Why does the US dominate university league tables?

Mei Li, Sriram Shankar, and Kam Ki Tang , School of Economics Discussion Paper No. 391, June 2009, School of Economics, The University of Queensland. Australia.

ABSTRACT:

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EPrint Type:	Departmental Technical Report
Keywords:	Poisson model, Tobit model, count data, higher education, ranking
Subjects:	
ID Code:	JEL Classification: C2, I2
Deposited By:	

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Abstract

According to Academic Ranking of World Universities, the world's top 500 universities are owned by only 38 countries, with the US alone having 157 of them. This paper investigates the socioeconomic determinants of the wide performance gap between countries and whether the US's dominance in the league table is largely due to its economic power or something else. It is found that a large amount of cross country variation in university performance can be explained by just four socioeconomic factors: income, population size, R&D spending, and the national language. It is also found that conditional on the resources that it has, the US is actually underperforming by about 4 to 10 percent.

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[#] We would like to thank Chris O'Donnell, James Laurenceson and Alan Duhs for their useful comments on earlier drafts. All remaining errors are obviously ours.

1. Introduction

In 2003, Shanghai Jiaotong University published the first Academic Ranking of World Universities (ARWU). Another league table, the THES-QS World University Rankings, was published a year later by Times Higher Education and Quacquarelli Symonds, followed by many other similar endeavours subsequently.[1] Not surprisingly, American universities dominate all these world university league tables. Why the US 'monopolizes' the world's top universities is an intriguing question.

The objective of this study is to identify the key socioeconomic factors that determine countries' performance in world university league tables. In doing so, we aim to shed light on the question posed in the title of the paper. The answer to this question has important policy implications. If the US's dominance in the league tables is more than just a result of its economic hegemony, then there is a great need to understand the factors at the micro or institutional level that are driving the success of its universities as it would provide valuable learning opportunities to other lagging countries in improving their university education systems. For example, Aghion et al. (2009) analyse how university governance affects research output at European and U.S. universities, after realising U.S. universities are obvious positive outliers in ranking performances. Also, in 2008, the University of Melbourne restructured its academic programs entirely based on a hybrid of the US university and European Bologna models, while all other Australian universities are watching as bystanders with both interest and reservation.

The ranking on league tables increasingly have real resource implications for universities. This is because, despite the criticisms of their accuracy, reliability and usefulness, university rankings have been quickly adopted as a quality assurance mechanism around the world. In particular, international students use league tables to help identify top

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[1] The Melbourne Institute has been ranking Australian universities (Williams & Dyke 2004; Williams 2007), and U.S. News & World Report published its first World's Best Colleges and Universities rankings in 2008 using the THE-QS data, after publishing America's Best Colleges and America's Best Graduate Schools for 25 years.

universities (Hazelkorn 2008). Research commissioned by the Higher Education Funding Council of England indicates that league tables are already influencing international recruitment, although more so in some markets than in others (HEFCE 2008). In Qatar, scholarships for study abroad are limited to students going to highly ranked institutions as identified by the ARWU and THES-QS rankings (Salmi & Saroyan 2007). Given this, it is not surprising that many institutions have already used their ranking positions for marketing purposes. Some institutions have even established a formal internal mechanism for reviewing their rank and the majority of them have initiated actions in order to improve their international ranking (Hazelkorn 2007; Healy 2009).

The importance of university league tables goes beyond the interests of prospective students and university administrators. Education has become increasingly an export item. For example, for Australia, which is one of the major players in international education, education constitutes the third largest export item, contributing US$10,230 million to its total exports in the year 2007-08 (DFAT 2008). Furthermore, as universities are a key place for conducting frontier research and a place for higher education, poor performance in league tables may indicate constraints on future development and growth.[2]

Due to the aforementioned factors, university rankings seem to be influencing policy makers and possibly the classification of institutions and the allocation of funding (Hazelkorn 2007). Authorities in many countries have already responded to the international competition in higher education. In 2005, Malaysia’s opposition called for a Royal commission of inquiry in response to a fall of a hundred places of its top two universities in the THES-QS ranking (Salmi & Saroyan 2007).[3] In April 2008, the French Minister for Higher Education and Research outlined that one of her priorities is to reinforce quality assurance of higher

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[2] A large body of literature has found important positive effects of education on economic growth and development, e.g. Barro (1991), Schofer et al. (2000) and Koop et al (2000).

[3] See section 3 for a critic of the volatile nature of THES-QS rankings.

education, which will entail a thorough analysis of international quality indicators, as well as the impact of global rankings.

A common feature across different league tables is that the distribution of the world's top universities is highly skewed toward a single country—the US. According to the most widely cited league table, ARWU, in 2008 the US has 17 top 20 universities identified in the table, 54 top 100, 90 top 200, 114 top 300, 139 top 400, and 159 top 500.[4] In comparison, China, though having a much larger higher education sector[5], has only 18 top 500 universities, 7 top 400, 6 top 300, but none in the top 200. Since university rankings in these league tables are determined by the statistical indicators underpinning the ranking score, such as the number of journal publications and the number of Nobel laureates, the 'reason' that the US is well ahead of other countries in the league tables is simply that its universities have published many more journal articles, recruited many more Nobel laureates and so forth. Simply put, the league tables indicate that the US has more of a specific type of human capital—academic talent—than other countries. Therefore, in trying to identify the key socioeconomic factors that determine countries' performance in university league tables, we are essentially seeking for the socioeconomic explanation of cross country differences in academic talent stocks.

To the best of our knowledge, there is no such quantitative analysis in the literature. Aghion et al (2009) use the ARWU league tables to measure university output in their examination of the effect of university governance. The focus of their analysis is on the institutional level, not on the macroeconomic level. Also, they focus on the comparison between the performances of European and US universities only. Marginson (2007) attempts to look at this issue; however, he only compares countries' share of top universities with their

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[4] Different league tables indicate the dominance of US universities to a different degree. For instance, the THES-QS ranking noticeably puts more UK and Australian universities in top spots than the ARWU does. However, the overall picture is largely the same.

[5] According to the UNESCO, in 2006, 5.6 million tertiary students graduated in China, as compared to 2.6 million in the US.

share of economic capacities measured by total GDP multiplied by GDP per capita. By using such simple summary statistics, the study does not control for other factors or noise in the data. More importantly, by considering only those countries that successfully enter the league tables, it confronts selection bias problems. In the current paper, we use regression methods to address these problems.

This paper is inspired by a number of quantitative analyses of Olympic medal tally results, including Bernard & Busse (2004), Johnson & Ali (2004) and Morton (2002). However, our modelling technique is different in the way that we employ count data models instead of the standard OLS regression or the Tobit model used by these studies. We demonstrate that the Poisson model provides a better modelling approach in the current context. Furthermore, as against the Olympic Games literature, endogeneity is potentially a much bigger problem in the current study. This is because, to the extent that a country's performance in university league tables is a proxy for its research capability, the causality from rankings to income cannot be ignored. Endogeneity is tested as part of the empirical analysis.

The rest of the paper is organized as follows. Section 2 outlines the methodology, while Section 3 explains the dataset used for the empirical work. Section 4 reports and discusses the findings, and Section 5 concludes.

2. The Methodology

Academic talent can be considered a specific type of human capital, in contrast to other types of human capital such as athletic talent or entrepreneurship. Similar to all other types of human capital, academic talent cannot be directly measured. What can be measured is the academic performance of people. A university's research and publication performance, and thus, ranking, reflects the size and quality of its stock of academic talent. Accordingly, a country's performance in the university ranking tally is an indication of the country's stock of this specific type of human capital. This study borrows from, and extends the methodology used in a niche Olympic Games literature, particularly Bernard and Busse (2004). This literature examines the socioeconomic determinants of countries' performance in the Olympic Games medal tally; likewise, here we seek to identify the key socioeconomic determinants of countries' performance in the university ranking tally.

In this paper, we focus on the ARWU league tables for reasons to be explained in the data section. The ARWU dataset provides the ranking of up to 500 universities in the world. This allows us to compute the number of top 500 universities that a country has in a particular year; we denote this variable by $TOP500_i$, where *i* indicates the country index. Later on, we also consider smaller subsets like top 300 and top 100 universities. The value of these variables for the vast majority of countries varies little over the six year period over which the ARWU league tables have been compiled: 2003-2008. The only notable exception is China whose share in the top 500 universities doubled during this period. The dataset is essentially cross-sectional rather than panel in nature. This does not necessarily cause any concerns because our primary interest is in identifying factors that explain the performance gap between countries, and therefore cross country analysis will suffice. The empirical work will focus only on the data for the latest year, 2008. We use the value of a single year rather than the sample average because, as explained below, in Poisson regressions the dependent variable must be an integer.

A large number of countries do not have a single university breaking into the ranks of the top 500. However, these countries should also be included in the analysis to avoid selection bias. To accommodate for zero and non-negative observations, we consider two basic modelling options: the Tobit model and the Poisson model.

The Tobit model is typically considered as a solution to modelling non-negative data samples containing a high proportion of zero observations. To motivate the use of the Tobit model, we follow Bernard and Busse (2004) and model $TOP500_i$ as a function of the size of the country's academic talent stock, T_i, over some threshold level, T^*, which in turn is a function of the world average level of academic talent stock.[6] Since academic talent is not directly observable, it is a latent variable. The Tobit model is given by:

$$y_i = \begin{cases} \ln\left(T_i / T^*\right) & \text{if } \ln\left(T_i / T^*\right) > 0 \\ 0 & \text{if } \ln\left(T_i / T^*\right) \le 0 \end{cases} \tag{1}$$

where y_i is the observed value of $TOP500_i$ for a given year.

To investigate what socioeconomic factors affect the accumulation of academic talent, it is further hypothesized that

$$\ln(T_i / T^*) = f(\mathbf{x}_i' \boldsymbol{\beta}) + e_i,\ e_i \sim iid(0, \sigma^2) \tag{2}$$

where $\mathbf{x}_i$ is a vector of independent, socioeconomic factors and $\boldsymbol{\beta}$ the corresponding unknown coefficients. Since the dependent variable is a measure of a country's talent stock versus the world average, the dependent variables should also be measured relative to their world average values. Nevertheless, in the case of cross sectional analysis, the world average values of the independent variables can simply be absorbed into the constant term and thereby do not need to be accounted for explicitly.

A merit of using the Tobit model is that it captures the non-negative nature of the data and confines the predicted values of the dependent variable to be non-negative, i.e. $\hat{y}_i \ge 0$. This is, however, only one of the two restrictions, the other restriction being $\sum_i \hat{y}_i = 500$. In

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[6] Bernard and Busse's specification of M_{it}^* in the Tobit model (equations 3 and 4 in their paper) is incorrect because by setting $M_{it}^* = \ln\left(T_{it} / \sum_j T_{ji}\right)$, a log function of world medal share, M_{it}^* must always be non-positive. Nevertheless, this does not affect their empirical analysis as one could alternatively set $M_{it}^* = \ln(T_{it} / T^*)$, where T^* represents some threshold level of athletic talent. In fact, this is exactly the specification used by Bernard and Busse in their working paper (2000). The use of panel data in their case, however, raises another issue in that T^* could be time varying because if the Olympic Games becomes more competitive overtime, the athletic talent threshold to earn a medal will also increase. This is not an issue in the current paper because we are using a cross sectional dataset.

OLS regressions, this restriction will be automatically satisfied because the expected value of the error term is assumed to be zero. However, in the case of Tobit regressions, even though the mean value of e_i in equation (2) is assumed to be zero, the forecast errors of the zero observations are not constrained to sum to zero.[7] As a result, the second restriction will not be satisfied, except by coincidence. While it is possible to rescale the predicted values so that the predicted sum is the same as the actual sum, any over (under) prediction actually indicates that overall, the model overestimates (underestimates) the coefficients. Unless by mere coincidence the degrees of overestimation or underestimation for different coefficients are the same, one cannot recover the 'true' coefficient values by rescaling the coefficient estimates with the same factor.

A potential solution to the above problem is to estimate the Tobit model using Bayesian estimation methods. Using Bayesian methods, we can make *prior* assumptions about the properties of the dependent variable and restrict the total sum of the predicted value to lie within a certain band around the actual sum. However, restricting the total sum to a narrow band would require simulation of an extremely large Markov chain. Furthermore, the Tobit model assumes that the latent variable has a continuous distribution. However, when the concerned variable is truly discrete, standard methods like maximum likelihood Tobit result in inconsistent parameter estimates (Mullahy 1986). Portney and Mullahy (1986) in their application conduct Tobit specification error tests of Nelson (1981) and Lin and Schmidt (1984) for their count measure and find considerable evidence of misspecification. Rosenzweig and Wolpin (1982) in their study on the impact of governmental efforts to reduce

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[7] The log likelihood for censored regression is

$$\ln L = \sum_{y_i>0} \frac{-1}{2}[\log(2\pi) + \log(\sigma^2) + \frac{(y_i - x_i{}'\beta)^2}{\sigma^2}] + \sum_{y_i=0} \ln[1 - \Phi(\frac{x_i{}'\beta}{\sigma^2})] .$$

The two parts correspond to the classical regression for the nonlimit observations and the relevant probabilities for the limit observation, respectively. While the first order condition for the constant term forces the sum of the residual term to be zero in the case of classical linear regressions, this is not the case for the Tobit model due to the presence of the discrete term in the above log likelihood function.

population growth and augment child survival and schooling in a developing country find that for their discrete fertility variable the estimated coefficient standard errors from the fertility equation to be biased. Hence, they unambiguously rule out the use of the Tobit model in their application.

An alternative to the Tobit model is the Poisson model. The Poisson distribution can be written as

$$\Pr(TOP500_i = y_i) = \frac{\exp(-\lambda_i)\lambda_i^{y_i}}{y_i\,!},\ \lambda_i \in \mathbb{R}^+, y_i = 0,1,2,... \qquad (3)$$

where

$$E(TOP500_i) = \text{var}(Y_i) = \lambda_i \qquad \text{(equidispersion)} \qquad (4)$$

To ensure λ_i to be non-negative, the most common specification for λ is an exponential function

$$\lambda_i = \exp(\mathbf{x}_i'\,\boldsymbol{\beta}) \qquad (5)$$

where **x** is a vector of independent variables and **β** the corresponding unknown coefficients.

Equations (4) and (5) together establish the Poisson regression model

$$E(TOP500_i \mid \mathbf{x}_i) = \lambda_i = \exp(\mathbf{x}_i'\,\boldsymbol{\beta}) \qquad (6)$$

The Poisson regression model has a number of merits: it captures the discrete and non-negative nature of the data; it allows inference to be drawn on the probability of the event occurrence; it allows for straightforward treatment of zero observations; it naturally accounts for the heterokedastic and skewed distribution inherent to non-negative data (Winkelmann and Zimmermann 1995). In the current context, it has an additional merit that it guarantees the sum of the predicted values to be equal to the actual sum. Assuming independence among the count variables, the log-likelihood for the Poisson regression model follows as:

$$L = \sum_{i=1}^{N} y_i \mathbf{x}_i'\boldsymbol{\beta} - \exp(\mathbf{x}_i'\boldsymbol{\beta}) - \ln(y_i\,!) \qquad (7)$$

The first order conditions, $\partial L / \partial \beta = 0$, yield a system of equations (one for each β) of the form:

$$\sum_{i=1}^{N} (y_i - \exp(\mathbf{x}_i{}'\boldsymbol{\beta}))\mathbf{x}_i = 0 \qquad (8)$$

Equation (8) ensures that the sum of predicted values is the same as the actual sum if **x** contains a constant term.

A potential problem confronting the Poisson model is that in many applications, the assumption of "equidispersion" is violated. For instance, in our dataset the mean of $TOP500_i$ is 5.33 and standard derivation 17.99 (see Table 2). This is referred as "overdispersion" in the literature,[8] and it could be eliminated to a certain extent by the inclusion of additional regressors. Alternatively, one can specify a distribution that permits more flexible modelling of the variance than the Poisson distribution. The standard alternative distribution used is negative binomial (NEGBIN), with variance either assumed to be a linear or a quadratic function of the mean (Cameron and Trivedi 1986). A much simpler alternative is to use the Generalized Linear Model (GLM) under the assumption that the true variance is proportional to the distribution used to specify the log likelihood:

$$\text{var}(TOP500_i \mid \mathbf{x}_i) = \sigma^2 \, \text{var}_{ML}(TOP500_i \mid \mathbf{x}_i) \qquad (9)$$

If there is overdispersion, one would expect $\sigma^2 > 1$.

The conventional *R*-squared statistics based on a sum of squared residuals does not apply to either the Poisson or the Tobit model. Wooldridge (2009) suggests calculating the *R*-squared as the squared correlation coefficient between y_i and $\hat{y}_i$, i.e. $\tilde{R}^2 = \left(corr(y_i, \hat{y}_i)\right)^2$, motivated by the fact that the usual *R*-squared for OLS regressions is equal to the squared correlation between y_i and the OLS fitted values.

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[8] However, as it is shown later our sample actually passes the overdispersion test.

Beside correlation, another, yet more direct, measure of goodness-of-fit is simply the extent to which the model can predict the actual value of the dependent variable for given values of the independent variables. Since the Poisson model already guarantees the sum of the predicted values to be equal to the actual sum, i.e. $\sum \hat{y}_i = \sum y_i$, we can use the sum of absolute forecast error as a ratio of the total actual value, i.e. $\sum |y_i - \hat{y}_i| / \sum y_i$ as a measure of goodness-of-fit. Yet, this measure is bounded from below at 0 but unbounded from above. In order to make the measure lie between 0 and 1 we propose to construct $\bar{R}^2 = \sum y_i / \left(\sum y_i + |y_i - \hat{y}_i| \right)$ as an alternative indicator of the goodness-of-fit. The value of $\bar{R}^2$ increases as forecast errors reduce, with 1 indicating a perfect match for every single observation and 0 indicating at least one infinitely large forecast error. A value of $\bar{R}^2$ equal to, say, 0.8 means that the average forecast error is approximately equal to 20 percent of the actual value. One should, however, remember that the Poisson and Tobit estimates are chosen to maximize the log-likelihood functions, not *R*-squared. As a result, unlike OLS regressions, adding more variables into the model does not necessarily improve $\tilde{R}^2$ or $\bar{R}^2$.

3. Data

There are numerous organizations publishing international university rankings, including Shanghai Jiaotong University’s Academic Ranking of World Universities (ARWU)[9], the Times Higher-Quacquarelli Symonds World University Rankings (THES-QS)[10], the Webometrics Ranking of World Universities[11] and *Newsweek* magazine’s Top 500 Global Universities[12]. Amongst them the ARWU and THES-QS rankings are most well-known and widely cited by academics and the media, e.g. *The Economist* (2005). A consensus is emerging in the literature that the ARWU, despite its limitations, provides a

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[9] http://www.arwu.org

[10] http://www.topuniversities.com

[11] http://www.webometrics.info/about.html

[12] http://web.archive.org/web/20060820193615/http://msnbc.msn.com/id/14321230/site/newsweek

superior indicator of university excellence in terms of objectivity and comprehensiveness (Marginson, 2007; Taylor & Braddock, 2007; Hazelkorn, 2007; Buela-Casal et al. 2007). The ARWU aims to measure the institutions' research strength using internationally comparable indicators such as number of alumni and staff winning Nobel Prizes and Fields Medals, publication count, as well as a per capita performance measure (Liu & Cheng 2005). On the contrary, the THES-QS ranking relies heavily on peer reviews, which are criticized for being strongly subjective and resulting in the high volatility of the rankings. Therefore, in this paper we focus only on the ranking statistics of ARWU.

For the independent variables, we examine a number of socioeconomic variables that potentially affect the accumulation of academic talent. Our benchmark model includes four independent variables: log population size ($LPOP$), log income ($LGDPPC$), R&D spending as a percentage of GDP (R_D), and a dummy for English as the native language (ENG). If academic talent is randomly distributed around the world, then other things being equal, countries with a larger population should have a larger academic talent stock. However, academic talent, like athletic talent, can be a result of nurture as well as of nature; therefore, the amount of available resources matters. We use income as a general measure of the financial resources available in a country, and use total expenditure on R&D as a specific measure because if the total R&D expenditure of a country goes up, the amount going to the higher education sector is likely to go up accordingly. The English language dummy is to test if English speaking countries are in a privileged position. At first glance, the answer seems to be an obvious yes given that the rankings primarily consider publications in English. However, many academic staff in non-English speaking countries now teach and publish in English.[13] Moreover, universities in English speaking countries have the advantage of being

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[13] Japanese universities, for instance, offer many postgraduate programs to "international or internationally-minded" students, and recruit international scholars without requiring the knowledge of Japanese language (Hazelkorn 2008).

able to recruit both native and non-native English speaking academics from around the world, whereas universities in non-English speaking countries are more confined in their recruitment if their staff members are required to teach in the local language. In summary, positive signs are expected for all these four variables.

Besides these four variables, we also try to include a number of other socioeconomic variables for robustness tests. These include the number of migrants as a percentage of total population (*MIG*), public expenditure on education as a percentage of GDP (*EDUGDP*), log public expenditure per tertiary student (*LEXPTER*), and the number of tertiary students as a percentage of population (*TERPOP*). The migration variable is to account for the fact that academics are highly mobile internationally. Public expenditure on education is yet another possible measure of resources. Different from the R&D expenditure, *EDUGDP* captures the resources flowing into all primary, secondary and tertiary sectors. The deployment of this variable can be motivated by the fact that, if a country's primary and secondary education is sound, it can produce good prospective tertiary students and academics. In comparison, the expenditure per tertiary student specifically measures the resources put into the higher education sector. Lastly, the number of tertiary students as a proportion of the population size measures the size of the higher education sector; countries with a larger higher education sector obviously need to employ more academics. Therefore, all four additional variables are expected to have positive signs on their respective coefficients. These additional independent variables, however, are found to be statistically insignificant and are subsequently dropped. In the next section, we report and discuss only the results of the key variables.[14]

Table 1 lists all the variables used in this paper and their sources and Table 2 shows their summary statistics. To mitigate reverse causality, the time periods of the independent

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[14] The results of models with additional variables can be obtained from authors on request.

variables are chosen to lag 2008 (we formally test for reverse causality later on). The data for individual countries are provided in Table A1.

A few observations on the figures in Table 2 are worth commenting. First, the total sum of $TOP500_i$ is slightly less than 500 because some countries/regions that have top 500 universities, like Taiwan, are excluded due to the lack of data for other variables. Second, besides $TOP500_i$, the table also shows the statistics of $TOP300_i$ and $TOP100_i$. In the case of $TOP300_i$, the total sum is larger than 300 because some ranking positions are shared by more than one university. Third, there is a high degree of concentration of top universities amongst a small number of countries. For instance, only 40 percent of the sample countries (i.e. 38 out of 93) have one or more top 500 universities, and the percentage falls to 15 percent as it comes to the top 100 universities. In other words, over half the countries in the sample have a zero value for their dependent variables. Lastly, when the additional independent variables are added, the sample size reduces from 93 to 79.

4 Empirical Results

4.1 Results for TOP500

We first report the Poisson model results for $TOP500_i$. The results for various model specifications are shown in Table 3. Models (a) and (b) show that either income or population size by itself does a very poor job in explaining $TOP500_i$; but once the two are combined as a single measure of the total economic size in model (c), the explanatory power improves dramatically. Model (d) further shows that *LGDPPC* has twice the effect of *LPOP*, indicating that income has individual effects even after controlling for the total economic size. The variables have the expected signs in all three models. Model (e) shows that adding R_D into the model only marginally improves its goodness-of-fit, and the variable is just significant at the 10 percent level with the expected sign. Model (f) further adds *ENG* as another control variable. It shows that the English language dummy has the expected sign and is significant at a level slightly higher than 5 percent. The inclusion of *ENG* also improves the significance of R_D to the 1 percent level. Despite both *ENG* and R_D being highly significant individually, their inclusion does not add much to the overall explanatory power of the model as compared to the more parsimonious model (d). In what follows, we consider model (f) as the benchmark model.

According to the benchmark model (f), other factors being equal, expanding the population size by one percent increases the number of top 500 universities in a country by 0.77 percent, while a one-percent rise in the income level increases that figure by nearly 1.5 percent. The model also shows that, other factors being equal, raising the expenditure of R&D by one percentage point of GDP increases the number of top 500 universities by 28 percent. While the effect may appear to be very large, a one percentage point increase in R&D actually represents more than doubling the R&D spending for an average country in the sample (the mean value of R&D is equal to 0.89 percent of GDP). Lastly, it is shown that an English-speaking country has 41 percent[15] more top 500 universities than a non-English speaking, but otherwise identical country.

Figure 1 shows the actual values and the prediction errors (actual minus predicted value) of $TOP500_i$ for each of the 38 countries that have at least one top 500 university. The full results are shown in Table 4, which reports the predicted values of $TOP500_i$ for each of the 93 countries in the sample, the prediction errors (the actual minus the predicted value) and the prediction errors in proportional terms if the actual value is bigger than zero. Although the US is the frontrunner in the ARWU league table, it actually underperforms by nearly 18 universities based on the benchmark model, followed by Japan (17 universities short). However, in proportional terms, Mexico is the most underperformed country with a shortfall

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[15] Since ENG is a dummy variable, the effect of a change of its value from 0 to 1 is computed as exp(0.344*1)/exp(0.344*0) – 1 = 0.41.

of 332 percent, followed by Russia with a shortfall of 186 percent. For countries that have zero actual observations, Iran is predicted to have the largest number of top 500 universities of about 2, followed by Malaysia with a predicted number of 1.5 and Kuwait of 1.4. The results indicate that, given these countries' human and non-human resources, they have the potential to perform better. This in turn suggests that there are some factors hindering them from fully realizing their potential, such as insufficient resources being channelled into the higher education sector (e.g. Mexico[16]), institutional barriers to participating in international academic communities (e.g. Iran[17]), or salary incentives being unconducive to publishing in high ranked international journals (e.g. Japan).

On the other hand, the UK outperforms the model prediction by 15 universities, or 36 percent in percentage terms. The next best 'outperformer' is a rising economic and political power—China, which has 13 universities, or 70 percent, more than the model's prediction. For countries with non-zero top 500 universities, China has the best outperformance in proportional terms. The third best outperformer in absolute terms is Germany, which has about 10 more universities than the model's prediction.[18]

Despite the aforementioned theoretical limitations of the Tobit model, it is useful to examine their empirical significance. The results for the Tobit model based on the benchmark model are also reported in Table 5 along with the Poisson model results for the ease of comparison. It can be seen that the signs for all variables remain correct in the Tobit regression. In terms of goodness-of-fit, both $\tilde{R}^2$ and $\bar{R}^2$ statistics indicate that the Poisson model provides a better fit for the data than the Tobit model. In fact, the total predicted

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[16] The higher education system in Mexico has undergone a long process of transition, which is regarded as "not necessarily positive" , and a range of problems have been identified, such as insufficient enrolment levels, poor staff salary, demoralized faculty, and non-existing student financial aid (Ordorika 1996).

[17] There are unverified claims that Iranian scholars and universities sometimes experience formal and informal barriers to international collaboration, such as being denied visa to attend academic conferences overseas (Pankratz 2008).

[18] Interestingly, the German government, after acknowledging the country has lost the glory of being one of the world's intellectual centres, has put forward a policy of creating a German Ivy League (Vogel 2006).

number of $TOP500_i$ by the Tobit model is equal to 663.4, which is 33 percent more than the actual sum of 496! More importantly, the fact that the Tobit model over predicts $TOP500_i$ implies that overall it overestimates the coefficients of the independent variables. An explanation for this result is that there is a high level of heteroskedasticity in the data set, as commonly seen in cross sectional data. In OLS regressions, heteroskedasticity affects the standard errors, but the estimates for the coefficients remain unbiased. However, in the case of the Tobit model, this will lead to biased estimates of the coefficients.[19] The Poisson model, on the contrary, automatically accounts for heteroskedasticity (see equation (5)).

4.2 Robustness Tests

The US dominates the ARWU league table with a total of 159 top 500 universities, equivalent to 31.8 percent. The UK is the next most prominent country on the league table, with a total of 42 top 500 universities, equivalent to 8.4 percent. Together they account for 40 percent of the top 500 universities. Therefore, it is important to test the robustness of the results with respect to the exclusion of these two ‘outliers’. The results are also shown in Table 5. The exclusion of the US and the UK has a very small effect on the coefficient values and virtually no impacts on their significance or signs for most variables. The only exception is that the significance of the English language dummy becomes significant at the l percent level and the magnitude of its coefficient also increases. Therefore, we can conclude that, the model for $TOP500_i$ is very robust to the exclusion of the top two performers.

A key distinction between the model for the university ranking and that for the Olympics Games is that the chance of having reverse causality onto income is higher for the former than for the latter. This is because academic talent is more likely to have bigger impacts on the macroeconomy than athletic talent due to the spillover effects of knowledge creation. Besides income, the expenditure on R&D may also incur endogeneity problems in

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[19] See David Madigan’s note on Logistic and Tobit Regression, available at http://stat.rutgers.edu/~madigan/COLUMBIA/

that top universities are more attractive to research funding. In testing endogeniety in the Poisson model we follow the procedure described by Wooldridge (2002), which requires instrumental variables for the potentially endogenous variables. One obvious choice of instrument for a potentially endogenous variable is its lagged value. Due to data limitation, we use the 1980 values of $LGDPPC_i$ and the 1996 values of R_D_i as their respective instruments. We first estimate the following reduced form OLS regressions:

$$LGDPPC_i = c_1 + c_2\, LGDPPC_{1980,i} + u_i \qquad (10)$$

and

$$R\_D_i = c_3 + c_4\, R\_D_{1996,i} + v_i \qquad (11)$$

Once we obtain the residuals $\hat{u}_i$ and $\hat{v}_i$, we estimate the Poisson regression model by regressing the count data on the explanatory variables and the residuals. The Wald test that the coefficients of the residuals are zero, cannot be rejected at the 5 percent significance level, indicating that there is insufficient evidence to support the claim that income and R&D expenditure are endogenous in the benchmark model. There are a number of possible explanations for the absence of evidence of reverse causality from $TOP500_i$ to income. Firstly, $TOP500_i$ only captures a specific type of human capital within the total human capital stock of a country; secondly, the research output used in determining the ARWU rankings is mostly academic research instead of commercial research; thirdly, the materialization of academic research in terms of commercialization or policy making may take years; and lastly, the benefit of academic research outcome often spills over to other countries, diluting the effect of difference in league table performance on income difference. Likewise, the lack of evidence of reserve causality from $TOP500_i$ to R&D spending may be due to the fact that the effect of $TOP500_i$ on university R&D spending may be too small to be discernible in the much bigger pool of national R&D spending.

Lastly, recall that when there is overdispersion, a negative binomial (NEGBIN) distribution is more appropriate than the Poisson distribution. We employ the procedure suggested by Wooldridge (2002) to test for overdispersion and to estimate the overdispersion parameter α for the Poisson model. The test suggests that when there is an overdispersion the variance is greater than the mean, i.e. $\mathrm{var}(y_i) = \mu_i(1+\alpha\mu_i)$, where $\mu_i = \exp(X_i\beta)$. The null hypothesis ($\alpha = 0$) that there is no overdispersion cannot be rejected at the 5 percent significance level, indicating that the Poisson model restriction that the mean is equal to the variance holds well.

4.3 Results for TOP300 and TOP100

Besides top 500 universities, we also consider countries' performance in more elite subgroups, top 300 and top 100 universities. The dependent variables are denoted respectively as $TOP300_i$ and $TOP100_i$. These results are reported in Table 6 while the results for $TOP500_i$ are also repeated in the table for the ease of comparison.

The signs of all variables remain the same across all three models. The goodness-of-fit of the three models is also very similar, indicating that the benchmark model maintains its explanatory power for all three dependent variables. Nonetheless, there are gradual changes of the magnitude of the coefficients. Specifically, the coefficient of population size reduces as it moves toward the more elite group (from 0.77 for $TOP500_i$ to 0.67 for $TOP100_i$). On the contrary, the coefficients of income, R&D expenditure, and English language all go up. The coefficient of income increases by 50 percent (from 1.50 to 2.27), while those of R&D expenditure and the English dummy increase by around three fold (from 0.28 to 0.81 for R_D and from 0.34 to 1.09 for *ENG*). It can be inferred from these results that, the more elite the academic talent, the more important the nurturing factors and the less random their distribution across countries. The results are somewhat expected in that, as the old saying goes: “genius is ten percent inspiration and ninety percent perspiration”; at the same time perspiration requires sufficient resources and a good working environment, and their distributions across countries are far from being random. Moreover, there is a strong tendency for the most talented academics to move to places where they can be best supported and most easily find their peers. Together these factors indicate that there is an agglomeration effect of academic talent clustering in countries with better resources and working environment.

Figure 2 shows the actual values and the prediction errors of $TOP100_i$ for each of the 15 countries that have at least one top 100 universities. The US continues to underperform, but the margin shrinks from the 10 percent in the case of $TOP500_i$ to 4.3 for the more elite top one hundred group. The margin of over performance for the UK also shrinks from 57 percent to 17.6 percent. The results are probably related to the fact that resources are, expectedly, not uniformly distributed across universities. Inequality in resources within the top 100 universities is likely to be smaller than within the top 500 universities. Therefore, aggregate measures of national resources will be a better proxy of the resources available to a smaller and more homogenous group of universities than those available to a larger, more diversified one.

For the most elite universities, the dominance of the US and the UK is even more striking. The two countries have 114 and 33 top 300 universities (38 percent and 11 percent), and 54 and 11 top 100 universities (54 percent and 11 percent) respectively. Once again we examine how robust the results for the most elite group of universities are by excluding these two top performing countries. Due to space limitations, we only report the results for $TOP100_i$. When the US is excluded from the sample, there is an increase in the coefficients of all the independent variables; when the UK is also excluded, the coefficient of population size returns to close to the value of the full sample. Also, when both countries are excluded, the coefficient of the English language dummy drops to less than the original value in the full sample, and its significance level also drops down to the 10 percent level. Therefore, we conclude that while overall the model remains robust with respect to the exclusion of the US and the UK, expectedly it is somewhat more sensitive for $TOP100_i$ than for $TOP500_i$.

5. Discussions and Conclusions

This paper aims to seek a better understanding of the socioeconomic determinants of countries' performance in university league tables. It focuses on the most widely cited university league table—Shanghai Jiaotong University's Academic Ranking of World Universities (ARWU). The ARWU league table, like other league tables, is dominated by a single country—the US. Sixty percent of the countries in the sample, on the contrary, do not have a single university successfully breaking into the top 500 rank. The analysis in the paper helps shed light on the large performance gap between countries in the league tables.

The empirical methodology needs to satisfy two restrictions: firstly, the predicted number of top universities for any country should be non-negative; secondly, the total predicted number of top universities should be identical to the actual total number. Standard Tobit regressions satisfy the first restriction but not the second, while standard OLS regressions satisfy the second but not the first one. Poisson regressions satisfy both restrictions and thereby are applied to identify the key socioeconomic determinants of the number of top 500 universities that countries had in 2008.

We find that a large proportion of cross countries difference in the ARWU league tables can be readily explained by a few variables, primarily population size and income, with the addition of R&D expenditure and an English language dummy. The findings confirm that resources, including R&D funding, are crucial in building an internationally competitive higher education sector. The model is robust to a number of specifications tests and exclusion of the top two performers, the US and the UK. It is also robust to the modelling of top 100 or top 300 universities.

Despite the observation that the US monopolizes the world's top universities, our finding indicates that there is nothing extraordinary about its performance. According to our model, the reason for the US's dominance is due to its large population and economic size, further enhanced by its large expenditure on R&D (2.7 percent of GDP compared to the sample mean of 0.89 percent) and its predominant language being English. In fact, given the resources it has, the US is underperforming by about 4 to 10 percent based on the model prediction. This finding does not necessarily come as a surprise in that on a very broad sense, the similarities of university systems across countries are probably bigger than their differences. This finding may nevertheless make sobering reading for administrators and policymakers who fix their eyes firmly on US universities in searching for a better model for their institutions.

On the other hand, one needs to be cautious in inferring from the findings, the relative merits of the US university model. Despite the fact that the US's performance falls short of the model prediction, we must emphasise that it is still the frontrunner by a large margin. Furthermore, the finding only indicates that down to top 100 universities, there is no discernible country specific effect in the US to be explained. It does not exclude the possibility that what distinguishes the US system from the others lies in the very top end of the league tables, say, the top 50 or top 20 universities, where the dominance of the US is strongest. Additionally, many academics in other countries were educated in US universities (and the other way round as well), and therefore their success could be attributed at least partly to the US model.

Another inference one might be tempted to draw from the findings is that, the US's current hegemonic position in the league tables could be challenged if its economic power weakens. This is particularly relevant in the context that the US’s economic hegemony is increasingly being tested by fast growing economies in Asia and Latin America, especially the BRIC (Brazil, Russia, India, and China) countries. However, such a scenario of declining US dominance in the league tables, while possible, is not necessarily warranted. For a given total amount of resources provided for the higher education sector, how the resources are distributed amongst universities can also make a significant difference to the overall national outcome. Therefore, one must be careful in making predictions of a country’s future performance simply based on a linear projection of its macroeconomic indicators.

The distributional factor may also explain why China is the best outperformer in the top 500 league table in proportional terms. Although China is only a lower-middle income country, its sheer size allows it to mobilize more resources than its income level suggests, and focus them on a small number of universities. According to recent estimates (Li 2004), approximately US$2.2 billion was distributed to a selected number of universities during the period between 1996 and 2000. One of the programs launched by the Chinese government, Project 985, was indeed designed to meet the policy objective that “China must have a number of first-rate universities of international advanced level”.

The strong effect of English language on countries’ performance suggests that universities in non-English speaking countries need concerted efforts in disseminating their research output in English medium in order to improve their rankings. Endeavour in this direction has already been observed in Europe and increasingly in Latin America and Asia, implying that the ‘natural’ advantage of English-speaking countries will be gradually eroded over time.

We conclude this paper by briefly discussing its limitations and providing pointers for future research opportunities. In focusing on socioeconomic factors, the analysis in this paper is silent on the importance of institutional factors,[20] such as student and staff numbers, the size of endowment, incentive structure, and the status of a public/private university. The last factor is of particular interest as it could have implications in policy debates, as to what extent the higher education sector, which is largely a semi public sector in most countries, should be allowed to be privatized. The importance of these factors may vary across different countries, and how institutional factors may interact with national factors would also be worth investigating. An analysis at the institutional level thereby will constitute a natural progression of this line of research.

Reference

Aghion, P, Dewatripoint, M, Hoxby CM, Mas-Colell, A & Sapir A 2009 ‘The governance and performance of research universities: evidence from Europe and the U.S.’ NEBR Working Paper # 14851.

Barro, RJ 1991, 'Economic growth in a cross section of countries', *The Quarterly Journal of Economics,* vol. 106, no. 2, pp. 407-43.

Bernard, AB & Busse, MR 2000, 'Who Wins the Olympic Games: Economic Development and Medal Totals', *National Bureau of Economic Research Working Paper Series*, vol. No. 7998.

---- 2004, 'Who Wins the Olympic Games: Economic Resources and Medal Totals', *Review of Economics and Statistics*, vol. 86, no. 1, pp. 413-7.

Buela-Casal, G, Gutiérrez-Martínez, O, Bermúdez-Sánchez, M & Vadillo-Muñoz, O 2007, 'Comparative study of international academic rankings of universities', *Scientometrics*, vol. 71, no. 3, pp. 349-65.

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[20] Aghion et al (2009) is a good example of research in this direction.

Cameron, AC & Trivedi, PK 1986, 'Econometric Models Based on Count Data: Comparisons and Applications of Some Estimators and Tests', *Journal of Applied Econometrics*, vol. 1, no. 1, pp. 29-53.

DFAT 2008, *Composition of Trade Australia*, Australian Government Department of Foreign Affairs and Trade.

Hazelkorn, E 2007, 'The Impact of League Tables and Ranking Systems on Higher Education Decision Making', *Higher Education Management and Policy*, vol. 19, no. 2.

---- 2008, *From Globalisation to Internationalisation – the Influence of Rankings on Japanese Higher Education*, OECD.

---- 2008, 'Learning to Live with League Tables and Ranking: The Experience of Institutional Leaders', *High Education Policy*, vol. 21, no. 2, pp. 193-215.

Healy, G 2009, 'Long way to the top for ranking role', *The Australian*, April 22.

Higher Education Funding Council for England 2008, *Counting What is Measured or Measuring What Counts? League Tables and Their Impact on Higher Education Institutions in England*, London.

Johnson, DKN & Ali, A 2004, 'A Tale of Two Seasons: Participation and Medal Counts at the Summer and Winter Olympic Games', *Social Science Quarterly*, vol. 85, no. 4.

Koop, G, Osiewalski, J & Steel, MFJ 2000, 'Modeling the sources of output growth in a panel of countries', *Journal of Business & Economic Statistics,* vol. 18, no. 3, pp. 284-99.

Li, L 2004, 'China's Higher Education Reform 1997-2003: A Summary', *Asia Pacific Education Review*, vol. 1, pp. 14-22.

Lin, T-F & Schmidt, P 1984, 'A Test of the Tobit Specification Against an Alternative Suggested by Cragg', *The Review of Economics and Statistics*, vol. 66, no. 1, pp. 174-7.

Liu, NC & Cheng, Y 2005, 'Academic Ranking of World Universities–Methodologies and Problems', *Higher Education in Europe*, vol. 30, no. 2.

Marginson, S 2007, 'Global University Rankings: Implications in General and for Australia', *Journal of Higher Education Policy and Management*, vol. 29, no. 2, pp. 131-42.

Morton, RH 2002, 'Who won the Sydney 2000 Olympics?: an allometric approach', *The Statistician*, vol. 51, pp. 147-55.

Mullahy, J 1986, 'Specification and testing of some modified count data models', *Journal of Econometrics*, vol. 33, no. 3, pp. 341-65.

Nelson, FD 1981, 'A Test for Misspecification in the Censored Normal Model', *Econometrica*, vol. 49, no. 5, pp. 1317-29.

Ordorika, I 1996, 'Mexican Higher Education in Transition: From Politically to Financially Driven Public Policies', *International Higher Education*, no. 5.

Pankratz, J 2008, 'Iran is recognizing the value of higher education', *The Record*.

Portney, PR & Mullahy, J 1986, 'Urban air quality and acute respiratory illness', *Journal of Urban Economics*, vol. 20, pp. 21-38.

Rosenzweig, MR & Wolpin, KI 1982, 'Governmental interventions and household behavior in a developing country : Anticipating the unanticipated consequences of social programs', *Journal of Development Economics*, vol. 10, no. 2, pp. 209-25.

Salmi, J & Saroyan, A 2007, 'League Tables as Policy Instruments: Uses and Misuses', *Higher Education Management and Policy*, vol. 19, no. 2.

Schofer, E, Ramirez, FO & Meyer, JW 2000, 'The effects of science on national economic development, 1970 to 1990', *American Sociological Review,* vol. 65, no. 6, pp. 866-87.

Taylor, P & Braddock, R 2007, 'International University Ranking Systems and the Idea of University Excellence', *Journal of Higher Education Policy and Management*, vol. 29, no. 3, pp. 245-60.

The Economist, 2005, ‘The brains business.” Sep 8th , the print edition.

Vogel, G 2006, 'A German Ivy League Takes Shape', *Science*, vol. 314.

Williams, R 2007, 'Ranking Australian Universities: Controlling for Scope', Melbourne Institute, University of Melbourne.

Williams, R & Dyke, NV 2004, *The International Standing of Australian Universities*, Melbourne Institute of Applied Economic and Social Research, Melbourne.

Winkelmann, R & Zimmermann, KF 1995, 'Recent Developments in Count Data Modelling: Theory and Application', *Journal of Economic Surveys*, vol. 9, no. 1, pp. 1-24.

Wooldridge, JM 2002, *Econometric analysis of cross section and panel data*, Cambridge, Mass.; London: MIT.

---- 2009, *Introductory econometrics: a modern approach*, 4th edn, South-Western Cengage Learning, Mason, Ohio.

Table 1 Definitions and sources of variables.

Variable	Definition	Year	Source	Expected sign	Note
$TOP500$	The number of top 500 universities in ARWU.	2008	ARWU		The dependent variable; similar definitions for $TOP300$ and $TOP100$
$LPOP$	Log total population	1999-2004 Average	WDI	+	To measure the size effect
$LGDPPC$	Log GDP per capita, (PPP, constant 2000 international dollar)	1999-2004 Average	WDI	+	To measure the general resource effect
R_D	Research and development expenditure (% of GDP)	1999-2004 Average	WDI	+	To measure the specific resource effect
ENG	Dummy, = 1 if English is the first language or widely used, = 0 otherwise		CIA World Factbook	+	To measure if being an English speaking country has advantage
MIG	International migration stock (% of population)	1999-2004 Average	WDI	+	To measure how open the labour market is (it is assumed that academic labour market is of similar degree of openness as the national labour market)
$EXPGDP$	Public expenditure on education (% of GDP)	1999-2004 Average	WDI	+	To measure the overall quality of the education system
$LEXPTER$	Log public expenditure per tertiary student (PPP, constant 2000 international dollar)	1999-2004 Average	WDI	+	To measure the quality of the higher education sector
$TERPOP$	Number of tertiary student (% of population)	1999-2004 Average	UNESCO Institute for Statistics	+	To measure the size of the higher education sector

Table 2 Summary statistics of the dependent and independent variables

	TOP500	TOP300	TOP100	LPOP	LGDPPC	R_D	ENG	MIG	EDUGDP	LEXPTER	TERPOP
Mean	5.33	3.24	1.08	16.21	9.09	0.89	0.25	8.09	4.80	8.16	2.95
Median	0	0	0	16.14	9.15	0.58	0	3.39	4.71	8.30	3.13
Maximum	159	114	54	20.97	11.07	4.42	1	64.11	11.03	10.82	6.34
Minimum	0	0	0	11.67	6.34	0.01	0	0.04	0.82	5.17	0.08
Std. Dev.	17.99	12.70	5.76	1.79	1.16	0.95	0.43	11.42	1.61	1.16	1.46
Skewness	7.03	7.46	8.54	-0.05	-0.47	1.58	1.17	2.91	0.60	-0.37	-0.14
Kurtosis	58.89	64.00	78.42	3.24	2.31	5.06	2.37	12.69	4.82	2.87	2.37
Sum	496	301	100	1507.23	844.92	82.69	23	639.17	378.82	645.00	232.85
No. of Obs.	93	93	93	93	93	93	93	79	79	79	79
No. of Obs. > 0	38	31	15								

Table 3 Estimation results of the Poisson model for TOP500

	(a)	(b)	(c)	(d)	(e)	(f)
Constant	-8.818***	-13.809***	-27.254***	-31.658***	-29.297***	-26.677***
	(2.475)	(4.637)	(1.823)	(1.766)	(2.125)	(2.072)
LPOP	0.611***			0.869***	0.826***	0.766***
	(0.150)			(0.055)	(0.048)	(0.060)
LGDPPC		1.580***		1.877***	1.677***	1.499***
		(0.474)		(0.230)	(0.262)	(0.231)
LPOP + LGDPPC			1.071***			
(=LGDP)			(0.064)			
					0.215*	0.279***
R_D					(0.127)	(0.098)
ENG						0.344*
						(0.180)
$\overline{R}^2$	0.430	0.469	0.635	0.767	0.768	0.768
$\tilde{R}^2$	0.096	0.109	0.892	0.966	0.957	0.965
No. obs.	93	93	93	93	93	93

Standard errors are reported in parentheses, and are Huber/White standard errors.

*, **, *** indicates significance at the 10%, 5%, and 1% level, respectively.

$$\overline{R}^2 = \sum y_i \,/\left(\sum y_i + \left|y_i - \hat{y}_i\right|\right);\ \tilde{R}^2 = \left(corr(y, \hat{y})\right)^2$$

Table 4 The Actual and predicted number of top 500 universities

	Actual Top500	Predicted Top500	Prediction Error	Error/Actual value (if actual > 0)
Argentina	1	1.74	-0.74	-0.74
Armenia	0	0.04	-0.04	
Australia	15	11.15	3.85	0.26
Austria	7	5.23	1.77	0.25
Azerbaijan	0	0.09	-0.09	
Belarus	0	0.36	-0.36	
Belgium	7	5.47	1.53	0.22
Bolivia	0	0.12	-0.12	
Brazil	6	4.88	1.12	0.19
Brunei Darussalam	0	0.47	-0.47	
Bulgaria	0	0.37	-0.37	
Cambodia	0	0.03	-0.03	
Canada	21	20.41	0.59	0.03
Chile	2	1.10	0.90	0.45
China	18	5.35	12.65	0.70
Colombia	0	0.75	-0.75	
Costa Rica	0	0.24	-0.24	
Croatia	0	0.52	-0.52	
Cyprus	0	0.30	-0.30	
Czech Republic	1	1.94	-0.94	-0.94
Denmark	4	4.09	-0.09	-0.02
Ecuador	0	0.32	-0.32	
Egypt, Arab Rep.	0	0.75	-0.75	
Estonia	0	0.22	-0.22	
Finland	6	4.21	1.79	0.30
France	23	21.21	1.79	0.08
Georgia	0	0.05	-0.05	
Germany	40	29.89	10.11	0.25
Greece	2	2.96	-0.96	-0.48
Hong Kong, China	5	3.78	1.22	0.24
Hungary	2	1.33	0.67	0.34
Iceland	0	0.46	-0.46	
India	2	2.79	-0.79	-0.40
Indonesia	0	0.93	-0.93	
Iran, Islamic Rep.	0	2.15	-2.15	
Ireland	3	3.45	-0.45	-0.15
Israel	6	4.61	1.39	0.23
Italy	22	13.87	8.13	0.37
Jamaica	0	0.13	-0.13	
Japan	31	47.64	-16.64	-0.54
Jordan	0	0.09	-0.09	
Kazakhstan	0	0.44	-0.44	
Korea, Rep.	8	9.87	-1.87	-0.23
Kuwait	0	1.41	-1.41	
Kyrgyz Republic	0	0.02	-0.02	
Latvia	0	0.21	-0.21	
Lesotho	0	0.01	-0.01	
Lithuania	0	0.35	-0.35	
Luxembourg	0	1.38	-1.38	
Macao, China	0	0.23	-0.23	

Madagascar	0	0.03	-0.03	
Malaysia	0	1.45	-1.45	
Malta	0	0.22	-0.22	
Mauritius	0	0.15	-0.15	
Mexico	1	4.32	-3.32	-3.32
Mongolia	0	0.02	-0.02	
Morocco	0	0.28	-0.28	
Mozambique	0	0.01	-0.01	
Myanmar	0	0.04	-0.04	
Netherlands	12	8.51	3.49	0.29
New Zealand	5	1.94	3.06	0.61
Nicaragua	0	0.03	-0.03	
Norway	4	4.75	-0.75	-0.19
Pakistan	0	0.58	-0.58	
Panama	0	0.20	-0.20	
Paraguay	0	0.09	-0.09	
Peru	0	0.55	-0.55	
Philippines	0	0.58	-0.58	
Poland	2	2.54	-0.54	-0.27
Portugal	2	2.07	-0.07	-0.03
Romania	0	0.80	-0.80	
Russian Federation	2	5.72	-3.72	-1.86
Singapore	2	5.42	-3.42	-1.71
Slovak Republic	0	0.68	-0.68	
Slovenia	1	0.74	0.26	0.26
South Africa	3	2.20	0.80	0.27
Spain	9	9.25	-0.25	-0.03
St. Lucia	0	0.03	-0.03	
St. Vincent and the Grenadines	0	0.01	-0.01	
Sudan	0	0.13	-0.13	
Sweden	11	8.02	2.98	0.27
Switzerland	8	6.28	1.72	0.22
Tajikistan	0	0.02	-0.02	
Thailand	0	1.19	-1.19	
Trinidad and Tobago	0	0.29	-0.29	
Tunisia	0	0.29	-0.29	
Turkey	1	2.54	-1.54	-1.54
Uganda	0	0.04	-0.04	
Ukraine	0	0.73	-0.73	
Uruguay	0	0.21	-0.21	
Zambia	0	0.03	-0.03	
United Kingdom	42	26.76	15.24	0.36
United States	159	176.87	-17.87	-0.11

Table 5 Estimation results of Tobit and Poisson models for TOP500

	Tobit Model (f)	Poisson Model (f)	Model (f) without US	Model (f) without US and UK
Constant	-550.182***	-26.677***	-29.926***	-29.241***
	(170.698)	(2.072)	(2.587)	(2.643)
LPOP	15.396***	0.766***	0.868***	0.848***
	(4.816)	(0.060)	(0.084)	(0.086)
LGDPPC	29.232***	1.499***	1.640***	1.606***
	(8.914)	(0.231)	(0.235)	(0.240)
R_D	4.477***	0.279***	0.292**	0.299**
	(1.617)	(0.098)	(0.123)	(0.117)
ENG	15.022**	0.344*	0.575***	0.460***
	(7.396)	(0.180)	(0.138)	(0.135)
$\bar{R}^2$	0.602	0.768	0.726	0.730
$\tilde{R}^2$	0.743	0.965	0.839	0.843
No. obs.	93	93	92	91

Same as Table 2.

Table 6 Estimation results for TOP100 and TOP300

	Model (f) TOP500	Model (f) TOP300	Model (f) TOP100	Model (f) TOP100 without US	Model (f) TOPp100 without US and UK
Constant	-26.677***	-28.671***	-36.212***	-42.210***	-41.883***
	(2.072)	(2.754)	(5.451)	(7.996)	(9.576)
LPOP	0.766***	0.706***	0.666***	0.770***	0.674***
	(0.060)	(0.065)	(0.087)	(0.152)	(0.132)
LGDPPC	1.499***	1.710***	2.271***	2.658***	2.789***
	(0.231)	(0.281)	(0.521)	(0.696)	(0.838)
R_D	0.279***	0.377***	0.807***	0.888***	0.886***
	(0.098)	(0.113)	(0.148)	(0.179)	(0.168)
ENG	0.344*	0.669***	1.091***	1.308***	0.701*
	(0.180)	(0.248)	(0.357)	(0.417)	(0.396)
$\bar{R}^2$	0.768	0.738	0.753	0.753	0.761
$\tilde{R}^2$	0.965	0.957	0.976	0.976	0.976
No. obs.	93	93	93	92	91

Same as Table 2.

Figure 1 The actual numbers of top 500 universities and the predicted errors for 38 countries

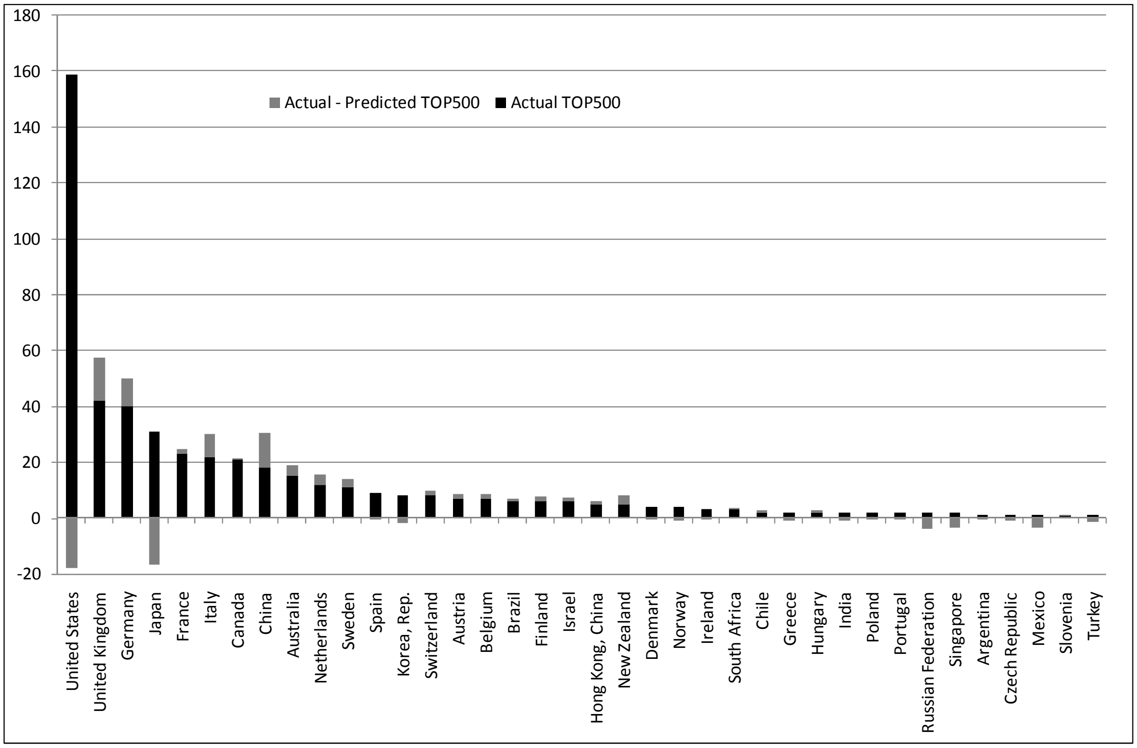

Figure 2 The actual numbers of top 100 universities and the predicted errors for 15 countries

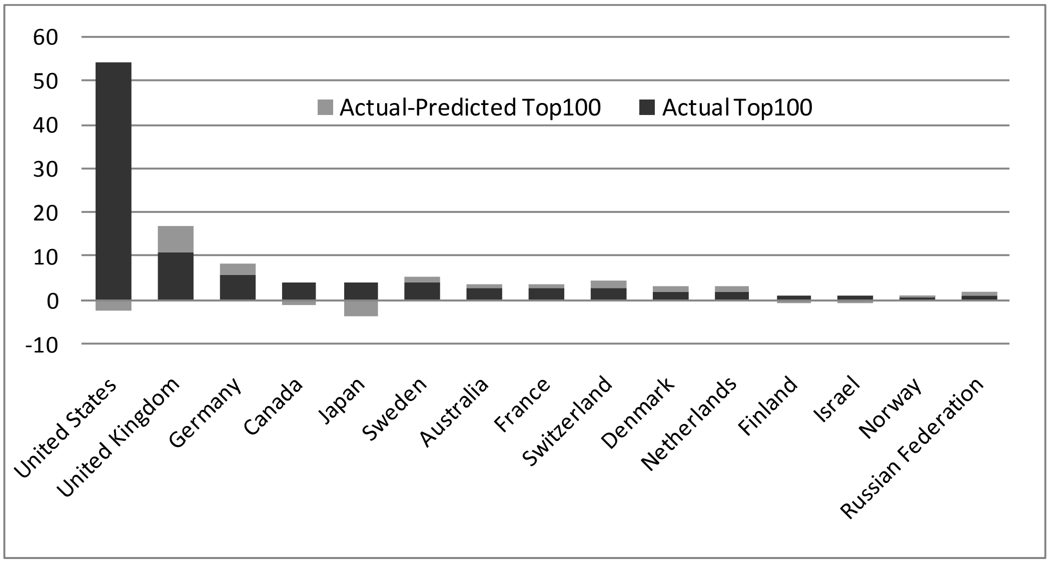

Table A1 Data for 93 countries

Country	Top500	Top300	Top100	LPOP	LGDPPC	R_D	ENG	MIG	EDUGDP	LEXPTER	TERPOP
Argentina	1	1	0	17.44	9.18	0.43	0	4.09	4.21	7.25	5.13
Armenia	0	0	0	14.93	7.94	0.23	0	9.47	3.22	6.91	2.29
Australia	15	9	3	16.79	10.30	1.66	1	20.91	4.68	8.85	4.76
Austria	7	2	0	15.90	10.40	2.07	0	12.59	5.70	9.63	3.04
Azerbaijan	0	0	0	15.91	7.97	0.33	0	2.04	3.55	6.06	1.45
Belarus	0	0	0	16.11	8.77	0.69	0	12.64	5.87	7.47	4.53
Belgium	7	6	0	16.15	10.32	1.95	0	8.06	6.05	9.32	3.54
Bolivia	0	0	0	15.96	8.18	0.29	0	1.14	5.93	7.34	3.54
Brazil	6	2	0	19.00	8.99	0.91	0	0.38	3.91	8.24	1.89
Brunei Darussalam	0	0	0	12.75	10.78	0.02	0	31.82	5.27	NA	1.25
Bulgaria	0	0	0	15.89	8.93	0.51	0	1.28	3.45	7.35	3.07
Cambodia	0	0	0	16.39	7.01	0.05	0	1.95	1.60	6.18	0.25
Canada	21	18	4	17.26	10.40	1.98	1	18.31	5.46	9.66	4.02
Chile	2	0	0	16.57	9.29	0.60	0	1.23	3.94	7.51	3.27
China	18	6	0	20.97	8.02	1.01	0	0.04	1.91	7.92	0.79
Colombia	0	0	0	17.57	8.60	0.18	0	0.28	4.71	7.52	2.29
Costa Rica	0	0	0	15.21	9.02	0.36	0	8.60	4.83	8.29	1.90
Croatia	0	0	0	15.31	9.33	1.12	0	14.04	4.48	8.39	2.38
Cyprus	0	0	0	13.47	10.06	0.29	0	12.67	6.01	9.34	2.01
Czech Republic	1	1	0	16.14	9.77	1.21	0	4.42	4.21	8.62	2.66
Denmark	4	3	2	15.49	10.37	2.43	0	6.14	8.33	10.00	3.69
Ecuador	0	0	0	16.34	8.67	0.06	0	0.83	1.37	NA	NA
Egypt, Arab Rep.	0	0	0	18.04	8.36	0.19	0	0.25	4.81	NA	3.44
Estonia	0	0	0	14.12	9.43	0.73	0	17.25	5.63	8.02	4.29
Finland	6	1	1	15.46	10.24	3.34	0	2.71	6.28	9.28	5.41
France	23	14	3	17.90	10.29	2.17	0	10.65	5.71	9.11	3.46
Georgia	0	0	0	15.35	7.88	0.24	0	4.52	2.28	NA	3.12
Germany	40	24	6	18.23	10.30	2.47	0	12.04	4.57	NA	NA
Greece	2	1	0	16.21	10.15	0.50	0	7.32	3.85	8.80	4.52
Hong Kong, China	5	3	0	15.72	10.32	0.58	1	41.57	4.21	9.92	2.17
Hungary	2	0	0	16.14	9.59	0.86	0	2.97	5.16	8.42	3.42
Iceland	0	0	0	12.56	10.35	2.75	0	6.22	6.99	9.14	3.96

India	2	0	0	20.76	7.51	0.73	1	0.59	4.08	7.20	1.01
Indonesia	0	0	0	19.16	7.95	0.06	0	0.13	2.77	NA	1.54
Iran, Islamic Rep.	0	0	0	18.00	9.01	0.59	0	3.39	4.66	7.88	2.42
Ireland	3	1	0	15.18	10.43	1.16	1	11.30	4.36	9.12	4.37
Israel	6	4	1	15.69	9.99	4.42	0	36.64	7.21	8.77	4.30
Italy	22	7	0	17.86	10.23	1.08	0	3.30	4.66	8.85	3.24
Jamaica	0	0	0	14.77	8.64	0.06	1	0.70	5.40	8.16	1.62
Japan	31	12	4	18.66	10.27	3.12	0	1.37	3.66	8.56	3.13
Jordan	0	0	0	15.42	8.24	0.34	0	40.70	4.94	NA	3.46
Kazakhstan	0	0	0	16.52	8.77	0.22	0	18.46	3.09	6.32	3.27
Korea, Rep.	8	3	0	17.67	9.83	2.54	0	1.19	4.31	7.29	6.34
Kuwait	0	0	0	14.65	10.52	0.17	0	64.11	6.30	10.82	1.54
Kyrgyz Republic	0	0	0	15.42	7.36	0.19	0	6.98	3.67	5.75	3.67
Latvia	0	0	0	14.67	9.19	0.40	0	21.79	5.45	7.55	4.50
Lesotho	0	0	0	14.47	7.11	0.05	1	0.29	11.03	9.26	0.26
Lithuania	0	0	0	15.06	9.28	0.64	0	5.69	5.53	7.97	4.15
Luxembourg	0	0	0	13.00	11.07	1.66	0	37.08	3.35	NA	0.63
Macao, China	0	0	0	13.02	10.15	0.07	0	54.46	3.21	9.22	3.67
Madagascar	0	0	0	16.64	6.72	0.20	1	0.37	2.95	7.37	0.20
Malaysia	0	0	0	16.99	9.26	0.59	0	6.10	7.01	9.18	2.54
Malta	0	0	0	12.89	9.90	0.35	1	2.35	4.78	9.06	1.84
Mauritius	0	0	0	14.00	9.10	0.36	1	1.42	4.01	8.32	1.04
Mexico	1	1	0	18.42	9.29	0.42	0	0.58	5.15	8.46	2.10
Mongolia	0	0	0	14.71	7.68	0.25	0	0.35	7.04	6.48	3.55
Morocco	0	0	0	17.18	8.07	0.60	0	0.42	6.32	8.07	1.06
Mozambique	0	0	0	16.75	6.34	0.50	0	2.00	3.33	8.01	0.08
Myanmar	0	0	0	17.66	6.65	0.10	0	0.25	0.82	5.39	1.08
Netherlands	12	9	2	16.59	10.42	1.81	0	9.88	4.90	9.51	3.16
New Zealand	5	2	0	15.19	10.05	1.11	1	17.50	6.73	9.06	4.82
Nicaragua	0	0	0	15.47	7.63	0.05	0	0.53	3.55	NA	1.91
Norway	4	2	1	15.33	10.71	1.64	0	6.89	7.27	9.94	4.39
Pakistan	0	0	0	18.78	7.58	0.16	1	2.78	2.10	NA	0.29
Panama	0	0	0	14.93	9.04	0.33	0	3.00	4.48	7.86	3.96
Paraguay	0	0	0	15.52	8.23	0.09	0	3.15	4.83	7.28	2.06
Peru	0	0	0	17.08	8.65	0.11	0	0.17	2.98	6.74	3.20

Philippines	0	0	0	18.18	7.90	0.14	1	0.43	3.16	5.93	3.02
Poland	2	0	0	17.46	9.39	0.60	0	2.05	5.20	7.77	4.65
Portugal	2	0	0	16.15	9.89	0.76	0	6.52	5.47	8.56	3.73
Romania	0	0	0	16.91	8.94	0.39	0	0.60	3.32	7.60	2.51
Russian Federation	2	1	1	18.79	9.15	1.15	0	8.22	3.42	6.98	5.79
Singapore	2	1	0	15.23	10.54	2.07	1	36.45	3.67	NA	NA
Slovak Republic	0	0	0	15.50	9.51	0.60	0	2.23	4.15	8.33	2.72
Slovenia	1	0	0	14.50	9.92	1.45	0	8.65	6.01	8.61	4.68
South Africa	3	1	0	17.62	8.95	0.80	1	2.33	5.42	8.30	1.51
Spain	9	3	0	17.53	10.15	0.96	0	6.14	4.28	8.61	4.44
St. Lucia	0	0	0	11.97	8.98	0.41	1	4.90	6.67	NA	1.34
St. Vincent and the Grenadines	0	0	0	11.67	8.63	0.10	1	7.16	9.55	NA	NA
Sudan	0	0	0	17.35	7.29	0.41	1	2.31	NA	NA	0.61
Sweden	11	9	4	16.00	10.29	3.88	0	11.55	7.39	9.58	4.24
Switzerland	8	7	3	15.80	10.44	2.75	0	21.92	5.66	9.91	2.36
Tajikistan	0	0	0	15.65	7.05	0.07	0	5.15	2.46	5.17	1.39
Thailand	0	0	0	17.93	8.71	0.26	0	1.47	4.92	7.51	3.37
Trinidad and Tobago	0	0	0	14.08	9.53	0.12	1	3.08	3.97	9.66	0.83
Tunisia	0	0	0	16.09	8.65	0.63	0	0.39	6.99	8.35	2.27
Turkey	1	0	0	18.05	9.08	0.66	0	1.86	3.74	8.31	2.47
Uganda	0	0	0	17.07	6.66	0.32	1	2.04	3.85	7.29	0.25
Ukraine	0	0	0	17.70	8.36	1.02	0	14.24	4.80	7.36	4.27
Uruguay	0	0	0	15.01	9.04	0.25	0	2.64	2.68	7.42	2.97
Zambia	0	0	0	16.19	6.98	0.01	1	3.11	2.18	7.50	0.23
United Kingdom	42	33	11	17.90	10.28	1.82	1	8.36	5.02	8.95	3.64
United States	159	114	54	19.47	10.58	2.68	1	12.51	5.60	9.26	5.23