

Lehmann, Erik; Warning, Susanne

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Teaching or research? What affects the efficiency of universities

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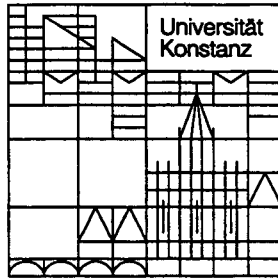
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Erik Lehmann
✓ Susanne Warning

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Erik Lehmann and Susanne Warning

Serie I – Nr. 322

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Teaching or Research?

What Affects the Efficiency of Universities

Erik Lehmann* and Susanne Warning*

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Abstract

We examine differences in the efficiency of UK universities in providing research and teaching. It appears that (i) universities are more efficient in providing teaching than research, (ii) the variation of efficiency is larger in research than in teaching, and (iii) the degree of (in)efficiency is affected by student characteristics like gender, age and their regional provenance and background but also past political regulation.

JEL-Classification: A 20, D 24, I 21

Keywords: educational economics, efficiency analysis, performance indicators

*University of Konstanz, Department of Economics, Box D-144, 78457 Konstanz, Germany. Corresponding Author, e-mail: Susanne.Warning@uni-konstanz.de, Phone: +49-7531-883359, Fax: +49-7531-88446. Parts of this paper were written while the first author was visiting Indiana University, Bloomington. The paper benefited from discussions at the 64th Science Conference of the Association of University Professors of Management, Munich; the annual conferences of the Verein fuer Socialpolitik, Innsbruck, the European Association of Labour Economists, EALE, Paris, and the European Association of Research in Industrial Economics, EARIE in Madrid. We would also like to thank Uschi Backes-Gellner, Oliver Fabel, Günther Fandel, Adam Lederer, Dieter Sadowski and participants from seminars at the IAAEG Trier and the University of Konstanz for helpful comments. The usual disclaimer applies.

1. Introduction

Higher education is one area where markets alone may fail in providing this service adequately (see Winston 1999). Thus, in most countries governments intervene to fund universities to ensure that education is universally accessible at a minimum. In the absence of market prices for their input and output factors there arises the question of how a university should allocate its limited resources. Based on the public pressure of prestige rankings regarding teaching and research published by the mass media, university administrators tend to overinvest in activities which may improve their ranking position. This leads to an ongoing debate about the relationship of research and teaching as substitutes or complements (Armstrong/Sperry 1994, Brickley/Zimmerman 1998). This study contributes to this literature examining the efficiency of universities in providing research and teaching. Moreover we try to detect the factors which affect the variation of universities in providing teaching and research on an efficient level.

Obviously, teaching quality cannot easily be measured using objective performance data. As a consequence there are instruments to measure teaching quality, such as evaluations by students or student-faculty ratio used as proxy. However, if university administrators try to improve their ranking position in the mass media, they could try to manipulate those instruments. And in fact, there is some evidence about the influence of teachers on their evaluation by students (Brickley/Zimmerman 1998). Otherwise, university managers could shift the scarce resources from research towards teaching in order to improve the student-teacher ratio. The incentive to shift resources from research toward teaching is obvious, since teaching quality rankings are easier to improve in the short term than research rankings. In the latter case, university

managers have to increase the number of researchers and undertake investments in laboratories where the output is unpredictable and associated with high uncertainty. Also the time between submitting a paper and its publication takes a length of time. Often, like in the case of patents as a research output, the property rights are not clear and patents are often published by research partners, such as private firms. Therefore, it takes a longer time until output is published and its impact is noticed by other researchers and can be measured by citations or publications.

However, a university's prestige depends on its research activities in the past, such as Oxford or Cambridge in the United Kingdom, or Harvard, Stanford or Chicago as examples in the United States. In this case, it is often argued that research and teaching are compliments rather than substitutes. It is believed that teaching benefits from high quality researchers because they are more likely to incorporate recent results in their classes. However, there is no empirical evidence for these spill-over effects, but some anecdotal evidence that high prestigious universities try to improve their research performance by reallocating resources from teaching towards research. From an economic point of view, resource reallocation may lead to overinvestments in one activity and underinvestments in the other.

In this study, we analyze whether universities are efficient in producing research, teaching or both. Although the quality of either research nor teaching can adequately be reflected by an efficient price system, it could be measured whether universities produce their output on an

efficient frontier or not. Thus, the efficiency of a university in providing teaching and research could be taken as a kind of second best information about their ability and quality.

We use DEA (Data Envelopment Analysis), a linear programming technique, to estimate the efficiency of universities.¹ To conduct this study, we used a data set of 112 universities from the UK. Our results provide strong evidence that it is easier to operate efficiently in teaching than in research. For example, the most optimistic estimation shows that 18% of the universities are efficient in teaching compared to 8% in research. Although the results vary among the different DEA estimations, we find this large differences in all specifications. As mentioned above, DEA is often applied to estimate the productivity of universities. Since most of the research is done in the field of operations research, data from universities are often taken to apply this data to evaluate new estimation procedures in linear programming. From an economic point of view, however, it may be also interesting to analyze the factors which determine the efficiency of universities or to reveal sources of inefficiency. Thus, we apply Tobit regressions to endogenize the efficiency scores provided by the DEA. The results reveal that the determinants of research and teaching differ depending on the underlying DEA model. For example, although we used three different specifications in research, the outputs, measured by publications or grants received from industry, are more homogenous than the outputs applied in the teaching specifications. In the latter case, the results differ between the

¹ There are several studies who use the advantage of DEA to estimate the efficiency of units if either the inputs and outputs cannot be simply evaluated by market prices or if the performance of a unit cannot be sufficiently expressed by one output measure like "shareholder value". Recent examples in the field of educational economics contains comparisons of universities (Johnes/Johnes 1993, Abbott/Doucouliaagos 2002), economics departments (Thursby 2000) or state and private schools (Gstach/Somers/Warning 2002, Kirjavainen/Loikkanen 1998, Ruggiero/Miner/Blanchard 2002).

model testing the value added to students, their employment after university or their drop-out rate. We receive a significant positive impact on efficiency in research the higher the A-Level Points or the share of female students. At the same time only the share of female students is highly significant in all teaching estimations. Otherwise, the influence of the location of students, whether they come from state-schools, from oversea or are mostly local students depends on the different assumptions of the DEA estimations.

The remainder of the paper is organized as follows. In the next section we introduce the concept of DEA for analyzing universities, then we describe the dataset and provide the results from the DEA estimations. In section three we analyze those data used in the Tobit analysis. The results are summarized in section 4.

2 Methodology, Data and Descriptive Statistics

2.1 The Productivity Analysis

Using Data Envelopment Analysis (DEA) we estimate the production function of universities in a non-parametric way considering multiple inputs and multiple outputs. Then we derive an efficiency score for every university. The intuition of DEA is to maximize the ratio of a weighted sum of outputs to a weighted sum of inputs.² Assume there are n universities, denoted by the index j . Each university uses m inputs to produce s outputs. Thus, university j uses the amount x_{ij} of input i to produce the amount y_{rj} of output r . DEA takes the observed

² See also Johnes/Johnes (1993) or Thursby (2000) for the use of DEA in this area.

inputs and outputs as given and calculates the weights of the inputs and outputs endogenously. These weightings are variable for every university in the objective function. The assigned weight to output r is u_r and the weight assigned to input i is v_i . In this way DEA extends the single input and single output case to compute efficiency for multiple inputs and multiple outputs. Following this intuition the generated score can be interpreted similar to an efficiency measure in economics. Thus, the basic model with constant returns to scale can be written as follows (Charnes/Cooper/Rhodes 1978):

$$\begin{aligned}
 & \max_{u_r, v_i} \frac{\sum_{r=1}^s y_{r0} u_r}{\sum_{i=1}^m x_{i0} v_i} \\
 (1) \quad & \text{subject to } \frac{\sum_{r=1}^s y_{rj} u_r}{\sum_{i=1}^m x_{ij} v_i} \leq 1 \quad (j = 1, 2, \dots, n) \\
 & \quad \quad \quad u_r \geq 0 \quad (r = 1, 2, \dots, s) \\
 & \quad \quad \quad v_i \geq 0 \quad (i = 1, 2, \dots, m)
 \end{aligned}$$

Assume that university 0 is evaluated. The objective is to calculate weights u_r and v_i that maximize the ratio of inputs and outputs of university 0. The constraint ensures that the ratio of 'virtual output' to 'virtual input' of the other universities does not exceed 1, in the case of optimal weights of the target unit. The non-negativity constraint must also hold for the weights as well as at least for one input and one output to ensure that each input and each output is regarded in the optimization program. For simplicity we make the assumption that the financial budget of state owned universities, as included in the dataset, could be calculated by the

university managers in advance.³ This simplification allows us to keep the inputs fixed and let us assume that university managers have to maximize outputs for given inputs.⁴ The maximization problem can be solved more easily after transforming the underlying decision problem into a linear program and then solving the corresponding dual program.⁵ The production function, however, provides no explicit parametric form as it is in the case of CES or Cobb-Douglas production functions (see Lovell 1993).

We use this standard approach to estimate the efficiency scores but allow for variable returns of scale (see Banker/Charnes/Cooper 1984). This assumption allows us to incorporate outputs in percentages. In this way we can ensure that for example the efficient universities have a maximum employment rate of 100 percent. Otherwise proportional augmentation of one output might lead to an optimal value larger than 100 percent and therefore would not make any sense. This condition is ensured by adding the further constraint $\sum_{j=1}^n \lambda_j = 1$ in the dual program that can be interpreted as convexity condition (Banker/Charnes/Cooper 1984). The corresponding dual program is:

³ The financial budget of universities in the UK consists of fixed payments, tuition by students (about 1000 GBP per student and year), payments depending on the research (publication) activity (measured every five years), and grants provided by the government and the private industry.

⁴ The converse is to assume that outputs like the number of students or the number of articles published in academic journals is fixed and university managers have to minimize the inputs.

⁵ This follows from the seminal paper by Charnes, Cooper, and Rhodes (1978). For every linear program there exists a dual program that delivers the same solution as the primal linear program.

$$\begin{aligned}
(3) \quad & \max_{\theta, \lambda, s^+, s^-} \theta + \varepsilon \left(\sum_{r=1}^s s_r^+ + \sum_{i=1}^m s_i^- \right) \\
& \text{subject to } \theta y_{r0} - \sum_{j=1}^n y_{rj} \lambda_j + s_r^+ = 0 \quad (r = 1, 2, \dots, s) \\
& \sum_{i=1}^m x_{ij} \lambda_j + s_i^- = x_{i0} \quad (i = 1, 2, \dots, m) \\
& \sum_{j=1}^n \lambda_j = 1 \\
& s_r^+ \geq 0 \quad (r = 1, 2, \dots, s) \\
& s_i^- \geq 0 \quad (i = 1, 2, \dots, m)
\end{aligned}$$

The above linear program is run for all n universities by choosing input and output weights that maximize its efficiency score. The most efficient university is then expressed by a score θ of value 1. All other universities with scores less than 1 are called inefficient units. A university with a score less than one has to improve all outputs following a radial measure to become efficient. The variables s_i^- and s_r^+ are so called slack-variables which ensure that the expressions hold with equality. They also indicate the augmentation potential in the output that cannot be reached by a radial increase.

2.2 Specifications, Data Measurement and Descriptive Statistics

Since DEA models are rather sensitive towards different measures of inputs and outputs, we apply different specifications for either research and teaching. Thus, we split the estimation models into three groups according to the examined task of the university: teaching, research, and a combination of both. We also follow the suggestions made by the *Performance*

Indicators Steering Group (PISG). They use performance indicators, mostly developed by Johnes and Taylor (1990), to evaluate universities in the UK and advise the government.⁶

As in traditional production theory, we use labor and capital as inputs. Typical inputs are the number of teachers and researchers, library spending and expenditures on computers. However, in contrast to production theory we have no common and single output for universities. Thus, we take different measures for research and teaching. Like the quantity of publications and the grants received by the government, or the quantity and quality of the students. We use different outputs to estimate the efficiency of universities in research and teaching applying basic inputs.

Research Efficiency: As the basic inputs we include the number of researchers (Johnes/Johnes 1993, Ng/Li 2000) and library spending (Athanasoulis/Shale 1997; Rhodes/Southwick 1993, Thursby 2000). We then estimate three different models depending on the kind of output: the *pure publication-model* (R1), the *grant-model* (R2) and the *grant-lag-model* (R3).⁷ In the "pure publication model" we include the number of articles listed in the ISI databases from 1998 until 2001 as the only outputs. To differentiate between areas, i.e. science vs. social science, we consider data from both the SSCI and the SCI. Next, we include research grants from industry as an additional output measure (see also Johnes 1995, Johnes/Johnes 1993 or Post/Sponk 1999). The second model or *grant-model*, includes the

⁶ The PISG was established in 1997 with the primary aim of constructing performance indicators (PI). The PIs developed by the PISG are based on the set of PIs suggested by Johnes/Taylor (1990).

⁷ We thus hope that the names of the different models reveal the underlying output measure. The abbreviation (R1) is used to express research-model 1 etc.

amount of research grants by the industry received in 1998/99 ("*Grant-model*"). However, according to Beasley (1995) and Glass et al (1998) grants can also be treated as input variables. We therefore use the grants received in the preceding period (1997/98) as an additional input and thus obtain the *grant-lag-model*. Obviously, we assume that all university managers have an incentive to increase all output variables.

Teaching efficiency: The basic inputs in the teaching models are the number of teachers (MacMillan 1998) and expenditures on library materials. Like Beasley (1995), Post/Sponk(1999) and Avkiran (2001) we apply the number of undergraduate and postgraduate students as basic outputs. The output specifications vary in further variable and are expressed by the *drop-out-model*, the *employment-model*, and the *value-added-model*. In the first specification, the *drop-out-model*, we use the graduation rate as additional performance measure of a university (Breu/Raab 1994). We assume that university managers may have an incentive to increase the rate of graduates instead of decreasing this rate. Furthermore we consider the percentage of graduates who are employed as a measure for the quality of teaching.⁸ The *employment-model* contains the percentage of graduates who are employed six months after graduation. The *value-added-model* figures on the difference of knowledge between university entry and exit (see Bratti 2001). In addition to the number of researchers and the expenditure on library, we include the percentage of students with A-level

⁸ We are aware that the probability of being employed six month after graduation is also influenced by the mobility of students, the location of the university, and other factors which are not (even remotely) under control of the university administrator. We thus use some of this variables in the Tobit estimations when endogenizing the efficiency scores.

points (see also Athanassopoulos/Shale 1997, Colbert et al 2000). To measure the output quality of teaching, we consider the percentage of students who finished with first-class honors degree and upper second-class honors degree.

Efficiency in research and teaching: However, universities produce both research and teaching. As in the previous models we include the number of teachers and researchers and library spending as inputs. In contrast to the above mentioned models, we include outputs for teaching and research. To indicate the output in teaching we choose the number of undergraduates and postgraduates. The output in research is captured by the number of papers in the SCI and SSCI in 1998-2001 (*teaching-publication-model*). Alternatively to the number of SSCI papers we used the total of research grants won in 1998/99 (*teaching-grant-model*).

The different input and output model specifications are summarized in Table 1. We collected this data set using the information about academic staff, quantity and quality of students, library spending, employment rate and grants provided by the *Higher Education Statistics Agency* (HESA), the *Universities and Colleges Admissions Services* (ECAS), the *Quality Assurance Agency for Higher Education*, and the *Higher Education Funding Councils for England, Wales and Scotland* (HEFCE). The number of articles published in academic journals from 1998 until 2001 are hand-collected from the Social Science Citation Index (SSCI) and the Science Citation Index (SCI) database.

Table 2 provides some descriptive statistics of the included variables. At first glance, the universities differ dramatically. For example, the employment rate varies from about 73% to 99% and the graduation rate lies between 100% and 67%. Also, some universities or colleges have no publications while others have published more than 11,000 articles in social sciences. However, they also differ in their size as measured by the numbers of researchers, teachers, and students.

2.3 Efficiency scores and Heterogeneity of Universities

The efficiency scores as shown in table 3 reflect the ability of universities to maximize their outputs with given inputs, like the number of researchers and library spending.⁹ Now, a small university with only few researchers may be able to produce a relatively large number of papers and thus fulfill the criterion of efficiency. If economies of scale (or spill-over effects) are relevant in writing and publishing articles or receiving grants, we try to capture this effect allowing for variable returns of scale.

Table 4 shows that, on average, the mean and median values are lower in the research specifications. For example, the *College of St Martin and St John* - along with the *London School of Economics, University College of London* and the universities of *Cambridge* and

⁹ Take the university of *Staffordshire* and the RT2 model from table 3 to consider the results from DEA. *Staffordshire* is inefficient with a level of efficiency of $\theta=0.33$. Thus, *Staffordshire* has to improve all outputs by 200 percent ($1/\theta$) to be technically efficient. Take the number of postgraduates as one output. To be technically efficient, *Staffordshire* should produce 1860 postgraduates instead of 620. Such an increase of 200% is similarly applied to all other outputs.

Oxford - are efficient in all eight specifications. No other university with similar resources and characteristics is producing more outputs, neither in research, teaching or in a combination of both. The *Imperial College*, on the other hand, is producing 96% of the teaching output of universities with similar resources and characteristics using specification T1 and T2. Still, the *Imperial College* is technically efficient in all three specifications for research (R1, R2, R3) and research and teaching (RT1, RT2). Within each group the results for the efficiency score are relatively homogeneous (see table 4).¹⁰ However, comparing the results for the three different features it can be observed that the average efficiency is the highest in teaching and is lowest in research. Also the standard deviation is higher in the research estimations (see table 4). Table 5 presents bivariate correlations between the different efficiency scores. They are rather homogeneous and highly correlated within the three different groups (teaching, research, and both), but differ across the three groups. The table also includes correlations between the estimated efficiency scores and the scores calculated and published by the mass media. Those scores are highly correlated, independently whether they try to predict research or teaching efficiency. Furthermore, all scores from the mass media press are rather high correlated with our research models.

Interestingly, only nine universities appear to be efficient in the research specification R1, and 22 are efficient in specification R3, respectively. As an example, Thursby (2000) reports that 67% of his sample of economics departments are efficient. Abbott and Doucouliagos (2002)

¹⁰ Additionally correlation coefficients with the rankings of *The Guardian* and the *Sunday Times* are provided.

also report high efficiency levels for Australian universities. However, such a comparison is rather difficult, since the proportion of efficient units strongly depends on the number of inputs and outputs. The more inputs and outputs are included, the higher would be the number of efficient units (see Nunamaker 1985 or Kerstens/Vanden Eeckaut 1999).

Nevertheless, those small numbers of efficient universities may also reflect political decisions in the past. To protect the traditional universities from an increasing number of students, new polytechnics are founded in the UK to channel the flood of students. Also, universities usually received their budgets independent from quality and quantity. Beginning in the 1980's, the newly founded polytechnics were treated as coequals to traditional universities. At the same time, financial budgets are now based upon the quantity and quality of publications as well as the number of students. Now, universities and polytechnics compete on the same market and for the same resources and are all together treated as 'universities'. These effects may explain some of the large differences in the efficiency scores, especially in research.

3 The Tobit Analysis

In the first stage of the analysis we obtained a performance measure for each university based on efficiency. In the second stage we relate the level of inefficiency to values of external variables that may affect inefficiency as well. In the previous sections, we included inputs and outputs which are mostly controlled by the university administrators and by the government. Now, we consider factors which may enhance the efficiency of universities. We first create a score which measures the inefficiency of a university, $1-\theta$, with values from zero to one for all different estimations. These scores are now proxies for the degree of inefficiency of a unit (see

Lovell 1993). Since the minimum value is 0 and the maximum 1 the endogenous variable is truncated at both high and low values. We thus apply tobit estimations instead of simple OLS which would require that all variables are within the interval of zero and one. Thus, let

$$(3) \quad y_i^* = \beta' x_i + u_i$$

with y_i^* as the latent variable (the potential score of inefficiency) and x_i as a vector of exogenous variables which may influence the degree of inefficiency. u_i are disturbances with $E(u_i) = 0$. The observed variable y_i is then given by

$$(4) \quad y_i = \begin{cases} \underline{c}_i & \text{if } y_i^* \leq \underline{c}_i \\ y_i^* & \text{if } \underline{c}_i < y_i^* < \bar{c}_i \\ \bar{c}_i & \text{if } \bar{c}_i \leq y_i^* \end{cases}$$

where $\underline{c}_i, \bar{c}_i$ are fixed numbers representing the censoring points (0, 100). The parameters are estimated by maximizing the log likelihood function described in Maddala (1983, p. 160f.).

The included exogenous variables are assumed to influence the "production process" of a university but are not fully under the control of university managers on the short run. The probability of unemployment, the percentage of students who finished with first-class honors degree and upper second-class honors degree or the drop out rate are chosen as outputs in the teaching DEA models. These outputs, and thus the degree of inefficiency, may be influenced by student characteristics like age, gender or geographical provenance (see Becker

et al. 1990 for a survey or Smith/Naylor 2001). We first include the percentage of mature students (*Mature Students*) to control for age effects. Since there is evidence that boys are performing poorly relative to girls at many age levels (see Becker et al. 1990) we also include the percentage of female students (*Female Students*) to control for gender differences. Furthermore, as Mazarol/Soutar (2001) point out, the geographical background of students may alter the performance of universities. This is considered by the percentage of local students (*Local Students*) and international students (*international Students*). In the UK, students from overseas (not UK and European Union) have to pay the full costs to the respective university and not only the tuition fees of 1,000 GBP like students from the UK or the European Union (Mazzarol/Soutar 2001). This increases the financial budget of those universities. Furthermore, students from overseas have no negative impact on the rate of unemployment.

As Winston (1999) points out, the quality of students is one of the main factors influencing the efficiency of education institutes. He assumes that those schools commanding most of the student quality input tend to choose an educational production technology that amplifies the effects that high-quality students have on each other. Thus, we include the percentage of students having attended a state school (*State-School*) and the A-level points for entry (*A-level*) to indicate the previous education level.

Next, we consider the percentage of female staff (*Female Staff*) at universities. However, there is no clear cut economic interpretation why gender differences should influence the efficiency of universities. However, there is no economic explanation why gender differences in

the staff should influence the efficiency of universities. There are some studies which provide evidence about the different role and performance of women as instructors in teaching (Ferber 1995, Robb/Robb 1999). According to those results, a high degree of female staff should lower the inefficiency in the teaching models. Otherwise, there is evidence that the publication rate of female is less than the publication rate for men (Kahn 1993, 1995; McDowell/Smith 1982). Since we explicitly use publications as the relevant outputs we assume that this variables enters positively, i.e. enhancing the inefficiency, in the equation. Finally, we use the amount of grants from industry (*Industry Grants*) as an explanatory variable for the inefficiency of universities to indicate that industrial grants may differ among regions due to differences in the endowment of industries.¹¹ We thus estimated the following Tobit regression for every DEA model results completely.

$$(5) \quad (1-\theta) = \beta_1 + \beta_2 * FemaleStud + \beta_3 * MatureStud + \beta_4 * LocalStud + \beta_5 * OverseaStud + \beta_6 * StateSchool + \beta_7 * Alevel + \beta_8 * FemaleStaff + \beta_9 * IndustryGrants + \varepsilon$$

The results are presented in the tables 7-9 for the three different DEA models - research, teaching and both. Since we use the (1-efficiency score) as the endogenous variable, a positive sign now indicates that the variable may increase the inefficiency of a university.

¹¹ However, we are aware that the included variables are also endogenous and thus influenced by the performance of universities, like research grants from the industry or the share of students from overseas. Another problem that we cannot control for are selection effects like the percentage of female staff. For example, Booth et al. (2000) show that research intensive universities and the older and traditional universities have significantly lower proportions of female professors and permanent lecturers.

From all included variables, the variable indicating the share of female students provides the most important impact on inefficiency. Independently of the kind of models, either research, teaching or both, this variable enters the estimation significantly negative.¹² This result confirms other studies that female students outperform their male colleagues (Smith/Naylor 2001, Smith et al. 2000).¹³ Also the share of mature students seems to enhance inefficiency. As assumed, a higher share of mature students may increase the drop-out rate and lower the probability of being employed in the first six month after the degree. Thus, this variable enters the regression significantly negative in the *drop-out-model* and *employment-model*.

The share of students from local regions (*Local-Students*) only enters significantly positive in the *drop-out-model*. Winston (1999) points out that the peer pressure effect is rather low for those students. They also may be engaged in extra-curricular activities - mainly domestic duties - and thus may perform relatively worse than students who live away from home (see Bratti 2001). As described above, students from overseas are attractive for universities since they have to bear the full costs with their tuition. Although this variable almost shows a negative sign, it is only significant in the *employment-model*. Since students from overseas are prevented by European law to work in the UK, they will return to their countries after receiving their degree and are thus not registered as unemployed in the statistics.

The results also show that the degree of inefficiency is not independent from the quality of students as measured by the variable *A-Level*. However, this variable is insignificant in the

¹² Only in the *employment-model*, the coefficient is not significant on the 10%-level, but at the 15% level.

¹³ See also Robb/Robb (1999) and Greene (1997) for gender differences and possible bias effects in methods like multiple choice exams, essay writing or verbal skills.

teaching models but not in the research estimations. Thus, we could not confirm the results by Johnes and Taylor (1990). They suggest that inter-university differences in degree results can be explained by entrants' mean A-level scores. Although we did not ignore the influence of student quality on outputs such as the probability of unemployment or the drop-out rate, we assume that those factors may be also influenced factors which are not included in the estimations. But we are surprised that this variable shows no significant impact in the *value-added*-model. One explanation for this result is that the "value added", which figures on the difference of knowledge between university entry and exit (Bratti 2001), is smaller the higher the percentage of A-level entries. Thus, this performance measure could lead to adverse effects: decreasing the percentage of A-level entries and increasing the percentage of students with first-class honors and upper second-class degree (degree inflation).¹⁴ Otherwise, the mean A-level score has a significant impact on the research models, when publications are included as outputs. Winston (1999) and Goethals et al. (1999) mention that students educate themselves and each other (peer group effects) and that those peer-group effects increase with student quality. This reduces the monitoring costs for teachers and the time spent per student (see Goethals et al. 1999). If teachers are also involved in research, higher student quality may increase the time for research and thus the number of papers published (see Brickley/Zimmerman 1998 for such effects).¹⁵

¹⁴ However, the results did not show that the A-level score has no positive impact on degree performance (see Smith/Naylor 2001 for such a study).

¹⁵ However, this result also shows some selection effects if research intensive universities like Oxford or Cambridge are able to select students (see Collier/Mayer 1986).

Also the type of secondary school seems to have a significant influence for explaining the degree of inefficiency. The variable *State-School* is significant positive, i.e. increasing inefficiency, in three specifications including outputs for teaching.

Another result is the significant negative impact of the percentage of female staff on efficiency. Since all research models include publications as outputs, the results show the predicted effects that the publication rate as measured by the number of papers is lower for women than for men (see Kahn 1993, 1995; McDowell/Smith 1982).¹⁶ This may be an explanation why research intensive university have a lower share of female staff (see Booth et al. 2000): since the financial budget of universities depends on their ranking by the *Research Assessment Exercise* (RAE), university administrators might tend to lower the number of female staff. Also the efficiency in the value-added-model is negatively affected by the share of female staff. However, we are not able to control for role-model effects in our estimations as suggested by Ferber (1995) or Robb/Robb (1999). Those studies provide evidence that female teachers have a significantly positive effects on the performance of female students. The high positive bivariate correlation of 0.7168 between the share of female students and the share of female staff may indicate a selection bias.

Finally, industry grants have a highly significant impact on the technical efficiency of universities. As Smith/Horowitz (1998) show, externally funded research may have a direct role in reducing the costs of an undergraduate education and thus increases the efficiency in the teaching specifications. Also research grants from the industry are more likely to be attracted

¹⁶ The correlation of the share of female staff and the number of publications is negative: -0.4056 with the SSCI and -0.3517 with the SCI.

by research-intensive universities, measured by the number of publications as outputs. However, there might be differences across universities due to differences in the endowment of industries which may privilege universities in industrial agglomerations or bigger cities.

4 Conclusion

The purpose of this study was to analyze efficiency differences in providing research and teaching. The results derived from DEA estimation suggest that, given levels of input, the number of universities that are efficient in teaching exceeds the number of universities that are operating efficient in research or both. This may be due to product-specific scale and scope economies for research and not for teaching. Threshold effects in research may prevent some universities from competing on the market for publications and research grants. Such effects are predominanting in teaching. Also, there is a strong path dependence in research activities but not in teaching. High research activities and research grants in the past may lead to high research output and grants in the future. Thus, newer institutions, such as the polytechnics, are disadvantaged compared to older and traditional universities. This may also explain the large difference in the share of efficient universities compared to other countries (see Thursby 2000, Abott/Doucouliafos 2002).

Finally, if teaching excellence is not rewarded in the same manner as research excellence, there is a selection bias of researchers towards research intensive universities. This could imply that research activity ought to be more highly concentrated in a smaller number of institutions (see Glass et al. 1995, Johnes 1997 for such a discussion).

The results obtained from the Tobit estimations suggest that differences in the efficiency scores could be explained by differences in the characteristics of students, like A-level points or gender, and by differences in the endowment of the universities. If universities are more focused on teaching, they could improve their efficiency by increasing the number of female students. If they are reluctant to improve their efficiency in research, they should attract higher quality students.

However, simply considering the average characteristics of the students enrolled and the respective universities can suffer from aggregation bias, although our results do not differ in general from studies which exploit individual-level data and address specific issues concerning the UK university system (see Collier/Mayer 1986; Smith et al. 2000, Smith/Naylor 2001 or Bratti 2001).

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Table 1: DEA-Models with Inputs and Outputs

Model-Type	Inputs	Outputs
"Pure-publication" (R1) (Research)	Number of Researchers Library spending	SSCI-papers 1998-01 SCI-papers 1998-01
"Grants" (R2) (Research)	Number of Researchers Library spending	SSCI-papers 1998-01 SCI-papers 1998-01 Research grants won (1998/99)
"Grants(lag)-publication" (R3) (Research)	Number of Researchers Library spending Research grants won (97/98)	SSCI-papers 1998-01 SCI-papers 1998-01
"Value-added " (T1) (Teaching)	Number of teachers A-level points Library spending	Number of undergraduates Number of postgraduates 2:1 /Firsts (%)
"Dropout" (T2) (Teaching)	Number of teachers Library spending	Number of undergraduates Number of postgraduates Graduation rate
"Employment" (T3) (Teaching)	Number of teachers Library spending	Number of undergraduates Number of postgraduates Employment rate
"S(S)CI" (RT1) (Research & teaching)	Number of teachers Library spending Number of researchers	Number of undergraduates Number of postgraduates SCI-papers 1998-01 SSCI-papers 1998-01
"Grant" (RT2) (Research & teaching)	Number of teachers Library spending Number of researchers	Number of undergraduates Number of postgraduates SCI-papers 1998-01 Research grants won 98/99

Table 2: Descriptive Statistics

This table shows the descriptive statistics of the variables (mean, median, maximum, minimum, and standard deviation) included in the DEA estimations. Firsts measures the percentage of students who finished with first-class honors degree and upper second-class honors degree. All variables are from the year 1998 (with exception of the grants won in the following period 1999). SSCI (Social Science Citation Index) and SCI (Science Citation Index) are from the four year period from 1998 to 2001. 112 universities are included.

	Mean	Median	Max	Min	Std.Dev
A-Level Points	17.759	16.3	29.8	9.6	5.050
Firsts	54.533	52.4	87.4	30.0	11.095
Graduation rate	84.893	85.0	100.0	67.0	7.486
Grants won 99 (in £)	14,987,000	3,945,000	126,190,000	20,000	25,646
Library spending (in £)	3,432,580	2,979,500	18,358,000	483,000	2,470,493
Employment rate	92.340	93.150	98.80	73.20	3.584
Number of Researchers	381.580	265	1611	21	360.65
Number of Teachers	655.560	578	1532	96	346.727
Number of Postgraduates	1193.830	870	4480	30	943.721
Number of Undergraduates	9116.970	7745	85701	1160	8318.285
SSCI (98-01)	348.045	186.50	1770.00	0.00	410.033
SCI (98-01)	1388.045	374.50	11617.00	0.00	2236.892

Table 3 : Efficiency scores of different input-output specifications

This table presents the efficiency scores of all observations for all models. Abbreviations like R1 present the different models in research and teaching and are explained in table 2. The type of institution is abbreviated by uni. (university) and col. (college) or poly (polytechnic). HE is Higher education. (*) indicates efficiency in all specifications.

DMU	R1	R2	R3	T1	T2	T3	RT1	RT2
Aberdeen	0.63	0.63	0.84	0.86	0.85	0.93	0.75	0.63
Abertay Dundee	0.26	0.26	0.91	0.70	0.90	0.86	0.45	0.45
Anglia Poly.	0.00	0.07	0.56	0.73	0.74	0.89	0.39	0.39
Aston	0.57	0.57	0.98	0.86	0.99	0.97	0.66	0.63
Bath	0.47	0.50	0.77	0.96	0.94	0.98	0.69	0.69
Bath Spa Uni. Col.	0.54	0.54	1.00	1.00	1.00	1.00	1.00	1.00
Birmingham	0.88	0.88	0.95	0.96	0.97	0.98	0.91	0.84
Bolton Institute of HE	0.29	0.29	0.57	1.00	0.73	0.92	0.64	0.64
Bournemouth	0.03	0.08	0.41	0.76	0.88	0.95	1.00	1.00
Bradford	0.37	0.37	0.72	0.69	0.87	0.95	0.49	0.49
Brighton	0.16	0.16	0.79	0.72	0.83	0.95	0.31	0.31
Bristol	0.91	0.91	1.00	1.00	0.95	0.96	0.92	0.71
Brunel	0.66	0.66	0.79	0.78	0.86	0.96	0.67	0.65
Buckinghamshire Chilterns Uni. Col.	0.21	0.22	0.88	0.61	0.88	0.94	0.29	0.30
Cambridge*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Canterbury Christ Church Uni. Col.	0.30	0.30	0.48	0.89	0.96	0.97	1.00	1.00
Cardiff	1.00	1.00	1.00	0.89	0.90	0.98	1.00	0.88
Central England	-	0.04	0.64	0.87	0.77	0.92	0.61	0.61
Central Lancashire	0.66	0.66	0.99	0.69	0.74	0.96	0.70	0.46
Cheltenham and Gloucester Col. of HE	0.19	0.28	0.94	0.66	0.87	0.88	0.39	0.45
Chester Col. of HE	0.10	0.11	0.45	0.58	0.98	0.98	0.39	0.39
Col. of St Mark and St John*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Coventry	0.12	0.18	1.00	0.71	0.76	0.91	0.37	0.39
De Montfort	0.21	0.21	0.85	0.98	1.00	0.90	0.54	0.54
Derby	0.29	0.29	0.60	0.67	0.75	0.91	0.31	0.25
Dundee	0.52	0.53	0.79	0.83	0.87	0.98	0.53	0.45
Durham	0.63	0.63	0.78	0.88	0.95	0.88	0.68	0.67
East Anglia	-	0.24	0.68	0.93	0.93	0.95	0.69	0.73
East London	-	0.04	0.58	0.86	0.71	0.75	0.53	0.53
Edge Hill Col. of HE	0.28	0.28	0.91	0.69	0.91	0.96	0.71	0.71
Edinburgh	0.68	0.68	0.81	1.00	0.92	0.97	0.73	0.73
Essex	0.66	0.69	0.79	0.83	0.88	0.95	0.76	0.76
Exeter	0.64	0.64	0.95	0.98	0.98	0.99	0.91	0.90
Glamorgan	0.69	0.69	0.78	0.74	0.74	0.94	0.85	0.80
Glasgow	0.70	0.70	0.87	0.87	0.87	0.95	0.75	0.65
Glasgow Caledonian	0.39	0.39	0.72	0.76	0.79	0.96	0.63	0.63
Goldsmiths Col	0.50	0.50	1.00	0.98	0.98	1.00	0.98	0.98
Greenwich	0.28	0.41	0.64	0.93	0.74	0.92	0.60	0.68
Heriot-Watt	0.46	0.48	0.77	0.70	0.94	0.96	0.74	0.74
Hertfordshire	0.37	0.37	0.58	0.76	0.80	0.95	0.51	0.51
Huddersfield	0.16	0.16	0.76	0.70	0.73	0.95	0.52	0.52
Hull	0.53	0.53	0.87	0.81	0.87	0.99	0.56	0.53
Imperial Col.	1.00	1.00	1.00	0.96	0.96	1.00	1.00	1.00
Keele	1.00	1.00	1.00	0.98	0.98	0.99	1.00	0.98
Kent	0.46	0.48	0.71	0.79	0.88	0.97	0.55	0.53

King Alfred's Col. Winchester	0.25	0.25	1.00	0.80	0.93	1.00	0.47	0.44
King's Col. London	0.97	1.00	1.00	0.88	0.92	0.97	0.99	0.86
Kingston	0.52	0.52	1.00	0.72	0.83	0.98	0.54	0.45
Lancaster	0.79	0.79	0.86	0.89	0.89	0.93	0.86	0.78
Leeds	0.70	0.70	0.80	0.94	0.93	0.99	0.89	0.89
Leeds Metropolitan	0.29	0.29	0.57	0.74	0.80	0.91	0.52	0.51
Leicester	0.72	0.72	0.79	0.84	0.96	0.94	0.85	0.84
Liverpool	0.83	0.83	1.00	0.89	0.93	0.96	0.96	0.96
Liverpool Hope Col.	0.24	0.24	0.95	1.00	0.88	0.96	0.76	0.76
Liverpool John Moores	0.34	0.34	0.96	0.73	0.80	0.94	0.37	0.37
London Guildhall	0.35	0.35	1.00	0.54	0.68	0.92	0.41	0.39
London School of Economics*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Loughborough	0.35	0.45	0.65	0.96	0.95	0.95	0.54	0.59
Luton	0.27	0.27	0.61	0.74	0.76	1.00	0.44	0.44
Manchester	1.00	1.00	1.00	1.00	0.95	1.00	1.00	0.90
Manchester Metropolitan	0.29	0.29	0.71	0.91	0.83	0.96	0.77	0.77
Middlesex	0.00	0.07	0.90	1.00	0.79	0.93	0.61	0.61
Napier	0.64	0.64	0.81	0.99	0.78	0.95	1.00	1.00
Newcastle	0.56	0.57	0.69	0.83	0.95	0.99	0.63	0.63
Northumbria at Newcastle	0.01	0.08	0.78	0.74	0.83	0.95	0.47	0.47
Nottingham	0.88	0.88	0.92	1.00	0.97	0.98	0.91	0.81
Nottingham Trent	0.44	0.44	0.81	0.71	0.84	1.00	0.48	0.47
Oxford*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Oxford Brookes	0.00	0.10	0.78	0.83	0.87	0.97	0.68	0.68
Paisley	0.40	0.40	0.62	0.91	0.78	0.84	0.95	0.95
Plymouth	0.42	0.42	0.73	0.74	0.85	0.93	0.44	0.35
Portsmouth	0.37	0.37	0.85	0.71	0.83	0.96	0.43	0.43
Queen Margaret Uni. Col. Edinburgh	0.51	0.51	0.69	0.92	0.92	0.97	0.53	0.31
Queen Mary and Westfield Col.	0.37	0.43	0.64	0.82	0.88	0.95	0.63	0.64
Queen's Belfast	0.56	0.56	0.83	0.83	0.92	0.98	0.78	0.78
Reading	0.62	0.62	0.89	0.98	0.95	1.00	1.00	1.00
Robert Gordon	0.24	0.24	0.90	0.86	0.85	0.98	0.65	0.65
Royal Holloway and Bedford New Col.	0.01	0.18	0.59	0.85	0.95	0.93	0.60	0.61
Salford	0.36	0.36	0.64	0.72	0.82	0.96	0.57	0.57
Sheffield	0.91	0.91	0.97	1.00	1.00	1.00	1.00	1.00
Sheffield Hallam	0.33	0.33	0.68	0.78	0.86	0.96	0.59	0.59
South Bank	0.00	0.26	0.63	0.67	0.71	0.88	0.73	0.81
Southampton	0.64	0.65	0.68	0.81	0.92	0.93	0.76	0.76
Southampton Institute	0.51	0.51	1.00	1.00	1.00	1.00	1.00	1.00
St Andrews	0.66	0.66	0.83	1.00	0.91	0.94	0.66	0.53
St Martin's Col.	0.01	0.01	0.06	0.77	1.00	0.99	0.88	0.88
St Mary's Col.	0.27	0.27	1.00	0.91	0.98	1.00	1.00	1.00
Staffordshire	0.00	0.08	0.44	0.69	0.85	0.92	0.33	0.33
Stirling	0.62	0.62	0.85	0.86	0.88	0.98	0.63	0.51
Strathclyde	0.45	0.45	0.76	1.00	0.96	0.99	0.98	0.98
Sunderland	0.33	0.33	0.60	0.76	0.75	0.95	0.53	0.53
Surrey	0.69	0.69	0.88	0.79	0.88	1.00	0.83	0.82
Surrey, Roehampton	0.04	0.07	0.46	0.74	0.86	0.95	0.43	0.43
Sussex	0.65	0.65	0.82	0.86	0.83	0.97	0.74	0.64
Swansea Institute of HE	0.09	0.10	0.43	0.64	0.88	0.97	0.28	0.27
Teesside	0.29	0.29	0.59	0.61	0.80	0.90	0.36	0.36
Thames Valley	0.39	0.39	0.70	0.48	0.68	0.89	0.62	0.57

Ulster	0.36	0.36	0.75	0.88	0.89	0.91	0.55	0.55
Uni. Col. Chichester	0.11	0.11	0.32	0.62	0.98	0.94	0.40	0.40
Uni. Col. Worcester	0.15	0.20	0.64	0.71	0.92	0.98	0.55	0.56
Uni. of Wales Col., Newport	0.02	0.10	1.00	1.00	0.89	0.93	0.70	0.70
University Col. London*	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Wales Institute, Cardiff	0.55	0.55	1.00	0.71	0.90	0.94	0.69	0.69
Wales, Aberystwyth	0.31	0.36	0.75	0.81	0.92	0.92	0.52	0.53
Wales, Bangor	0.40	0.41	0.78	0.71	0.88	0.92	0.49	0.49
Wales, Lampeter	0.65	0.65	0.68	1.00	1.00	1.00	1.00	1.00
Wales, Swansea	0.33	0.33	0.72	0.76	0.90	0.97	0.50	0.50
Warwick	0.63	0.63	0.77	1.00	0.96	1.00	0.75	0.75
West of England, Bristol	0.00	0.09	0.59	0.64	0.83	0.95	0.54	0.55
Westminster	0.32	0.33	0.58	1.00	0.83	0.91	1.00	1.00
Wolverhampton	0.10	0.11	0.49	0.86	0.75	0.86	0.42	0.42
York	0.83	0.90	0.91	0.98	0.99	0.94	0.91	0.91

Table 4: Descriptive statistics of the DEA-efficiency scores

This table presents the efficiency scores of all observations for all models. Abbreviations like R1 indicate the different models in research and teaching and are explained in table 2.

	R1	R2	R3	T1	T2	T3	RT1	RT2
Mean	0.4562	0.4636	0.7805	0.8355	0.8821	0.9525	0.6858	0.6672
Median	0.4021	0.4179	0.7876	0.8428	0.8844	0.9560	0.6678	0.6444
Maximum	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Minimum	0.0002	0.0096	0.0644	0.4817	0.6766	0.7497	0.2768	0.2456
Std. Dev.	0.2909	0.2788	0.1828	0.1290	0.0853	0.0408	0.2185	0.2185

Table 5: Correlation of the DEA-Scores

This table presents the bivariate correlations of the estimated efficiency scores. Abbreviations like R1 indicate the different models in research and teaching and are explained in table 2. The table also contains correlations between the efficiency scores and scores published by the mass media like STR (Sunday Times research), STT (Sunday Times teaching), GR (Guardian research) and GT (Guardian teaching).

	R1	R2	R3	T1	T2	T3	RT1	RT2	STR	STT	GR
R1	1	-	-	-	-	-	-	-	-	-	-
R2	.99	1	-	-	-	-	-	-	-	-	-
R3	.87	.85	1	-	-	-	-	-	-	-	-
T1	.46	.48	.30	1	-	-	-	-	-	-	-
T2	.58	.58	.50	.57	1	-	-	-	-	-	-
T3	.54	.53	.54	.35	.52	1	-	-	-	-	-
RT1	.70	.71	.58	.62	.59	.51	1	-	-	-	-
RT2	.59	.62	.47	.61	.60	.48	.97	1	-	-	-
STR	.68	.69	.53	.55	.76	.50	.50	.47	1	-	-
STT	.58	.60	.48	.40	.61	.45	.40	.37	.79	1	-
GR	.72	.75	.50	.55	.67	.47	.56	.53	.92	.74	1
GT	.59	.61	.45	.44	.61	.50	.48	.46	.71	.70	.77

Table 6: Tobit-Estimation for "Research & Teaching"

This table presents the results from the tobit regression in the "research and teaching" -model. The dependent Variable is the (1-efficiency-score). All coefficients multiplied by 100. Left-censored indicates the number of cases with an inefficiency score of zero.

	"SSCI"	"Grant"
Female-Students	-0.926 (-2.405)**	-0.775 (2.001)**
Mature-Students	0.063 (0.219)	0.114 (0.390)
Local-Students	-0.191 (1.210)	-0.217 (1.363)
International-Students	-0.156 (0.393)	-0.165 (0.413)
A-Level	0.053 (0.052)	0.477 (0.468)
State-School	0.659 (1.814)*	0.620 (1.701)*
Female-Staff	0.915 (1.959)**	0.933 (1.988)**
Industry Grants	-3.256 (2.251)**	-3.224 (2.265)**
Constant	3.362 (0.072)	-7.359 (0.158)
Adj-Rsquare	0.247	0.194
Left Censored	18/112	15/112

Table 7: Tobit-Estimation for "Teaching"

This table presents the results from the tobit regression of the "teaching" -models. The dependent Variable is the (1-efficiency-score). All coefficients multiplied by 100. Left-censored indicates the number of cases with an inefficiency score of zero.

	"Value-Added"	"Drop-out"	"Employment"
Female-Students	-0.537 (2.427)**	-0.521 (4.819)***	-0.105 (1.465)
Mature-Students	-0.085 (0.515)	0.236 (2.938)***	0.126 (2.305)**
Local-Students	0.025 (0.275)	0.091 (2.053)**	0.032 (1.092)
International-Students	-0.290 (1.282)	0.012 (0.109)	-0.124 (1.663)*
A-Level	0.800 (1.390)	-0.019 (0.070)	0.024 (0.127)
State-School	0.621 (3.010)***	0.060 (0.600)	0.044 (0.664)
Female-Staff	0.792 (2.933)***	0.192 (1.427)	-0.117 (1.344)
Industry Grants	-0.924 (1.257)	-0.650 (1.818)*	-0.539 (2.071)**
Constant	-43.786 (1.654)*	16.737 (1.293)	14.340 (1.670)*
Adj-Rsquare	0.189	0.573	0.230
Left Censored/Total	21/112	11/112	17/112

Table 8: Empirical Results: Tobit-Estimation for "Research"

This table presents the results from the tobit regression of the "research" -models. The dependent Variable is the (1-efficiency-score). All coefficients multiplied by 100. Left-censored indicates the number of cases with an inefficiency score of zero.

	"Pure Publication"	"Grant(lag)-Input"	"Grant-Publication"
Female-Students	-0.799 (2.111)**	-0.014 (2.585)***	-0.637 (1.808)*
Mature-Students	-0.086 (0.298)	0.470 (1.066)	-0.002 (0.079)
Local-Students	0.002 (0.156)	-0.300 (1.263)	-0.045 (0.314)
International-Students	-0.577 (1.450)	-0.238 (0.403)	-0.526 (1.429)
A-Level	-1.841 (1.837)*	0.800 (0.526)	-1.671 (1.795)*
State-School	0.168 (0.469)	0.518 (0.949)	0.305 (0.911)
Female-Staff	1.136 (2.467)**	1.578 (2.240)**	1.008 (2.351)**
Industry Grants	-4.706 (3.193)***	-5.258 (2.400)**	-4.560 (3.214)***
Constant	88.310 (1.936)*	11.566 (0.167)	69.252 (1.634)
Adj-Rsquare	0.506	0.199	0.540
Left Censored/Total	9/109	22/109	10/112