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# **The Impact of Regional Endowment and University Characteristics on University Efficiency**

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## **Abstract**

This study examines the impact of both university characteristics and regional endowment factors on the efficiency of universities at providing teaching and research. Evidence from 94 universities located in different areas of the UK provides compelling evidence that factors beyond the control of the university management shape technical efficiency. In particular, we analyze whether regional endowment can disadvantage universities and thus reduce their efficiency in producing their outputs. Our overall results show that (i) universities are more efficient providers of teaching than research; (ii) the variation in efficiency is larger for research than for teaching, and (iii) student ability negatively correlates with the degree of inefficiency. Finally, we find compelling evidence that regional endowment significantly matters for teaching and research efficiency. While (iv) university characteristics significantly matter for research efficiency, (v) environmental factors or regional endowment strongly influence teaching, research, and overall efficiency.

*Keywords: efficiency, data envelopment analysis, resource allocation, teaching and research, regional endowment*

# 1. Introduction

There is an increasing debate about the importance of regional universities within a more and more globalized and integrated world (Agasisti and Pèrez-Esparills 2010; Crespi and Geuna 2008; Stephan 2008). Universities play a central role in promoting national or regional competitiveness (Audretsch et al. 2004, 2005 among others). Teaching and research lead to localized spillover effects and influence regional competitiveness and welfare. If globalization and increased integration are diminishing the importance of nations, then the spillover effects from universities may be a major determinant of competitive advantages. National and regional governments try to foster spillover effects by allocating funds and grants. Consequently, in the past several decades, higher education policy has become an important component of economic and welfare policy.

To allocate scarce financial resources towards those universities where the money would generate the highest return, policy makers must be able to discriminate among the outstanding and highly promising universities and the others.

Government policy induces mechanisms to promote competition among higher education institutions, where market forces should reveal the best ones.

Furthermore, a variety of performance indicators and rankings have been generated to match the demand and supply for university outputs. Students, researchers, and financial donors should therefore be able to choose the universities where they hope to receive the highest returns on their investment.

Besides the performance indicators and rankings often provided by popular media, scientific research has provided performance measures to allow for the multiple input-output problem universities face (Cowan 1985). In particular Geraint Johnes and colleagues (Johnes 1995; Johnes and Johnes 1993; Johnes and Taylor 1990) developed this idea and promoted technical efficiency as a measure of university performance in the UK. Other researchers have adopted the measure (e.g., Abbott and Doucouliagos 2003; Avkiran 2001; Worthington and Higgs 2010 – Australia; Agasisti and Perez-Esparells 2010 – Italy, Spain; Crespi and Geuna 2007; Athanassopoulus and Shale 1997; Glass et al. 1998 – UK; Warning 2004 – Germany or Ng and Li 2000 – China).

Most governments see higher education institutions as providers of public goods and significantly intervene in this market, providing funding and direction for

universities. If governments want to invest their money with the largest returns on investments, they are reluctant to invest in universities that appear to perform poorly. However, this leads to adverse incentives for university managers if either the performance indicators do not really reflect or if regional factors strongly shape those indicators and they are thus beyond the control of the managers. While some universities are rewarded for good luck, others may be penalized. This paper copes with this problem and analyzes why and how university efficiency correlates with university specifics on the one hand and regional factors on the other hand. Our result strongly confirms that regional endowment shapes a university's technical efficiency.

Our study analyzes 112 universities located in various regions of the UK. In the UK universities were evaluated and funded based on performance indicators such as cost per student, non-completion rates, degree results, employability of recently graduated students, and research ratings (Reidpath and Allotey 2010; Worthington and Higgs 2010 among others). Such a formal evaluation standard provides university managers with an incentive to over invest in activities for which output reacts elastically to changes in inputs. Use of the non-completion rate may encourage teaching staff to let as many students pass as possible, independent of the resources employed and independent of the performance of the students. Possibly, research might be neglected in order to focus on teaching.

A university's prestige also depends on its research activities and historical record, as demonstrated by Oxford and Cambridge in the United Kingdom (Williams and Filippakou, 2010), two universities where research and teaching are compliments rather than substitutes. Others argue that teaching benefits from high quality researchers because they are more likely to incorporate recent results in their classes. Otherwise, highly prestigious universities may reallocate resources from teaching towards research and try to improve their research performance (Armstrong and Sperry 1994). Thus, resource reallocation may lead to overinvestment in one activity, like research, at the cost of the other, teaching. Although, there does not exist an efficient price system to reflect the quality of research or teaching adequately, it can be measured whether universities produce their output efficiently or not. Consequently, 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 in the absence of a price system.

We analyze whether environmental factors that are beyond the control of university managers can explain variations in the efficiency of universities. If the area the university is located in significantly enhances efficiency scores, then technical efficiency will only be a poor measure for the performance of individual universities. Otherwise, if regional effects are of little importance, then efficiency would provide a suitable concept to evaluate universities and university management. A study close to ours is Agasisti and Pérez-Esparrells (2010), which shows significant differences in technical efficiency across regions in Spain and in Italy. They reveal regional heterogeneity and hypothesize that socioeconomic differences in Italy strongly shape university efficiency while the decentralization process influences efficiency of Spanish universities. Nevertheless, their analysis focuses on differences in responsibility for funding universities – either the state (central government) in Italy or the regional government in Spain. In this study, we not only explicitly consider variables indicating regional endowment and social, labor, and economic welfare indicators, but we also control for university characteristics.

We employ DEA (Data Envelopment Analysis), a linear programming technique, to estimate the efficiency of UK universities and find compelling evidence that efficiency is easier to attain in teaching than in research. Then, we endogenize the DEA inefficiency scores. Our regression results reveal that inefficiencies across universities in producing teaching, research and the combination of both can be explained by regional endowments. Higher student entry qualifications always accompany lower inefficiency. Additional university characteristics only matter for explaining the inefficiency in producing research, while regional factors correlate with the degree of inefficiency in teaching, research, and the combination of teaching and research.

While other studies apply this two-step method – first calculating technical efficiency scores and then treating these inefficiency scores as endogenous variable in regressions – only a few papers employ this method for universities. Among them are Rhodes and Southwick (1995) for the US, MacMillan (1998) for Canadian universities, and Warning (2004) for Germany. Our study differs from these studies in several ways. First, we analyze factors affecting efficiency in teaching and research separately. Second, we collected a broader set of variables than employed in these other studies, and third, we focus and separate the

variables according to whether they are under control and influenced by the respective university managers or not.

The remainder of the paper is organized as follows. In the next section we introduce the methodology and data both for the efficiency analysis in the first stage and for the econometric analysis in the second stage. Section 3 provides the empirical results of both stages. Finally, section 4 summarizes the results.

## **2. Methodology, Data, and Models**

### **2.1 Methods**

To reveal the determinants of university efficiency we follow a two stage approach. First, we apply data envelopment analysis (DEA) to calculate the efficiency of universities for teaching, research, and the combination of both. Second, we are interested in the determinants of inefficiency, so that the DEA inefficiency score serves as the endogenous variable in a regression analysis. University characteristics and environmental factors are used to explain the degree of inefficiency in teaching, research and both.

In the first stage of the analysis we apply DEA to derive an efficiency score for every university based on multiple inputs and outputs. Assuming a multi-dimensional production function for universities DEA calculates weights attached to the inputs and outputs for each institution, and identifies a ratio of a weighted sum of outputs to a weighted sum of inputs. Weights are – due to an optimization process – individually optimal for the university. The efficiency score takes values between zero and one. Efficient universities take the value 1 and all other universities, which are then called inefficient, show scores less than 1. A university with a score less than 1 has to improve all outputs following a radial measure to become efficient. We assume variable returns to scale for the production process (Banker et al. 1984), which allows incorporating outputs in percentages. In this way we 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 would not make any sense. Furthermore, we assume that university managers can calculate the financial budget of state owned universities, as in the dataset, in advance. This allows us to keep the inputs fixed: University managers maximize

outputs for given inputs. Consequently, we apply an output-oriented DEA model allowing for variable returns to scale. As we employ the standard DEA model with output-orientation and variable returns to scale we do not outline the technical details here but refer to excellent textbooks for an in depth description of the analysis, especially for the mathematics of the methodology (e.g., Cooper et al. 2006, Thanassoulis 2001).

In the second stage of the analysis we apply regression analysis to relate the level of inefficiency – calculated in the first stage – to university characteristics and environmental factors. While university administrators and government mostly control inputs and outputs, here we consider factors that may enhance the efficiency of universities but which are not part of the production process. Since the endogenous variable of inefficiency ranges between 0 and 1 we estimate Tobit regressions, with one as the upper and zero as the lower limit. This is consistent with the majority of other work employing a two stage approach, e.g., for universities Rhodes and Southwick (1993). To account for potential heteroskedasticity we estimate robust standard errors (White 1980).

## **2.2 Data Description and Models for the Efficiency Measurement**

The first stage of the analysis applies DEA to obtain efficiency scores. We estimate overall efficiency, teaching efficiency, and research efficiency separately. Thus, we split the empirical models into three groups according to the university task examined: teaching, research, and a combination of both. Input and output factors are selected according to the suggestions of 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. Following traditional production theory, we use labor and capital as inputs. Typical inputs of universities are the number of teaching and research staff, and library spending. In contrast to classical production theory universities have no common and single output. Therefore, we take different measures for teaching and research, such as the quantity and quality of students or the quantity of publications and the grants received. Since DEA models are rather sensitive regarding different measures of inputs and outputs, we run different specifications for teaching, research, and a combination of both.

Teaching efficiency: The basic inputs in the teaching models are the number of teachers (MacMillan 1998) and expenditure on library materials (Athanasoulis and Shale 1997; Rhodes and Southwick 1993, Thursby 2000). Like Beasley (1995), Post and Sponk (1999) and Avkiran (2001) we use the number of undergraduate and postgraduate students as basic outputs. The two teaching specifications vary in further output variables. In the first specification, the drop-out-model (T1), we use the graduation rate as an additional performance measure of a university (Breu and Raab 1994) to capture the quantitative dimension of teaching. Alternatively, in the second specification (T2), the percentage of graduates who are not unemployed six months after graduation measures the quality of teaching (employment-model).

Research efficiency: As basic inputs for the research models we include the number of researchers (Johnes and Johnes 1993, Ng and Li 2000) and library spending. We then run two different specifications depending on the kind of output: the grant-publication model (R1) and the grant-lag model (R2). Both models consider the number of articles listed in the ISI databases from 1998 until 2001 as common outputs. To differentiate between areas, i.e. science vs. social science, we consider data from both the Social Science Citation Index (SSCI) and the Science Citation Index (SCI) (Warning 2004). The grant-publication model (R1) – in addition to publication data – includes the amount of research grants received (Johnes 1995, Johnes and Johnes 1993, Post and Sponk 1999) in 1998/99. It includes all grants and contracts from industrial and commercial companies and public corporations operating in the UK. 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 factor for the second specification, the grant-lag model (R2).

Efficiency in teaching and research: Universities produce both teaching and research simultaneously. 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 consider outputs for both teaching and research. The number of undergraduates and postgraduates in both combined models indicates the output of teaching. Further research output variables differ across the two models: the number of papers in the SCI and SSCI between 1998 and 2001 in the

graduate-publication model (TR1), and the number of SCI papers and total of research grants won in 1998/99 in the graduate-SCI model (TR2).

Table 1 summarizes the different input and output specifications for the first stage analysis. Universities differ in large by their mean and median values indicating that the variables are not normally distributed. While some universities receive more than 100 Million GBP for research grants, others only receive some thousands. While some universities publish some thousands papers in journals listed in the SSCI and SCI, other universities does not publish any paper in those journals. Finally, the descriptive data also provide large difference in size as the number of employees (teachers, researchers) or students (both post- and undergraduates) indicates.

Table 1: DEA models for teaching, research, and teaching&research

Model specification	Inputs	Outputs
dropout (T1) (teaching)	Number of teachers Library spending	Number of undergraduates Number of postgraduates Graduation rate
employment (T2) (teaching)	Number of teachers Library spending	Number of undergraduates Number of postgraduates Employment rate
grant-publication (R1) (research)	Number of researchers Library spending	SCI-papers 1998-01 SSCI-papers 1998-01 Research grants won 1998/99
grant lag (R2) (research)	Number of researchers Library spending Research grants won 97/98	SCI-papers 1998-01 SSCI-papers 1998-01 Research grants won 1998/99
graduate-publication (TR1) (teaching&research)	Number of teachers Library spending Number of researchers	Number of undergraduates Number of postgraduates SCI papers 1998-01 SSCI papers 1998-01
graduate-SCI (TR2) (teaching&research)	Number of teachers Library spending Number of researchers	Number of undergraduates Number of postgraduates SCI papers 1998-01 Research grants won 1998/99

The analysis is based on 112 British universities. We collected information on academic staff, the quantity and quality of students, library spending, the employment rate and grants from the Sunday Times University Ranking and from the Guardian University Ranking in 1999; both are publicly available. 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. We searched for publications of institutions as we are interested in the output of the university and not in the output of single persons. In

this way we ensure that papers count for the university that the researcher was affiliated (and mostly paid) while the paper was written. Table 1 in the Appendix provides the descriptive statistics of the input and output variables.

## **2.3 Data for Econometric Models**

While the first stage of the analysis obtains an efficiency score focusing on teaching, research and the combination of both for each university, for the second stage of the analysis we use exogenous variables which are not part of the “production process” of a university to explain a university’s degree of (in)efficiency. The exogenous variables belong to two groups: The first group contains university characteristics; the second one consists of environmental factors of the university.

University characteristics include student ability, internationality, and staff structure. Student ability is measured by the percentage of students admitted to first-year courses whose highest qualifications were A-levels (Sunday Times ranking). If universities are able to select students, they must have been more successful in the past which may lead to a lower degree of inefficiency. This may also hold for the percentage of overseas students (Guardian teaching ranking). They pay higher fees, contribute to positive spillover effects for research and should positively shape the efficiency of universities. The percentage of overseas students also indicates the degree of internationality of a university. Finally, we include the percentage of part time staff (Guardian research ranking). Here we expect that the percentage of part time staff is positively associated with inefficiency. Universities which operate technically inefficient are either not able to employ a higher percentage on full time staff or diseconomies of scale in employment, adverse selection effects with part time jobs or lower motivation and incentive effects may lead to higher inefficiency scores.

While the previous variables are more or less under the control of the universities, their impact of environmental variables is less direct and less obvious. First, we included the percentage of students in the respective area. If a university is located in an area with a high potential for recent and future students, they may operate at a more efficient level compared to universities located in an area with less “human resources”. Since universities, faculties and departments hold a minimum endowment with lecturers and researchers, universities with less access to local

students are probably operating at a lower level of technical efficiency. Second, we use the unemployment rate in the region to express economic activity: The higher the economic activity, the higher may be the amount of grants and other financial resources provided to the university. Also, the likelihood for students to find a job will increase in those regions. We assume that universities located in an area with a higher economic activity may show a lower degree of inefficiency. Finally, we include a dummy variable indicating whether the university is located in London to control for a “capital” effect.

Data on environmental factors are hand-collected from the neighborhood statistics of the UK government (<http://www.neighbourhood.statistics.gov.uk>) and stem from the 2001 census, the year closest to our university data. This UK official statistics source provides information about the British economy, population and society at the national and local level. We searched by postcode of the university to identify regions. Employment rate refers to the region of the university (North East, North West, etc.), the percentage of students refers to the area (metropolitan district, non-metropolitan district, unitary authority). As environmental data are not available for Northern Ireland and Scotland we stay with 94 universities for the econometric analysis. Table A.2 in the Appendix presents the descriptive statistics of the exogenous variables.

## **3 Empirical Analysis and Results**

### **3.1 Efficiency Results and Heterogeneity of Universities**

Efficiency differs significantly across universities. The scores of efficiency reflect the ability of universities to maximize their outputs with given inputs, such as the number of researchers and library spending. Take a university showing a DEA efficiency score of 0.66: It is inefficient with a level of inefficiency of 0.37. Thus, it has to improve all outputs by 151 percent ( $1/0.66$ ) to become efficient. Take the number of postgraduates as one output as an example. To be efficient the university should produce 906 postgraduates instead of 600. Such an increase of 151 percent is similarly applied to all other outputs of the institution. Table 2 presents the descriptive statistics of the different DEA specifications.

Table 2: Descriptive statistics of the DEA-efficiency scores for all specifications

Model	Mean	Std. Dev.	Min	Max	No. of efficient universities
T1: drop out model	0.8821	0.0853	0.6766	1	11
T2: employment model	0.9525	0.0408	0.7497	1	17
R1: grant-publication model	0.4636	0.2788	0.0096	1	10
R2: grant lag model	0.7805	0.1828	0.0644	1	22
TR1: graduate-publication model	0.6858	0.2185	0.2768	1	18
TR2: graduate-SCI model	0.6672	0.2185	0.2456	1	15

Average efficiency scores from the teaching specifications are 0.88 and 0.95.

These scores are relatively similar with small standard deviations. In contrast, efficiency scores from the research specifications differ substantially (0.78 and 0.46) with larger standard deviations. Mean efficiency values from the combined models are in-between and seem relatively homogeneous.

Only ten universities, or 8.9 percent of our sample, appear to be efficient in research specification R1 (grant-publication), while 22 (19.6 percent) are efficient in specification R2 (grant lag). Thursby (2000) reports 67 percent of the economics departments in his sample are research efficient. Abbott and Doucouliagos (2002) 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 the number of efficient units (see Nunamaker 1985 or Kerstens and Vanden Eeckaut 1999). Nevertheless, the small number of efficient universities in this study may also reflect political decisions in the past. To protect the traditional universities from an increasing number of students, new polytechnics were founded in the UK to absorb the flood of students. Beginning in the 1980s, the newly founded polytechnics were treated as the equivalent of traditional universities. Financial budgets are based upon the quantity and quality of publications, as well as the number of students. Thus, universities and polytechnics compete in the same market for the same resources. These effects may explain some of the large differences in the efficiency scores, especially in research.

Briefly, the descriptive analysis from the DEA efficiency scores reveals higher efficiency in teaching than in research, whereas research efficiency scores vary more than teaching efficiency scores.

### 3.2 Results of the Econometric Analysis

In this section we analyze whether the estimated scores differ across universities. Since the scores are censored – zero and one – the ordinary least square model is not an appropriate estimation technique. While the descriptive statistics (see table 2) illustrate that our scores are not censored at the left side (zero), some of the scores equal “1”, indicating that the respective university is technical efficient in this estimation. Thus, we use Tobit estimation techniques with robust coefficients. Table 4 presents the results for different DEA model specifications. Since we use (1-efficiency score) as the endogenous variable, a positive sign indicates that the variable goes along with higher inefficiency, i.e. lower efficiency of a university.

Table 4: Results of the Tobit regression analyses

	drop out model (T1)	employment model (T2)	grant- publication model (R1)	grant lag model (R2)	graduate- publication model (TR1)	graduate SCI model (TR2)
A levels entry	-0.0035*** (-9.90)	-0.0010*** (-4.21)	-0.0089*** (-5.50)	-0.0047*** (-3.92)	-0.0059*** (-4.37)	-0.0053*** (-4.26)
Oversea students (%)	0.0012 (0.75)	-0.0008 (-1.05)	-0.0130*** (-3.66)	-0.0068* (-1.68)	-0.0025 (-0.64)	-0.0023 (-0.59)
Part time staff (%)	0.0006 (0.80)	0.0003 (0.71)	0.0085*** (2.80)	0.0035 (1.61)	0.0032 (1.11)	0.0032 (1.11)
Students in area (%)	-0.0029 (-1.55)	-0.0012 (-0.89)	-0.0140* (-1.76)	-0.0072 (-1.15)	-0.0139* (-1.89)	-0.0136* (-1.92)
Unemployment in region (%)	0.0219** (2.05)	0.0149** (2.00)	-0.0200 (-0.46)	0.0105 (0.27)	0.0282 (0.64)	0.0334 (0.78)
London	-0.0287 (-1.37)	-0.0130 (-0.76)	-0.1290 (-1.27)	-0.1542* (-1.88)	-0.2176*** (-2.79)	-0.2286*** (-3.01)
Constant	0.2965*** (5.11)	0.0783** (2.33)	1.4117*** (6.29)	0.6037*** (3.25)	0.7781*** (3.59)	0.7343*** (3.57)
F(6,88)	27.80***	5.98***	12.6***	5.09***	7.03***	6.93***
ML (Cox- Snell) R2	0.5370	0.2480	0.4730	0.2270	0.2860	0.2810
Observations	94	94	94	94	94	94

Notes:

1. \*\*\* p<0.01; \*\* p<0.05; \* p<0.10
2. Upper limit equals 1, lower limit equals 0
3. Robust standard errors
4. t-values in parentheses

Although we estimate different specifications, the influence of the exogenous variables does not differ significantly across the estimations within models. This indicates the robustness of the included variables. Otherwise, we observe that these variables have a different impact on either teaching or research.

The most convincing, but not surprising, effect is the impact of student ability on university efficiency. The percentage of A-levels for entry measures student quality and significantly decreases with inefficiency of universities. However, as Williams and Filippakou (2010) state, this may be also due to path dependencies. The better the students in the past, the more attractive the university in the present, and the better this university will perform in the future. This negative correlation between student quality and university inefficiency holds for all specifications: teaching, research, and the combination of both. Universities that have the chance to select good students show better efficiency in total than less selective ones. As a consequence, better students go along with lower inefficiency as those students are less time consuming for the staff. These results are obvious for teaching specifications (T1, T2): Given equal resources it is easier to improve students' success for better students. More surprising is the negative correlation between student ability and inefficiency in the research specification (R1, R2). If universities compete for excellent students as future researchers and Ph.D. students, universities with excellent students will have an advantage and thus be less inefficient in research (Maxwell and Smith, 2010). Otherwise, universities with high research reputation may be able to be more selective and vice versa. The results for the overall models (TR1, TR2) are compatible with both arguments. Overseas students are assumed to negatively correlate with university inefficiency. While we could not find a statistically significant relation for the teaching specifications, the percentage of overseas students enrolled significantly impacts technical efficiency in research. In previous years overseas students, particularly those from Asia (Park 2009), selected research intensive universities. They may also serve as driving forces in research in the natural sciences (Stephan 2008).

The percentage of part time staff as a choice variable shows a significant and positive correlation with research inefficiency. However, this variable neither has a statistically significant impact in the teaching models (T1, T2) nor in the joint models (TR1, TR2). Excellent research seems to be more difficult with part time staff. First, part time positions are not really attractive for excellent researchers and we would observe adverse selection effects. Second, for researchers who only work half of the day – on average – it is particularly difficult to conduct research (Akerlind, 2005).

Summing up, the most effective choice variable for universities is the selection of highly accomplished students. Additionally, a decline in the enrollment of overseas students and an increase in part time staff correlates with higher technical inefficiency.

Now, we turn to those variables that are not directly under the control of university management. First, let us examine the percentage of students in the area. The results provide evidence that universities in areas with a high percentage of students show lower technical inefficiency in all three specifications. Proximity lowers the costs of advertising to attract students. Then, the higher the number of potential students is, the better the selection process and the competitive situation of a university for excellent students. Second, we include the unemployment rate of the respective region to control for socioeconomic effects. As discussed above, this variable reflects and captures socioeconomic factors like educational background and aging of the population. Unemployment does not have a statistically significant effect on research inefficiency. However, in both teaching specifications the unemployment rate significantly increases inefficiency scores. In particular, those universities are disadvantaged in that their students have a lower probability of being employed afterwards. Also the graduation rate is lower in those universities, either due to voluntarily transfers by students to other schools or due to higher failure rates.

Finally, universities located in London significantly differ from other locations. While this dummy variable is not statistically significant in the teaching specifications, being located in London goes along with significantly lower inefficiency scores in the research and the combined model. Both probably capture the attractiveness of the city and make it easier to attract excellent students, staff and researchers.

### **3.3 Robustness of the Results**

The results of our two stage analysis appear robust. First, we discuss the robustness of the DEA results. DEA is sensitive to measurement errors and the choice of input and output factors. To ensure robustness of the first stage DEA results, we ran two specifications for all three models – teaching, research, and the combination of both. Correlations between these specifications are positive but not close to one, thus we are optimistic that our specifications are different enough

to capture various aspects of each model. Table 3 presents bivariate correlations of the efficiency scores. They are similar and highly correlated within the three different groups (teaching, research, and both), but differ across the three groups.

Table 3: Correlation of the DEA scores

	T1	T2	R1	R2	TR1	TR2	T_ST	T_G	R_ST
T1	1.0000								
T2	0.5733	1.0000							
R1	0.4537	0.4453	1.0000						
R2	0.2696	0.3254	0.6096	1.0000					
TR1	0.5056	0.4236	0.6717	0.3740	1.0000				
TR2	0.5045	0.3897	0.5804	0.3148	0.9722	1.0000			
T_ST	0.4624	0.3840	0.6441	0.3633	0.3741	0.3371	1.0000		
T_G	0.4934	0.4529	0.5903	0.2625	0.4305	0.4037	0.7367	1.0000	
R_ST	0.5565	0.3675	0.7245	0.3580	0.4621	0.4206	0.7756	0.6953	1.0000
R_G	0.4638	0.3189	0.7408	0.3627	0.4575	0.4153	0.7591	0.7106	0.9462

T1: drop out, T2: employment, R1: grant-publication, R2: grant lag, TR1: graduate-publication, TR2: graduate-SCI, T\_ST: Sunday Times teaching, T\_G: Guardian teaching, R\_ST: Sunday Times research, R\_G: Guardian research

Now, we turn to the robustness of the econometric analysis. First, determinants of inefficiency do not substantially change across specifications within the same model (teaching, research or teaching and research), which makes us confident that the revealed correlations are robust. Second, the ability effect is robust even for other measures than the percentage of A-levels for entry. Including the percentage of students from state schools or the average A-level points generates similar results. Third, applying simple OLS regressions instead of tobit regressions does not change the results qualitatively.

## 4 Conclusions

Universities differ with respect to efficiency in teaching, research and a combination of both teaching and research. Efficiency in these areas is influenced by the same factors: lower inefficiency in teaching, research and a combination of both goes along with better students. Environmental factors matter for the degree of inefficiency of a university in teaching, research, and overall efficiency. Thus, our results provide further evidence and confirm the more descriptive results of

Agasisti and Pérez-Esparrells (2010). Indeed, regional factors matter for the (in)efficiency of universities after controlling for institutional characteristics. Furthermore, our analysis suggests that the number of universities that are efficient in teaching exceeds the number of universities conducting research efficiently. Three factors may drive this result: First, there are path dependencies in conducting research (Williams and Filippakou 2010). Previous success at research activities and research grants may facilitate successful research and grant receipt in the future. Thus, younger institutions, such as the former polytechnics, are disadvantaged compared to older and traditional universities. This may also explain the large difference in the share of efficient universities in the UK compared to other countries (see Abbott and Doucouliagos 2003; Thursby 2000). Second, improving teaching quality is easier than improving research quality, at least in the short term. Therefore the near term incentive to invest in teaching is higher than in research. This provides further evidence for the arguments put forward by Armstrong and Sperry (1994). Third, if teaching excellence is not rewarded in the same manner as research excellence, then there is a selection bias of researchers towards research intensive universities. This implies that threshold effects in research may prevent some universities from competing in the market for publications and research grants.

Turning back to our initial question, we would suggest that policy makers carefully handle efficiency scores as a measure for university excellence and as a performance indicator in allocating financial resources. While environmental factors are not under the control of universities management, we suggest putting more weight on this environmental disadvantage. Following our results, university managers should try to attract the best students, while also increasing their recruitment of overseas students.

Future research can extend this study in several ways. For instance, a more detailed analysis about the co-evolutionary effects of regional competitiveness and the efficiency of universities would be interesting. A selection of countries in which regional endowments differ also, like Italy, Spain or Germany could shed more light on how universities are shaped by their regions.

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## Appendix

Table A.1: Descriptive statistics of input and output factors

	Mean	Median	Max	Min	Std.Dev
Number of researchers	381.580	265	1611	21	360.65
Number of teachers	655.560	578	1532	96	346.727
Library spending (in £)	3,432,580	2,979,500	18,358,000	483,000	2,470,493
Number of undergraduates	9116.970	7745	85701	1160	8318.285
Number of postgraduates	1193.830	870	4480	30	943.721
Employment rate	92.340	93.150	98.80	73.20	3.584
Graduation rate	84.893	85.0	100.0	67.0	7.486
Grants won 98 (in £)	13,761,000	3,910,000	117,160,000	10,000	23,265,000
Grants won 99 (in £)	14,987,000	3,945,000	126,190,000	20,000	25,646,000
SSCI papers (98-01)	348.045	186.50	1770.00	0.00	410.033
SCI papers (98-01)	1388.045	374.50	11617.00	0.00	2236.892

This table shows the descriptive statistics of the variables included in the first stage of the analysis. It shows input and output factors for the data envelopment analysis (DEA). 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.

Table A.2: Descriptive statistics of the of the exogenous variables

Variable	Mean	Std. Dev.	Min	Max
A levels entry	67.5663	18.1817	15.20	98.00
Oversea students (%)	9.8821	6.5796	0.30	46.40
Part time staff (%)	9.9812	9.2370	0.00	42.50
Students in area (%)	11.1298	4.0808	5.03	25.59
Unemployment in region (%)	3.4266	0.7425	2.31	4.53
London	0.1789	-	-	-

This table shows the descriptive statistics of the exogenous variables included in the second stage of the analysis, the econometric estimations. University characteristics are from the year 1998, environmental factors are from the year 2001. 112 universities are included for university characteristics, 94 universities for regional variables.