the lower end of the student-within-own-university efficiency score, department 35 needs to adopt a strategy such as that suggested for department 1, whereas, for students who are efficient within their own university, the same strategy as that suggested for department 26 is required.

This begs the question of how departments might achieve the goals of improving the different types of efficiency. It is likely that university characteristics such as expenditure and student staff ratios affect teaching efficiency, and further research into the effect of such factors on each type of efficiency defined here is an obvious next step to provide answers to the above question. The extent to which certain university characteristics affect degree results has been a subject of considerable investigation: previous studies suggest that size of graduating class and tutorial groups have a negative impact on degree results (Connolly and Smith, 1986; Smith 1990); while average staff salaries and academic expenditure per student are positively related to degree achievement (Smith & Naylor, 2001). Data limitations for the specific departments under investigation here prevent further such analysis.

5. CONCLUSION

The purpose of this paper has been to apply DEA to a dataset of individual graduates in order to identify, first, whether an individual DEA produces different measures of efficiency from those produced using a higher level DEA, and, second, whether the former method offers additional insights into efficiency compared to the latter. The individual DEA approach used here has disentangled the effect of the individual and the effect of the department attended in determining degree achievement, in order to derive a measure for each individual which represents only the department's efficiency. Such individual efficiencies have been used to derive a mean measure of each department's efficiency, which has then been compared with efficiencies derived using a department level DEA. The main point to emerge is that the measures of efficiency derived from individuals are not particularly highly correlated with the department level DEA efficiency scores. In contrast, measures of the efficiency of departments derived from individuals' efficiencies which have not been corrected for differences in individuals' efforts are much more highly correlated with department level DEA efficiency scores. These results suggest that department or university level DEAs provide efficiency scores which reflect the efforts and characteristics of the students rather than those of the department or institution to which they belong. Thus the unit of analysis in DEA is important, and using aggregate data may produce misleading results.

Furthermore, the results can identify for each institution whether they need to stimulate their students' efforts or whether they need to increase their own efforts in order to perform better. Indeed, it is possible that a different strategy is required depending on whether or not the individual is efficient within his own institution. Further research is clearly needed into how universities might best achieve these two aims.

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Figure 1: Decomposing efficiencies

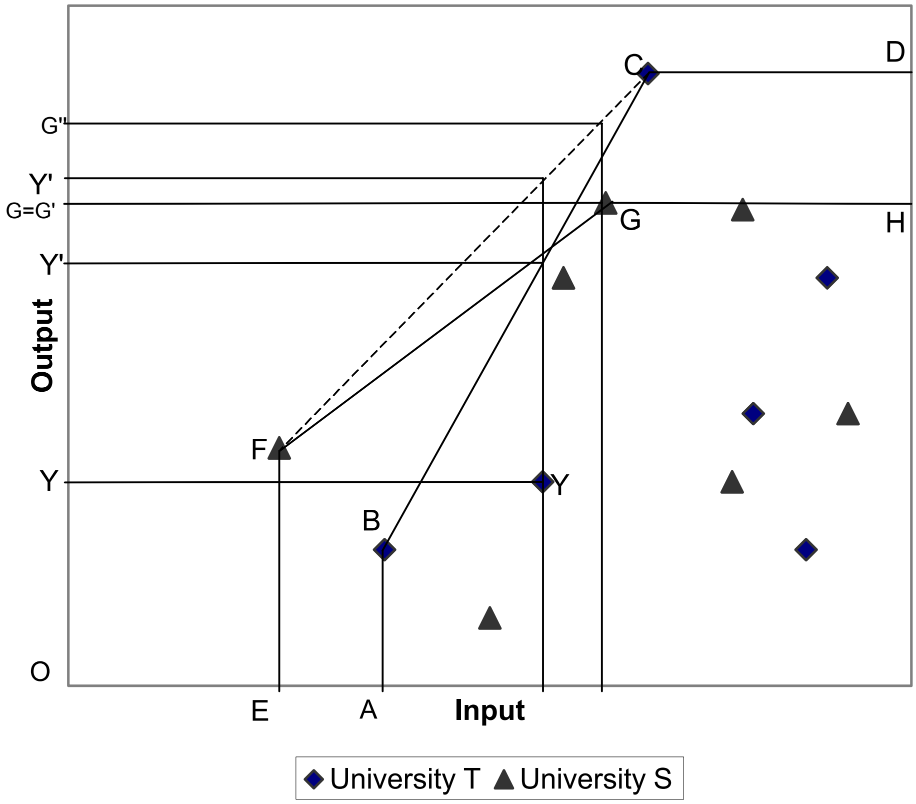

Figure 2a: University 26

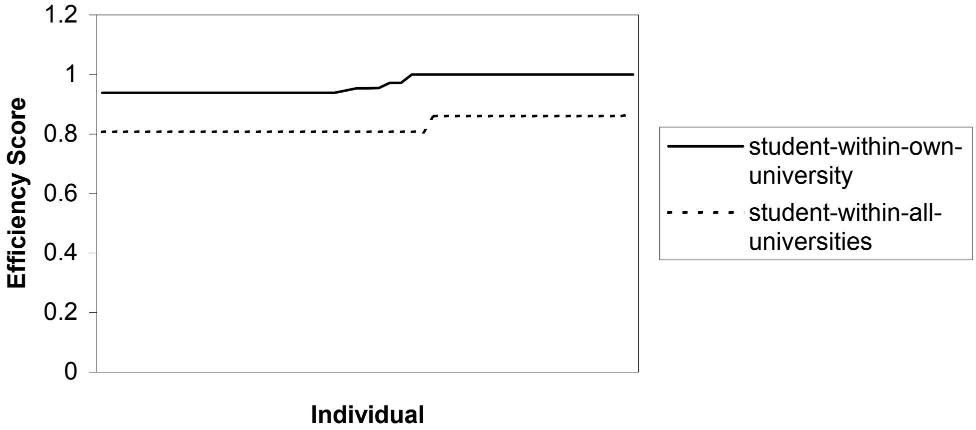

Figure 2b: University 1

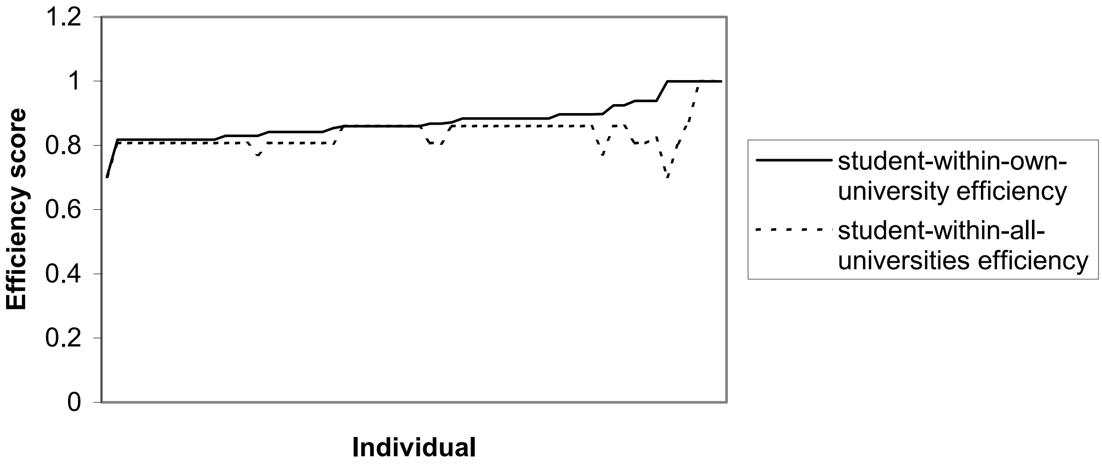

Figure 2c: University 35

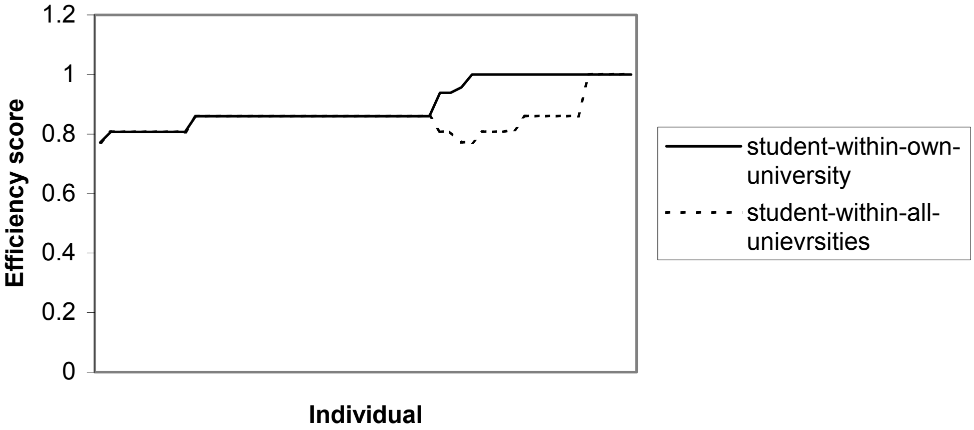

Table 1: Degree results by personal characteristics of the sample

	Degree classification					**Number of graduates**
	Other	**3rd**	**Lower 2nd**	**Upper 2nd**	**1st**	
Previous academic qualification:	**Mean score by category**					
A level score (Mean)	13.23	15.78	18.85	21.18	21.89	2568
Gender:	**Percent in each category**					
Male	1.9	5.6	39.3	45.8	7.5	1817
Female	1.3	4.8	34.8	50.9	8.3	751
Nationality:						
UK	1.5	4.9	37.5	48.2	7.9	2138
Not UK	2.8	7.7	40.2	42.6	6.7	430
Marital status:						
Married	0	7.0	37.2	46.5	9.3	43
Not married	1.7	5.3	38.0	47.3	7.7	2525
Type of degree:						
Part-time	0	3.1	25.0	50.0	21.9	32
Not part-time	1.7	5.4	38.1	47.2	7.5	2536
Accommodation:						
Lived at home	0	7.0	33.6	51.6	7.8	128
Did not live at home	1.8	5.2	38.2	47.0	7.7	2440
School type:						
Attended an independent school	1.9	6.8	37.5	48.5	5.3	693
Did not attend an independent school	1.7	4.8	38.1	46.8	8.6	1875
Number of graduates	44	137	975	1214	198	

Table 2: Summary of efficiency measures across all students

Run 1	Min	Max	Mean	Median
Student-within-own-university efficiency	0.702	1	0.859	0.860
Student-within-all-universities efficiency	0.702	1	0.843	0.860
University-within-all-universities efficiency	0.807	1	0.983	1
Run 2				
Student-within-own-university efficiency	0.702	1	0.870	0.860
Student-within-all-universities efficiency	0.702	1	0.843	0.860
University-within-all-universities efficiency	0.702	1	0.972	1
Run 3				
Student-within-own-university efficiency	0.702	1	0.886	0.860
Student-within-all-universities efficiency	0.702	1	0.844	0.860
University-within-all-universities efficiency	0.702	1	0.955	1
Run 4	Min	Max	Mean	
Student-within-own-university efficiency	0.507	1	0.821	0.867
Student-within-all-universities efficiency	0.507	1	0.806	0.867
University-within-all-universities efficiency	0.733	1	0.982	1
Run 5				
Student-within-own-university efficiency	0.507	1	0.832	0.867
Student-within-all-universities efficiency	0.507	1	0.806	0.867
University-within-all-universities efficiency	0.507	1	0.971	1
Run 6				
Student-within-own-university efficiency	0.507	1	0.850	0.867
Student-within-all-universities efficiency	0.507	1	0.806	0.867
University-within-all-universities efficiency	0.507	1	0.952	1

Note:
1. The inputs and outputs included in each run are described in the appendix.

Table 3: Correlation of DEA efficiencies derived from different runs

Correlations between runs[1]:	1&2	1&3	2&3	4&5	4&6	5&6	1&4	1&5	1&6	2&4	2&5	2&6	3&4	3&5	3&6
Student-within-own-university efficiency	0.873	0.843	0.962	0.938	0.928	0.987	0.896	0.848	0.837	0.768	0.886	0.871	0.742	0.854	0.883
Student-within-all-universities efficiency	1	1	1	1	1	1	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
University-within-all-universities efficiency	0.767	0.725	0.938	0.746	0.718	0.951	0.988	0.739	0.709	0.756	0.976	0.927	0.715	0.916	0.975

Note:
1. See Appendix for definitions.

Table 4: Summary of efficiency measures by department of study

a) Efficiencies derived using Run 1[1]

		Student-within-own-university efficiency			Student-within-all-universities efficiency			University-within-all-universities efficiency		
Department	number of graduates	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
30	7	0.94	1.00	0.97	0.81	0.86	0.83	0.81	0.86	0.85
9	29	0.82	1.00	0.95	0.70	0.86	0.81	0.86	0.86	0.86
28	28	0.90	1.00	0.96	0.77	0.86	0.82	0.86	0.86	0.86
26	49	0.93	1.00	0.96	0.77	0.86	0.83	0.81	0.86	0.86
23	12	0.90	1.00	0.97	0.77	0.86	0.83	0.86	0.86	0.86
10	53	0.77	1.00	0.88	0.70	1.00	0.83	0.86	1.00	0.94
25	40	0.81	1.00	0.88	0.77	1.00	0.84	0.81	1.00	0.96
33	54	0.77	1.00	0.86	0.77	1.00	0.82	0.86	1.00	0.97
5	56	0.77	1.00	0.85	0.77	1.00	0.83	0.81	1.00	0.97
6	55	0.77	1.00	0.85	0.77	1.00	0.83	0.86	1.00	0.97
24	14	0.81	1.00	0.86	0.81	1.00	0.84	0.81	1.00	0.97
8	90	0.77	1.00	0.87	0.77	1.00	0.84	0.86	1.00	0.97
27	41	0.80	1.00	0.88	0.77	1.00	0.85	0.86	1.00	0.97
1	58	0.70	1.00	0.86	0.70	1.00	0.83	0.81	1.00	0.98
11	77	0.72	1.00	0.86	0.70	1.00	0.84	0.86	1.00	0.98
31	77	0.76	1.00	0.86	0.70	1.00	0.84	0.86	1.00	0.98
36	65	0.77	1.00	0.86	0.77	1.00	0.84	0.86	1.00	0.98
29	35	0.81	1.00	0.87	0.77	1.00	0.85	0.86	1.00	0.98
35	51	0.77	1.00	0.87	0.77	1.00	0.85	0.81	1.00	0.98
12	38	0.77	1.00	0.84	0.77	1.00	0.83	0.86	1.00	0.99
20	57	0.77	1.00	0.85	0.70	1.00	0.84	0.81	1.00	0.99

34	59	0.70	1.00	0.85	0.70	1.00	0.84	0.86	1.00	0.99
4	52	0.72	1.00	0.86	0.70	1.00	0.85	0.86	1.00	0.99
17	166	0.70	1.00	0.86	0.70	1.00	0.85	0.86	1.00	0.99
19	41	0.70	1.00	0.86	0.70	1.00	0.85	0.86	1.00	0.99
2	41	0.70	1.00	0.87	0.70	1.00	0.87	0.86	1.00	0.99
13	119	0.70	1.00	0.83	0.70	1.00	0.83	1.00	1.00	1.00
14	57	0.70	1.00	0.84	0.70	1.00	0.84	0.81	1.00	1.00
15	198	0.70	1.00	0.84	0.70	1.00	0.84	1.00	1.00	1.00
18	61	0.77	1.00	0.84	0.77	1.00	0.84	1.00	1.00	1.00
22	53	0.70	1.00	0.84	0.70	1.00	0.84	1.00	1.00	1.00
32	30	0.70	1.00	0.84	0.70	1.00	0.84	1.00	1.00	1.00
7	70	0.70	1.00	0.85	0.70	1.00	0.84	0.86	1.00	1.00
16	399	0.70	1.00	0.85	0.70	1.00	0.85	1.00	1.00	1.00
37	21	0.70	1.00	0.86	0.70	1.00	0.86	1.00	1.00	1.00
3	201	0.70	1.00	0.87	0.70	1.00	0.87	1.00	1.00	1.00
21	14	0.70	1.00	0.87	0.70	1.00	0.87	1.00	1.00	1.00

b) Efficiencies derived using Run 2[1]

		Student-within-own-university efficiency			Student-within-all-universities efficiency			University-within-all-universities efficiency		
Department	number of graduates	Min	Max	Mean[2]	Min	Max	Mean[2]	Min	Max	Mean[2]
9	29	0.82	1.00	0.96	0.70	0.86	0.81	0.81	0.86	0.85
28	28	0.90	1.00	0.96	0.77	0.86	0.82	0.81	0.86	0.85
30	7	0.94	1.00	0.97	0.81	0.86	0.83	0.81	0.86	0.85
23	12	0.90	1.00	0.97	0.77	0.86	0.83	0.86	0.86	0.86
26	49	0.94	1.00	0.97	0.81	0.87	0.83	0.81	0.87	0.86
10	53	0.82	1.00	0.95	0.70	1.00	0.83	0.77	1.00	0.87
12	38	0.81	1.00	0.95	0.77	1.00	0.83	0.77	1.00	0.88
11	77	0.79	1.00	0.94	0.70	1.00	0.84	0.81	1.00	0.89
32	30	0.81	1.00	0.93	0.70	1.00	0.84	0.81	1.00	0.90
37	21	0.82	1.00	0.96	0.70	1.00	0.86	0.86	1.00	0.90
5	56	0.81	1.00	0.90	0.77	1.00	0.83	0.77	1.00	0.92
19	41	0.70	1.00	0.91	0.70	1.00	0.85	0.81	1.00	0.93
27	41	0.80	1.00	0.91	0.77	1.00	0.85	0.81	1.00	0.93
4	52	0.81	1.00	0.92	0.70	1.00	0.85	0.70	1.00	0.93
6	55	0.77	1.00	0.88	0.77	1.00	0.83	0.86	1.00	0.94
13	119	0.81	1.00	0.89	0.70	1.00	0.83	0.77	1.00	0.94
25	40	0.81	1.00	0.89	0.77	1.00	0.84	0.81	1.00	0.94
31	77	0.78	1.00	0.90	0.70	1.00	0.84	0.70	1.00	0.94
33	54	0.77	1.00	0.87	0.77	1.00	0.82	0.81	1.00	0.95
20	57	0.77	1.00	0.89	0.70	1.00	0.84	0.77	1.00	0.95
8	90	0.77	1.00	0.89	0.77	1.00	0.84	0.81	1.00	0.95
18	61	0.77	1.00	0.89	0.77	1.00	0.85	0.86	1.00	0.95
35	51	0.77	1.00	0.90	0.77	1.00	0.85	0.77	1.00	0.95

21	14	0.81	1.00	0.92	0.70	1.00	0.87	0.70	1.00	0.95
1	58	0.70	1.00	0.87	0.70	1.00	0.84	0.70	1.00	0.96
14	57	0.70	1.00	0.87	0.70	1.00	0.84	0.81	1.00	0.96
24	14	0.81	1.00	0.87	0.81	1.00	0.84	0.81	1.00	0.96
7	70	0.77	1.00	0.88	0.70	1.00	0.84	0.77	1.00	0.96
29	35	0.81	1.00	0.89	0.77	1.00	0.85	0.81	1.00	0.96
34	59	0.71	1.00	0.89	0.70	1.00	0.85	0.86	1.00	0.96
2	41	0.70	1.00	0.90	0.70	1.00	0.87	0.82	1.00	0.96
17	166	0.70	1.00	0.87	0.70	1.00	0.85	0.81	1.00	0.97
36	65	0.77	1.00	0.86	0.77	1.00	0.84	0.81	1.00	0.98
22	53	0.70	1.00	0.86	0.70	1.00	0.84	0.85	1.00	0.98
15	198	0.70	1.00	0.86	0.70	1.00	0.84	0.86	1.00	0.98
16	399	0.70	1.00	0.85	0.70	1.00	0.85	0.90	1.00	1.00
3	201	0.70	1.00	0.87	0.70	1.00	0.87	1.00	1.00	1.00

Notes:
1. See Appendix for definitions of runs.
2. The mean is derived for each university department of economics as the sum of efficiencies for that university department divided by its number of graduates.

Table 5: Efficiency scores derived from 12 DEA runs at department level

	Efficiency Scores											
Department	Run 7a	Run 7b	Run 8	Run 9	Run 10a	Run 10b	Run 11	Run 12	Run 13a	Run 13b	Run 14	Run 15
1	0.956	0.956	0.145	0.596	0.965	0.939	0.904	0.628	0.965	0.94	0.904	0.691
2	0.992	0.992	0.121	0.873	1	0.999	1	1	1	1	1	1
3	1	1	0.675	0.995	1	1	1	1	1	1	1	1
4	0.972	0.972	0.15	0.854	0.99	0.983	1	1	0.99	0.984	1	1
5	0.95	0.95	0.14	0.463	0.958	0.923	0.885	0.463	0.958	0.924	0.902	0.556
6	0.953	0.953	0.139	0.494	0.959	0.916	0.931	0.614	0.961	0.923	0.931	0.614
7	0.964	0.964	0.175	0.688	0.973	0.949	1	0.703	0.979	0.961	1	1
8	0.971	0.971	0.323	0.7	0.988	0.951	1	1	0.993	0.974	1	1
9	0.936	0.936	0.073	0.383	0.951	0.884	0.892	0.438	0.966	0.919	1	1
10	0.95	0.95	0.169	0.512	0.95	0.912	0.799	0.558	0.95	0.927	0.858	0.703
11	0.962	0.962	0.193	0.625	0.965	0.941	0.833	0.625	0.965	0.943	0.924	0.709
12	0.955	0.955	0.095	0.552	0.971	0.932	0.887	0.647	0.974	0.952	0.887	0.771
13	0.957	0.957	0.504	0.519	0.958	0.919	0.946	0.586	1	1	1	1
14	0.962	0.962	0.143	0.606	0.995	0.936	1	1	0.995	0.943	1	1
15	0.974	0.974	1	0.661	0.975	0.94	1	1	0.975	0.94	1	1
16	0.973	0.973	1	0.743	0.973	0.954	1	1	0.973	0.973	1	1
17	0.973	0.973	0.454	0.811	0.977	0.966	1	0.814	0.983	0.976	1	0.882
18	0.972	0.972	0.248	0.485	0.986	0.932	1	1	1	1	1	1
19	0.976	0.976	0.103	0.632	0.998	0.952	0.925	0.785	0.998	0.966	0.957	0.886
20	0.958	0.958	0.143	0.585	0.966	0.932	0.882	0.592	0.983	0.959	1	0.742
21	1	1	0.053	0.705	1	1	1	0.79	1	1	1	1
22	0.967	0.967	0.178	0.606	0.967	0.942	0.873	0.696	0.967	0.959	0.873	0.873
23	0.963	0.963	0.038	0.72	1	1	1	0.786	1	1	1	1
24	0.962	0.962	0.041	0.441	1	1	1	1	1	1	1	1

25	0.958	0.958	0.1	0.617	0.972	0.949	0.887	0.682	0.976	0.967	0.889	0.83
26	0.949	0.949	0.128	0.453	0.977	0.925	0.999	0.731	0.983	0.967	1	1
27	0.974	0.974	0.122	0.814	0.975	0.972	0.915	0.885	0.975	0.99	0.92	1
28	0.946	0.946	0.085	0.396	0.947	0.909	0.729	0.397	0.947	0.919	0.774	0.456
29	0.978	0.978	0.088	0.705	0.987	0.974	0.937	0.838	1	0.998	1	1
30	0.949	0.949	0.018	0.53	1	1	1	0.687	1	1	1	1
31	0.963	0.963	0.193	0.546	0.989	0.941	1	0.865	0.989	0.952	1	1
32	0.962	0.962	0.091	0.7	0.972	0.945	0.976	0.891	0.972	0.945	0.978	0.894
33	0.946	0.946	0.163	0.32	0.974	0.902	1	0.52	0.974	0.923	1	0.566
34	0.968	0.968	0.154	0.774	0.985	0.97	1	0.911	0.985	0.979	1	1
35	0.978	0.978	0.142	0.824	0.982	0.977	0.777	0.824	0.997	0.999	0.916	0.891
36	0.969	0.969	0.163	0.684	0.976	0.962	1	0.708	0.976	0.962	1	0.709
37	1	1	1	1	1	1	1	1	1	1	1	1
Minimum	0.936	0.872	0.018	0.320	0.947	0.884	0.729	0.397	0.947	0.919	0.774	0.456
Mean	0.966	0.935	0.236	0.638	0.978	0.952	0.945	0.775	0.982	0.966	0.965	0.886

Note:
A description of the inputs and outputs included in each of the runs are provided in the appendix.

Table 6: Correlations between department efficiencies derived from individual-level DEAs and those derived from department level DEAs

a) University-within-all-universities efficiencies (department mean[1]) compared with department level efficiencies

University → Individual ↓	Run 7[2]	Run 8	Run 9	Run 10[3]	Run 11	Run 12	Run 13[4]	Run 14	Run 15
Run 1	0.571**	0.362*	0.442**	0.173	0.224	0.464**	0.196	0.193	0.123
Run 2	0.427**	0.260	0.327*	0.149	0.250	0.468**	0.142	0.245	0.110
Run 3	0.538**	0.375*	0.397*	0.249	0.354*	0.503**	0.248	0.304	0.183
Run 4	0.483**	0.375*	0.454**	0.161	0.227	0.466**	0.165	0.201	0.131
Run 5	0.357*	0.294	0.338*	0.098	0.253	0.480**	0.073	0.237	0.119
Run 6	0.496**	0.412*	0.430**	0.266	0.372*	0.541**	0.244	0.304	0.195

b) Student-within-all-universities efficiencies (department mean[1]) compared with department level efficiencies

University → Individual ↓	Run 7[2]	Run 8	Run 9	Run 10[3]	Run 11	Run 12	Run 13[4]	Run 14	Run 15
Run 1	0.968**	0.314	0.847**	0.676**	0.342*	0.689**	0.595**	0.327*	0.465**
Run 2	0.968**	0.314	0.847**	0.676**	0.343*	0.689**	0.595**	0.327*	0.466**
Run 3	0.968**	0.324	0.839**	0.670**	0.352*	0.698**	0.591**	0.331*	0.469**
Run 4	0.981**	0.355*	0.947**	0.826**	0.334*	0.701**	0.693**	0.295	0.466**
Run 5	0.981**	0.355*	0.947**	0.826**	0.334*	0.701**	0.693**	0.295	0.466**
Run 6	0.982**	0.361*	0.946**	0.823**	0.340*	0.707**	0.694**	0.297	0.468**

Notes:
1. The individual efficiencies are averaged across the department to which the individuals belong in order to derive the mean value for that department.
2. Model 7a is correlated with Models 1, 2 and 3. Model 7b is correlated with Models 4, 5 and 6.
3. Model 10a is correlated with Models 1, 2 and 3. Model 10b is correlated with Models 4, 5 and 6.

4. Model 13a is correlated with Models 1, 2 and 3. Model 13b is correlated with Models 4, 5 and 6.
5. See appendix for definitions of models
** significant at 1% * significant at 5%

Appendix

Definitions of Output and Input Measures

Individual Data

Output measures:

DEGMARK	pass/other = 38, 3rd = 45, lower 2nd = 55, upper 2nd = 65, 1st = 75
DEGVALUE	pass/other = 2.00, 3rd = 2.20, lower 2nd = 2.30, upper 2nd = 2.45, 1st = 2.85 (weights from Mallier and Rodgers 1995)

Input measures:

ASCORE	Score based on best 3 A levels or equivalent (i.e. 2 AS levels = 1 A level) For A levels: A = 10; B = 8; C = 6; D = 4; E = 2. For AS levels: A = 5; B = 4; C = 3; D = 2; E = 1. Note that duplicate subjects are not counted.
GENDER	1 = female, 0 = male
MARITAL	1 = married, 0 = not married
NATION	1 = from UK, 0 = otherwise
PT	1 = on a part-time course; 0 = not on a part-time course
HOME	1 = lived in the parental home; 0 = did not live in the parental home
NOTIND	1 = did not attend an independent secondary school; 0 attended an independent secondary school

Department Data

Output measures:

AVVALUE	mean value of DEGVALUE
AVMARK	mean value of DEGMARK
NUMGRADS	total number of graduates
NUM121	total number of graduates with 1st or upper second
%121	percentage of graduates with 1st or upper second

Input measures:

AVASCORE	mean value of ASCORE
NUMPT	number of graduates on a part-time course
NUMMAR	number of graduates who are married
NUMFEM	number of graduates who are females
NUMUK	number of graduates who are from the UK
NUMHOME	number of graduates who lived in the parental home
NUMNOTIND	number of graduates who did not attend an independent school
%PT	percentage of graduates not on a part-time course
%MAR	percentage of graduates who are married
%FEM	percentage of graduates who are female

%UK	percentage of graduates who are from the UK
%HOME	percentage of graduate who lived in the parental home
%NOTIND	percentage of graduates who did not attend an independent school

Specification of Outputs and Inputs in Various DEA Runs

Run	Output(s)	Input(s)
Individual level DEA runs		
Run 1	DEGVALUE	ASCORE
Run 2	DEGVALUE	ASCORE, GENDER, MARITAL, NATION,
Run 3	DEGVALUE	ASCORE, GENDER, MARITAL, NATION, PT, HOME, NOTIND
Run 4	DEGMARK	ASCORE
Run 5	DEGMARK	ASCORE, GENDER, MARITAL, NATION,
Run 6	DEGMARK	ASCORE, GENDER, MARITAL, NATION, PT, HOME, NOTIND
Department level DEA runs		
Model 7a	AVVALUE	AVASCORE
Model 7b	AVMARK	AVASCORE
Model 8	NUMGRADS, NUM121	AVASCORE
Model 9	%121	AVASCORE
Model 10a	AVVALUE	AVASCORE, NUMMAR, NUMFEM, NUMUK
Model 10b	AVMARK	AVASCORE, NUMMAR, NUMFEM, NUMUK
Model 11	NUMGRADS, NUM121	AVASCORE, NUMMAR, NUMFEM, NUMUK
Model 12	%121	AVASCORE, %MAR, %FEM, %UK
Model 13a	AVVALUE	AVASCORE, NUMMAR, NUMFEM, NUMUK, NUMPT, NUMHOME, NUMNOTIND
Model 13b	AVMARK	AVASCORE, NUMMAR, NUMFEM, NUMUK, NUMPT, NUMHOME, NUMNOTIND
Model 14	NUMGRADS, NUM121	AVASCORE, NUMMAR, NUMFEM, NUMUK, NUMPT, NUMHOME, NUMNOTIND
Model 15	%121	AVASCORE, %MAR, %FEM, %UK, %PT, %HOME, %NOTIND