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The differentiation of the strategic profile of higher education institutions. New positioning indicators based on microdata

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We address the issue of differentiation of the profile of universities and offer a set of new indicators based on microdata at the individual level and the application of robust nonparametric efficiency measures.

In particular, we use efficiency measures in order to characterize the way in which universities use their inputs (academic and non academic staff, funding) in the effort to position themselves in the space of output (undergraduate teaching, postgraduate education, fundamental research, contract research, third mission), while keeping efficiency under control.

The strategic problem of universities is defined as making best use of existing resources in the short run, while enlarging the scope of autonomy in procuring additional resources in the long run. In order to make best use of resources universities are led to increase their specialization and differentiate their offering profile. This happens even if the European institutional landscape does not encourage universities to differentiate.

Introduction

Universities are again in a period of turbulence. While in previous periods of political debate about universities the main pressure comes from the increase in student

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participation rates [CLARK, 1983], the current debate addresses the role of universities as knowledge producers and their responsiveness and efficiency in delivering to society what is expected.

In this context, opinion makers and governments increasingly rely on rankings of universities for making policy decisions, and university rectors and administrators use rankings to support claims of excellence or to call for resources.

In this paper we discuss the limits of validity of ranking indicators for universities and propose an alternative methodology based on the notion of positioning indicators. This is based on a novel combination of administrative data and recently developed efficiency techniques.

We provide evidence of the potential of positioning indicators based on a new cross-country dataset on universities in six European countries (United Kingdom, Italy, Spain, Switzerland, Portugal, Norway) called Aquameth.[1]

Ranking indicators for universities

While ranking is a popular exercise, its validity rests on a set of assumptions that are usually hidden to readers and users, but must be the object of close scrutiny from social scientists involved into research and advice to policy makers.

From a general point of view, and without entering into a detailed analysis of existing rankings, it is important to make explicit the assumptions associated with the ranking methodology. We discuss three critical issues, in increasing order of difficulty.

Units of analysis

Firstly, the units of analysis should be carefully defined. In theory, the units of analysis should be homogeneous, i.e. comparable. Rankings based on research assessments, such as the RAE (Research Assessment Exercise) of the UK Government, or the evaluation made by the Italian CIVR (Comitato di Indirizzo e Valutazione della Ricerca) assume as unit of analysis the departments, grouped into relatively homogeneous disciplinary classes. This practice follows the traditional ranking of departments in the US system, based on research indicators, and routinely published by magazines and websites. Separate rankings are carried out for graduate schools or undergraduate programs, using different sets of indicators.

At this level of disaggregation, ranking may indeed have a meaning, provided the indicators are well chosen. Indicators should be based on validated and verifiable data. The aggregation formula should be transparent.

[1] Aquameth stands for: Advanced Quantitative Methods for the Evaluation of the Performance of Public Sector Research, a project carried out within the Network of Excellence PRIME, Sixth Framework Program.

The aggregation of different indicators, however, even in a relatively homogeneous domain, inevitably creates biases. It is well known that even using the same type of indicators (e.g. count of papers in international journals) there may be large differences simply changing the set of journals under consideration or changing the time window. Indicators of quantity of publications may not be consistent with indicators of citations, or relevance, as the large debate on the Hirsch index witnesses. Finally, there are many dimensions of research performance that are not captured by international publications. All these issues are critical and require further research and experimentation, but at least have a clear theoretical foundation. Correction of biases and integration of quantitative indicators with peer review are in principle possible.

Consequently, rankings applied to elementary units (departments) using relatively homogeneous indicators (international publications) are methodologically defensible.

Aggregation

The distortions introduced by aggregation are much less understood, and potentially create a lot of noise. Universities are ranked by computing the average value of scores (or whatever indicators) assigned to departments. In this perspective, universities are seen as collections of departments.

We suggest that the meaning of this aggregation strongly depends on the institutional framework. Departments compete in more or less narrowly defined scientific fields or disciplines. Let us assume that their ranking is a reasonable approximation of their quality. Why should universities have positively correlated rankings across disciplines? And what happens if correlation approaches zero?

The case of European countries is paradigmatic [CLARK, 1983; NEAVE & VAN VUGHT, 1994; AMARAL & AL., 2002; BONACCORSI & DARAIO, 2007A]. In the United Kingdom, the institutional framework provides incentives for differentiation of universities along the dimensions of pure research, applied and contract research, postgraduate education, undergraduate education, vocational training. The government allocates funds separately between research and education, creating clear and separate incentives. Students pay relatively large fees to the university independently on the quality of the specific school they attend, putting pressure on the administration for receiving consistent value across all schools. Postgraduate education is largely international, creating pressures on quality of programmes across all departments. Universities define their strategic profile accordingly. In this system we would expect positive (and perhaps strong) correlation between rankings of all departments. Under these conditions, the aggregation of research ranks at the level of university is meaningful.

A totally different situation arises in Continental Europe. In these systems there are not systematic incentives for universities to recruit academic staff according to consistent policies defined centrally. Rules for recruitment are left to scientific communities, and markets for academic careers are less competitive [MUSSELIN, 2004; 2005]. The role of Presidents, as an institutional role that negotiates with academic communities in order to implement a strategy, is much weaker. Here we would expect zero correlation among ranks of departments.

For example, in the Italian system, a recent analysis of research profile of all academicians has shown that very few universities rank high (or low) in the majority of their departments while the bulk of them have uncorrelated ranks. As a result, almost all universities crowd the central area of the distribution of the aggregate score [D'ANGELO & AL., 2006]. Under these conditions the relative position in the ranking may be due to the size of the university, the age or the subject mix, rather than to quality.

As a result, rankings at university level, even if based only on research indicators, introduce noise due to institutional heterogeneity.

Distributional properties of indicators

Evaluation exercises carried out by governments are usually based on a large array of indicators, which allow to take into account the intrinsic multi-dimensionality of research performance. For example, the last edition of RAE in UK has included a large number of indicators on non-publication output of research, allowing an extremely interesting analysis of trade-offs between open science and contract research or other research activities [CRESPI, 2007].

In addition, they refer to the whole population of academicians, or leave to department themselves to play the game of whom to include in the assessment exercise.

A totally different approach has been followed by the Shangai ranking, which is based on a small number of simple indicators, largely based on the extreme top quantiles of the distribution of quality (such as number of Nobel prizes, number of papers in *Nature* or *Science*, number of highly cited scientists). These indicators refer to a small number of scientists and are likely to be positively correlated, at least in the long run. In fact, the literature on Nobel prizes has shown that visibility in top journals and disproportionately large number of citations are good predictors of prize award [MARCHETTI, 1989]. Therefore what is ranked here is not the quality of the research of the university, but the university's relative ability in attracting top scientists.

In addition, scientists that are highly cited, or publish largely in generalist top journals are more likely to work on core areas of science. This leaves outside the possibility of excellent quality in extremely specialised areas of science. Universities that build reputation on specialized areas are underrepresented in this type of rankings.

BONACCORSI [2007] have argued *in favour* of analyses based on extreme tails of the distribution, such as the number of ISI highly cited scientists, but at national level or in the comparison between USA and Europe. This comparison makes evident the inferiority of Europe as a whole, due to the relative scarcity (with the exception of UK) of universities that are consistently excellent in all disciplines, because they pursue excellence *institutionally* and therefore constitute an attractive environment for top scientists. As a result, the Shangai ranking reproduces and amplifies the distortion discussed above, in the sense that it is not meaningful for those institutional frameworks in which there is large variance of research quality *within* universities, as it is the case for most of European countries.

Commensurability

An even more difficult issue arises when the ranking at university level is based on the combination of indicators that take into account research, teaching, and third mission. Several issues arise here. First, these dimensions are not additive. There is no way to build up aggregated indicators without assuming a weighting scheme which is theory- or value-laden, or is totally arbitrary. In a certain sense, these dimensions are incommensurable.

Second, these dimensions are linked by complementarity and substitution effects, so that increasing the output in one direction may reduce (or increase) the output in another one. Again, without a clear knowledge of these relations, any additive measure is misleading.

To address these issues, traditional econometric techniques are unsatisfactory. Using MARSH'S [2004 : 2] words: "…[econometric] problems could potentially result in econometric estimates that *misinform* analysts who, in turn, could produce *misleading policy* recommendations. To be more precise, some of the most intriguing problems in current policy making would benefit from better estimation of these complex relations."

Under these conditions, rankings should be substituted by positioning indicators, which represent in multidimensional spaces the position of individual units of observation, without any assumption on the existence of a common metrics across the various dimensions.

Summing up, rankings are legitimate for homogeneous elementary units (departments for research, schools for education), or for universities in those institutional systems in which aggregation of elementary units is subject to positive correlation. In these cases, rankings should be based on the appropriate selection of indicators. Indicators based on extreme properties of the relevant distributions are highly informative on institutional differences across countries, but are not informative on the universe of universities.

On the contrary, the characterization of universities should take into account their embeddedness into institutional systems and their intrinsic multidimensionality in inputs and outputs. This makes positioning indicators an attractive alternative. We illustrate this with reference to the collection of data on universities in six European countries, carried out within the Project Advanced Quantitative Methods for the Evaluation of the Performance of Public Sector Research (Aquameth), under the European Network of Excellence PRIME.

Positioning indicators

Administrative data

The basic idea is to make use of administrative data. Universities are required to provide standardized data to national government (usually the Ministry of Research or a government agency) or to national associations of universities, or conferences of rectors, or the like. These data are typically reported in official documents. are not sensitive data, but are almost never published in easily accessible sources, or are available only in paper format and limited editions.

We underwent a process of collection of these data and discovered, partially to our own surprise, how rich administrative data are. During the project, a long and careful work of source identification and data cleaning was carried out. All data were digitalized. An initial work of data validation was experimented, usually in discussion with officials from administration but no external or cross-validation was attempted.

By analogy with the statistical definition of microdata as applied to firms (vs individuals) we use the same term to refer to universities. The possibility to disentangle lower levels of organization (department, research team) depends on available data.

Using this approach a large dataset on European universities in six countries (UK, Spain, Italy, Portugal, Norway, Switzerland), covering 271 institutions has been constructed. It is important to stress that the dataset is based on the *census* of universities, not a sample.

For each university we have available the data presented in Table 1 for the period 1995–2003 (with some breaks). The Aquameth project, developed under the PRIME Network of Excellence, has produced a number of studies on the university system in these countries, addressing also a number of transversal issues [BONACCORSI & DARAIO, 2007A].

Comparability

The next step was to examine the cross-country comparability of data, as discussed at length in [BONACCORSI & AL., 2007D] (see also on definitions of HE institutions: [MC CORMICK, 2004; SLIPERSAETER & AL., 2005]). It turned out that for some variables international comparability was methodologically acceptable, while for others there was no way to carry out such a comparison. Three main categories of comparability problems arise.

Table 1. Aquameth database structure

Area	Categories
General information	Year of foundation City, province, region (NUTS) Number and type of faculties/schools/disciplines covered Governance (public, private) Type (university, technical college) Other relevant historical information.
Revenues	Total revenues of the university General budget of the university (in federal countries divided between national and regional appropriations) Tuition and Fees Grants and contracts, if possible divided between government, international, private and private non-profit Other revenues
Expenditures	Total expenditures (excluding investments and capital costs) Personnel expenditures, if possible divided between personnel categories Other expenditures
Personnel	Total staff (FTE or headcount) Professors Other academic staff Technical and administrative staff
Education production	Number of undergraduate students Number of undergraduate degrees Number of PhD students Number of PhD degrees
Research and technology production	ISI publications Technological production indicators

First, there are differences in the organization and governance structure of national HE systems (*institutional context*). As it is well known, European systems differ in terms of comprehensiveness (unitary systems include vocational training in the university while dual systems have a separate track), role of private universities (large role in some countries, almost absent in others), constitutional architecture (national role in most countries, regional role in federal countries such as Spain or Germany) [HUISMAN & KAISER, 2001; KYVIK & SKOVDIN, 2003; KYVIK, 2004]. Separate analyses by groups of homogeneous countries are mandatory here, at least for those variables mostly dependent on these features. Alternatively, normalization of variables around the national average have been experimented.

Second, individual universities are heterogeneous with respect to the *subject mix*. This may introduce large distortions, because cost per students and other indicators largely differ across disciplines [FILIPPINI & LEPORI, 2007]. In the Aquameth project two solutions were tested. Across all countries a distinction has been operationalized between generalist universities and specialist ones, and quantitative analyses have been carried out separately. As an alternative, for some countries data on disciplinary area were available, and a categorization in four areas was adopted (Human and Social Sciences, Engeneering and Technical Sciences, Natural Sciences and Medicine), connecting data on academic staff and publications to data on students. Universities associated to hospitals were identified with a dummy.

Third, *administrative definitions* may differ in irreducible way. As an example, the definition of private funding to universities in Portugal includes also contract research, while in other countries they are separated. There is no way to get around this problem. The only solution was the construction of new indicators as the normalization of individual universities around the country average.

Taking into account all these issues the cross-country analysis was carried out at three levels, in increasing order of comparability:

- national case studies;
- comparative analysis of findings from national studies (descriptive statistics, model estimation on national data);
- integrated dataset.

Positioning

Each university is characterized by a vector of values, whose meaning has been clarified and, whenever possible, made comparable at international level. Building up positioning indicators means locating a point in the appropriate space of variables, depending on the purpose of the analysis (see for the case of research [SLIPERSAETER, 2005; JONGBLOED & AL., 2005]).

Since variables cannot be aggregated, the positioning does not lead to a ranking. Universities can visualize their spatial position in two- or three-dimensional space, or compute their position with respect to other universities. Positioning indicators are built for the purpose of institutional learning, not media visibility.

So far a limited number of exercises has been developed as a demonstrator of the potential of these indicators. It is possible to track the position and evolution of universities with respect to the following structural elements:

- *research orientation*, as measured by the share of PhD recipients over the total population of undergraduate students;
- *research intensity*, as measured by average number of publications per unit of academic staff;
- *offering profile*, introducing a distinction between generalist and specialist universities;
- *rate of growth* in total number of undergraduate students;
- *degree of autonomy*, as measured by the ratio between non-government funding sources and total funding.

In turn, we have experienced some techniques for representation and analysis of positioning indicators. These are: (a) descriptive statistics; (b) mapping; (c) robust nonparametric efficiency analysis. We present them alongside examples from the Aquameth dataset.

Evidence on positioning of European universities

Descriptive statistics

In international sources descriptive statistics are tabulated with respect to total or average values. For example, we know about the total number of publications in a given country, the total number of researchers, or the Full Time Equivalent (FTE). From these data we can compute simple productivity ratios such as publications per researcher (see for example [KING, 2004]).

By construction, it is not possible to investigate on the distribution of the indicator. As a result, the only possible use of such indicators is cross-country comparison – which is, in fact, what governments obsessively do.

Using microdata opens a totally new perspective, the construction of indicators for which are known not only the first moment of the distribution (average) but other moments as well (range, variance, skewness). This is particularly valuable in S&T and HE indicators. One of the few stylized facts in these fields, in fact, is that the distributions are highly skewed, so that the median is largely different from the mean, and log tails are ubiquitous. This apply to publications produced, citations received, individual productivity of scientists in the life-cycle, as well as patent citations or patent quality.

Obviously, the dream for S&T and HE scholars would be to have microdata at the level of individual researchers. A preliminary analysis along this line has been provided by EVIDENCE [2006] based on ISI data on UK. While this may be realized in the medium term on a large scale by combining non-ISI sources with massive data mining techniques, it is a great leap to access microdata at the level of universities.

As an example, we computed the confidence intervals around the average values of the two indicators of research activity:

- research orientation (Intensity of PhD recipients out of the total student (=undergraduate) population)
- research intensity (Individual scientific productivity of academic staff in terms of publications per capita).

Linking average values with a measure of dispersion provides extremely valuable and new information. It appears from Figure 1 and 2 that, irrespective of the mean value, there is a distinction between countries that exhibit little dispersion around the mean (such as Italy, Spain, Portugal) and countries that, on the contrary, show large variability (like UK, Switzerland and Norway).

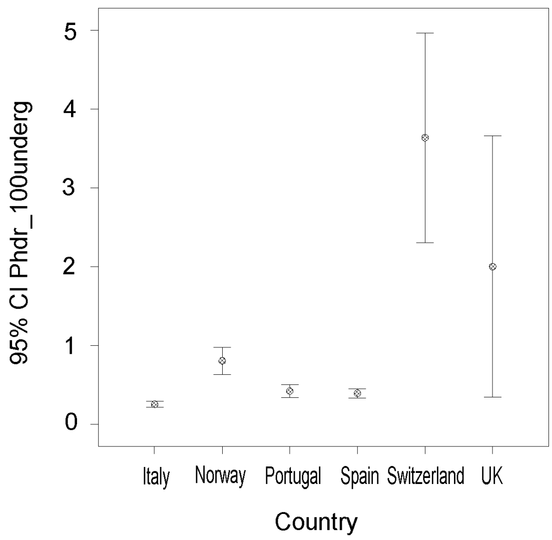

Figure 1. 95% Confidence intervals on the average of the share of PhD recipients over the total population of undergraduate students (data for the year 2000)

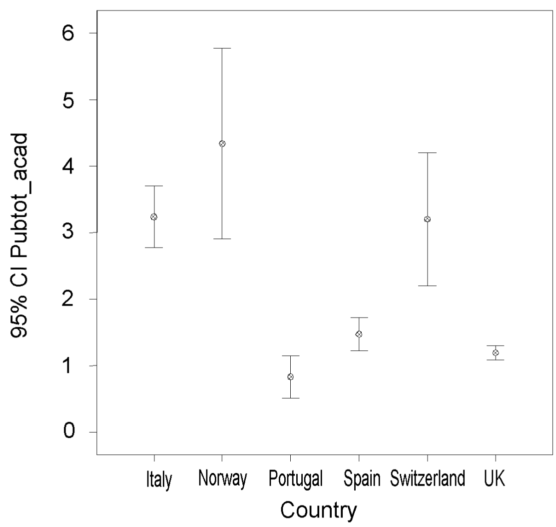

Figure 2. 95% Confidence intervals on the average number of publications per unit of academic staff (data for the year 2000)
Note: The data for UK are not comparable with the other countries because they come from the RAE

In [BONACCORSI & DARAIO, 2007A] we have offered an institutional interpretation: the former countries provide no incentive for strategic differentiation of universities, so that they look similar to each other in research orientation and intensity, while the latter are characterized by strong differentiation. While this interpretation should be validated on a larger scale, the value of descriptive statistics that explore moments of the distribution greater than one should be evident.

Another interesting application of descriptive statistics with microdata refers to the analysis of growth of universities. This is a largely unexplored issue. How do universities grow in terms of number of students? Which is the resulting size distribution? How does it change?

In Figure 3 the rate of growth of enrolled students in a interval of 5–7 years is reported for all countries.

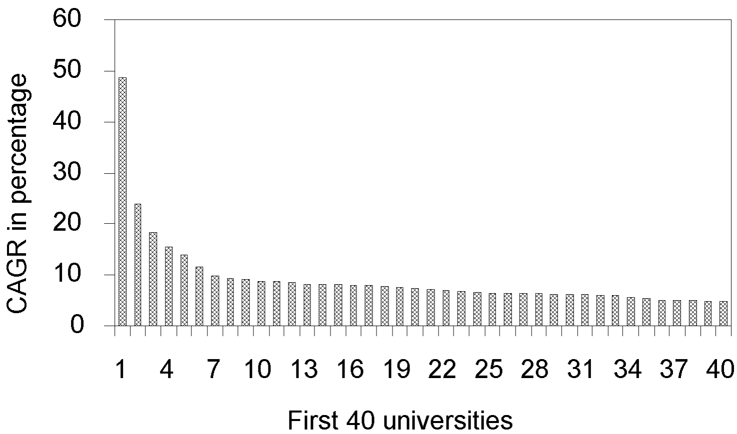

Figure 3. Distribution of universities by average annual rate of growth of students – Top 40.
Adapted from [BONACCORSI & DARAIO, 2007A]
Notes: On the y-axe there is the Compound Annual Growth Rate (CAGR) in percentage, on the x-axe there are the top 40 universities by CAGR(Compound Annual Growth Rate):
1 Teramo, 2 Lucerne, 3 The University of Wales, 4 Homerton College, 5 Roma Tre, 6 The University of Salford, 7 The University of Hull, 8 Birkbeck College, 9 Rose Bruford College, 10 Institute of Education, 11 The University of Bath, 12 City University, 13 Bergamo, 14 The University of Dundee, 15 Roma Tor Vergata, 16 Napoli II, 17 Napoli Navale, 18 Carlos III, 19 Messina, 20 The Royal Veterinary College, 21 The University of Lancaster, 22 The University of Teesside, 23 Molise, 24 Jaume, 25 Pompeu Fabra, 26 The University of York, 27 Basilicata, 28 Liverpool Hope, 29 Bath Spa University College, 30 The University of Central Lancashire, 31 The University of Warwick, 32 Tuscia, 33 Girona, 34 Leeds Metropolitan University, 35 The University of Southampton, 36 Chieti, 37 The North-East Wales Institute of Higher Education, 38 King's College London, 39 The University of Leeds, 40 Verona

By examining the characteristics of the identified units it is evident the existence of a small number of “gazelle universities”, i.e. small and young universities growing very rapidly, mostly based on student services and no research. This is an interesting finding for further research.

Mapping

A very simple representation is based on the mapping of the position of individual universities in two- or three-dimensional maps. The value of a microdata approach is evident: the number of potentially useful maps increases very fast with the number of available indicators (as a function of the square or cube approximately, for visualization purposes). Each of these maps conveys different information, and can be used fruitfully in the decision making process.

Figure 4a displays a two-dimensional map in which the following indicators of research activity are reported: the intensity of publication per academic staff, and the share of the university budget represented by private funding (an indirect measure for the ability to mobilize contract research), and the respective average value. A clear distinction emerges between universities that perform poorly along both dimensions, those that are located along the negative diagonal, revealing trade-offs between the dimensions, and those that outperform the others. Interestingly, the latter set is almost exclusively formed by UK universities. Figure 4b permits an identification by name. We show the name of a selected sample of universities.

Figure 5a contrasts the rate of growth in student enrolment with size at initial date (number of students). While a negatively sloped curve is to be expected, it is visible a large group of large and steady universities, mainly from Italy and Spain. Again, this kind of mapping may generate intense institutional learning with respect to growth strategies, particularly once the identities of universities in the map are revealed (Figure 5b shows a selected number of universities’ names).

Of course, the broad national characterization is only one of the possible levels of analysis, not necessarily the most important one. Diversity among individual universities within countries is perhaps more interesting to explore.

An alternative representation, with more information compressed into a visualization, is the radar map proposed by LAREDO [2003] with respect to the Angevine university system. In a radar map each university gets a profile to be compared with the average or median value for several variables. This representation is complementary to two- or three-dimensional maps, which trade-off the number of variables plotting all the observations at the same time.

The construction of maps is a preliminary step for building cluster representations, an exercise which is still in preparation.

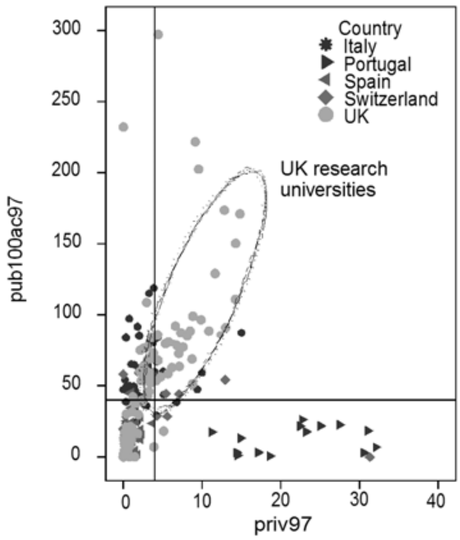

Figure 4a. Mapping of average scientific productivity vs share of private funding (year 1997)
Note: the horizontal line corresponds to the average value of the variable 'number of publications per 100 academic staff' (pub100ac97) across countries; the vertical line corresponds to the average value of the variable 'percentage of private funds on the total funds' (priv97) across countries.

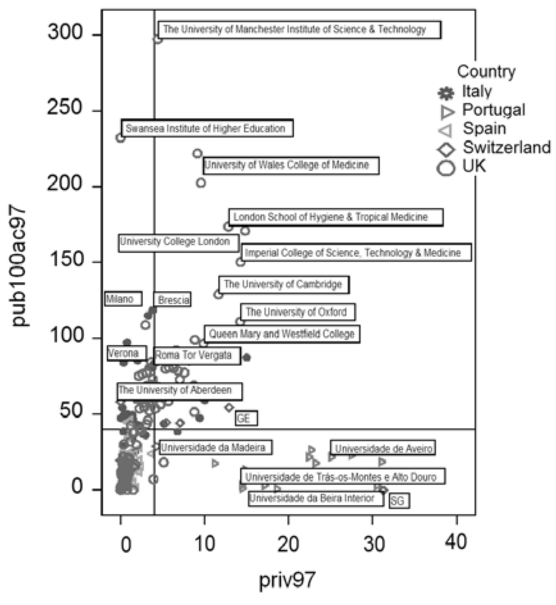

Figure 4b. Positioning of individual universities in the mapping average scientific productivity vs share of private funding (year 1997)
Note: GE= university of Geneva, SG= University of St. Gallen

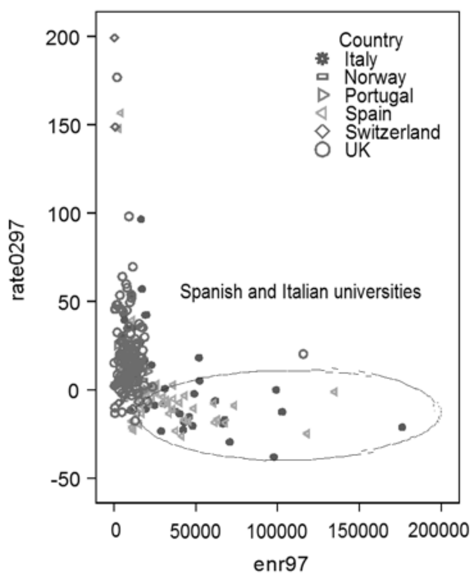

Figure 5a. Mapping of size of universities vs growth in enrollments, 1997–2002

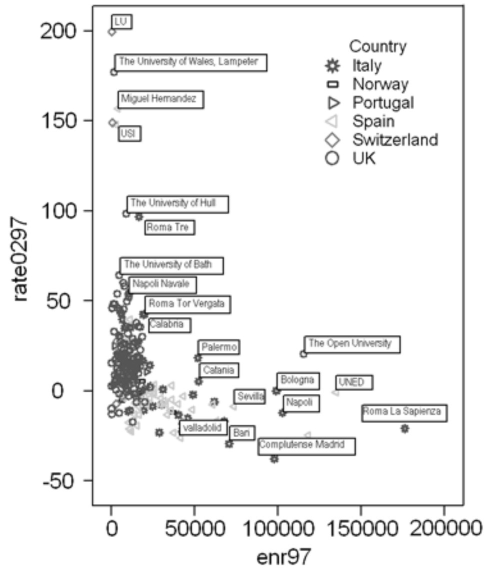

Figure 5b. Positioning of individual universities in the mapping size of universities vs growth in enrollments, 1997–2002

Notes: LU= University of Lucerne, USI= Università della Svizzera Italiana, UNED= University of Neuchâtel

Robust conditional nonparametric efficiency

S&T and HE indicators are routinely classified into input (e.g. R&D expenditure, personnel) and output (e.g. publications, patents, product innovations) indicators (for a critical view on this issue, see [GODIN, 2005]). Decision makers may be interested not only in the level of input or output, but in the *relation* between the two. This is called technical efficiency, as opposed to economic efficiency as dependent on a particular price system.

Unfortunately, no efficiency analysis can be carried out based on official S&T statistics. The only indicators available are simple one input / one output indicators, such as patents per dollar spent in R&D, or publications per FTE researcher.

But S&T and HE activities are intrinsically multi-input multi-output phenomena. These indicators are not suited to tell policy makers whether they are doing the best use of resources.

Traditionally, the analysis of efficiency in higher education has been the object of a large specialized literature based on Data Envelopment Analysis (DEA), or more generally, on nonparametric techniques. Conventional DEA suffers from a number of intrinsic limitations: needs for large samples to avoid huge bias/statistical imprecision (the so called 'curse of dimensionality'), sensitivity to outliers and so on. These limitations may be overcome by a new family of nonparametric techniques, called robust or partial frontiers [CAZALS & AL., 2002; DARAIO & SIMAR, 2005]. For a general presentation of the last developments see [DARAIO & SIMAR, 2007]. These techniques produce estimates of technical efficiency that are more robust to the presence of outliers, and do not suffer from the curse of dimensionality cited above.

We think that these techniques are particularly useful in S&T and HE. In fact, in these fields small numbers of observations, highly skewed distributions, and outliers are the rule, not the exception.

In a number of recent contributions [BONACCORSI & DARAIO, 2004; 2006; BONACCORSI & AL., 2006; 2007] we have provided evidence of the advantages of these new tools.

A striking case refers to indicators that address the issue of trade-offs between dimensions of performance.

From a policy point of view, trade-offs create a number of difficult dilemmas:

- Are teaching and research complement or substitute? If they are substitute, should the policy promote the specialization of universities in one or the other dimensions? If this is true, can we conclude that the Humboldtian model is obsolete?
- Are pure research and contract research complement or substitute? If they are complement, which organizational solutions can maximize the potential synergies? If they are substitute, how can universities balance sources of research funding? or should they just stop "selling the Ivory Tower" altogether?

- Are research activities and third mission complement or substitute? Most policy making in OECD countries has been implicitly based on the assumption that the commitment of universities to third mission is not detrimental to long term research capability. Is this assumption empirically wrong?

It is clear that these problems are crucial for policy making. Unfortunately, existing statistical sources do not permit any systematic analysis of these issues, and case studies and national or local surveys, although in many cases revealing, lack of generality.

We have found that robust nonparametric techniques, applied to microdata, provide interesting results. In particular, conditional efficiency measures (for an introduction and more detailed technical information see [DARAIO & SIMAR, 2007]). Using these measures, it is possible to disentangle whether the technical efficiency of a university is affected or not by some external factors. Figure 6 is based on a simple nonparametric model of teaching efficiency, whose inputs are number of academic and non-academic staff, and whose outputs are number of graduate students. Universities receive an efficiency score which is measured taking into account the impact of research intensity on their teaching efficiency.

In Figure 6 conditional analysis shows whether the efficiency of the model under investigation is influenced by an external factor i.e. the intensity of PhD students as a measure of research intensity.

The effect is measured by the ratio between conditional and unconditional efficiency score (called Q^{z}_{m} in Figure 6). The scatterplot presented in Figure 6 displays each university with a circle, and the nonparametric regression line (reported on the figure), summarizes the global impact of the external factor on the efficiency.

If the effect is positive, the ratio between conditional and unconditional robust efficiency Q^{z}_{m} goes upward, on the contrary, if the impact is negative we have to observe a decreasing nonparametric regression line. If we observe a straight line, this trend points to an absence of impact coming from the external factor.

What we see is a sharp decrease in teaching efficiency in the initial range of the external variable, followed by a region of flat (or very weakly increasing) effect. Most universities are located in the area of negative effect, implying that, in fact, universities that allocate more resources to PhDs are less efficient in producing degrees. Interestingly, a minority of universities are located in the flat or weakly increasing region. Here the notion of positioning indicators comes into evidence. What are the characteristics of universities located in this region vis-à-vis the large majority?

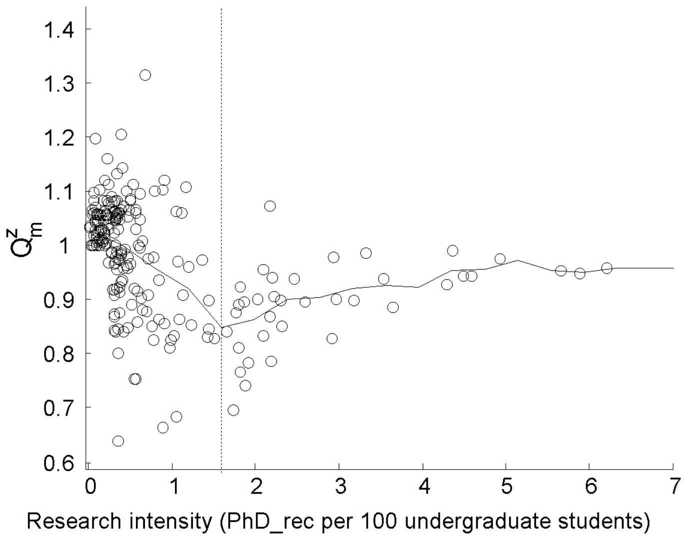

Figure 6. Effects of research intensity (Z) on the teaching efficiency of universities. Z is the number of PhD recipients per 100 undergraduate students. Adapted from [BONACCORSI& AL., 2007]
Note: From this plot we excluded the outlying Institute of Education with a research intensity of 78.65

A number of detailed information for these groups of universities, according to the impact of the external factor (PhDr_100und) are available in Tables 2 and 3 where some descriptive statistics with the characterization of the profile of these groups is reported. It appears that the universities which do not show a trade off between undergraduate and postgraduate education (i.e. those universities that have a value of PhDr_100und higher than 1.7 and lie on the flat region in Figure 6) are older, bigger (in terms of personnel) and have a higher number of publications and external funds.

Finally, the list of universities that lies on the flat (or very weakly increasing) region, i.e. universities with a research intensity higher than 1.7, is showed in Table 4.

Table 2. Some descriptive statistics by groups of universities: Age, inputs and outputs

Table 2a. All universities

	Average	Std	Min	Max
Age at 2000	165.12	209.57	1	833
Ac_tot	1303.15	1102.08	91	7316
Tecadm_staff	910.44	705.64	83.5	5011
Enrolled	18947.22	18801.7	44.5	134389
Graduated	2514.6	2088.95	20	16482.5
Phd_rec	115.31	136.66	1.5	847
Pubblications	443.39	471.74	4.5	2493.5

Table 2b. Universities with PhDr_100und ≥1.7

	Average	Std	Min	Max
Age at 2000	204.73	196.5	32	833
Ac_tot	2117.66	1528.88	169	7316
Tecadm_staff	1380.76	758.18	184.5	2902
Enrolled	10114.89	5389.69	44.5	21268.5
Graduated	1966.04	1158.9	20	4690.5
Phd_rec	286.07	188.39	27.5	847
Pubblications	826.02	598.53	70	2476.9

Table 2c. Universities with PhDr_100und ≤1.7

	Average	Std	Min	Max
Age at 2000	156.98	211.75	1	824
Ac_tot	1135.72	911.15	91	6028
Tecadm_staff	813.77	655.84	83.5	5011
Enrolled	20762.75	20032.29	1557	134389
Graduated	2627.36	2218.25	256.5	16482.5
Phd_rec	80.21	90.18	1.5	659.5
Pubblications	364.74	400.02	4.5	2493.5

Legend:
PhDr_100und = number pf PhD recipients per 100 undergraduate students, proxy of the research intensity;
Age at 2000 = number of years from foundation date;
Ac_tot = total number of academic staff;
Tecadm_staff = total number of technical and administrative staff;
Enrolled = number of enrolled students;
Graduated = number of graduated students;
Phd_rec = total number of PhD recipients;
Publications = total number of publications.

Table 3. Some descriptive statistics by groups of universities: Various indicators

Table 3a. All universities

	Average	Std	Min	Max
Extern_funds	0.07	0.08	0	0.44
Acad_nonac	1.54	0.89	0.42	9.31
Grad_enr	0.15	0.06	0.02	0.46
Pub_acad	0.26	0.2	0.01	1.05
Phdr_grad	0.06	0.14	0	1.75
Phdr_acad	0.08	0.05	0	0.24
Phdr_100underg	1.2	5.4	0.01	78.65
Actot_enr	0.11	0.32	0.01	4.51
Techad_enr	0.08	0.28	0.01	4.15
Grad_ac	2.28	1.13	0.1	6.96
Tot_pers	2213.59	1702.7	177.5	9534.5

Table 3b. Universities with PhDr_100und ≥1.7

	Average	Std	Min	Max
Extern_funds	0.11	0.04	0.04	0.22
Acad_nonac	1.56	0.77	0.72	3.68
Grad_enr	0.2	0.06	0.1	0.46
Pub_acad	0.25	0.12	0.16	0.65
Phdr_grad	0.21	0.28	0.07	1.75
Phdr_acad	0.15	0.05	0.06	0.24
Phdr_100underg	5	12.51	1.73	78.65
Actot_enr	0.35	0.72	0.09	4.51
Techad_enr	0.25	0.66	0.07	4.15
Grad_ac	1.15	0.62	0.1	2.14
Tot_pers	3498.42	2149.01	379	9498

Table 3c. Universities with PhDr_100und ≤1.7

	Average	Std	Min	Max
Extern_funds	0.06	0.08	0	0.44
Acad_nonac	1.54	0.91	0.42	9.31
Grad_enr	0.14	0.05	0.02	0.31
Pub_acad	0.26	0.21	0.01	1.05
Phdr_grad	0.03	0.02	0	0.14
Phdr_acad	0.06	0.04	0	0.19
Phdr_100underg	0.42	0.34	0.01	1.65
Actot_enr	0.06	0.03	0.01	0.28
Techad_enr	0.05	0.03	0.01	0.22
Grad_ac	2.51	1.07	0.53	6.96
Tot_pers	1949.49	1469.11	177.5	9534.5

Legend:
External_funds = percentage of funds coming from private sources;
Acad_nonac = ratio of academic on non-academic staff;
Grad_enr = ratio of graduate students on enrolled ones;
Pub_acad = number of publications per academic unit;
Phdr_grad = number of PhD recipients per graduated student;
Phdr_acad = number of PhD recipients per academic unit;
PhDr_100und = number pf PhD recipients per 100 undergraduate students, proxy of the research intensity;
Actot_enr = number of academic units per enrolled student;
Techad_enr = number of technical and administrative staff per enrolled student;
Grad_ac = number of graduated student per academic unit;
Tot_pers = total number of personnel

Table 4. List of universities with a research intensity higher than 1.7 in decreasing order

N. obs.	University	Country	Phdr_100underg
1	Institute of Education	UK	78.65
2	University of Basle (BS)	Switzerland	6.22
3	The University of Cambridge	UK	5.89
4	Federal Institute of Technology Zurich (ETHZ)	Switzerland	5.65
5	Federal Institute of Technology Lausanne (EPFL)	Switzerland	4.94
6	The University of Oxford	UK	4.58
7	University College London	UK	4.49
8	The Royal Veterinary College	UK	4.37
9	University of Berne (BE)	Switzerland	4.30
10	London School of Economics and Political Science	UK	3.66
11	University of Zurich (ZH)	Switzerland	3.53
12	The School of Oriental and African Studies	UK	3.33
13	The University of Birmingham	UK	3.17
14	Imperial College of Science, Technology & Medicine	UK	2.97
15	The University of Reading	UK	2.93
16	The University of Bristol	UK	2.92
17	The University of Sheffield	UK	2.59
18	University of Geneva (GE)	Switzerland	2.46
19	The University of Surrey	UK	2.33
20	King's College London	UK	2.31
21	The University of Bath	UK	2.23
22	The University of Sussex	UK	2.20
23	The University of Southampton	UK	2.18
24	The University of Leicester	UK	2.18
25	University of Neuchâtel (NE)	Switzerland	2.17
26	The University of Manchester Institute of Science & Technology	UK	2.10
27	University of Lausanne (LS)	Switzerland	2.09
28	The University of Aberdeen	UK	2.03
29	The University of Nottingham	UK	1.90
30	The University of Liverpool	UK	1.87
31	The University of Edinburgh	UK	1.87
32	The University of East Anglia	UK	1.82
33	The University of Newcastle-upon-Tyne	UK	1.82
34	Loughborough University	UK	1.79
35	The University of Leeds	UK	1.79
36	Queen Mary and Westfield College	UK	1.77
37	The University of Warwick	UK	1.73

Conclusions

The integration of micro-data at European level, taking into account all possible comparability issues, is a fundamental requisite for the European Research Area. Currently most decision making is based on aggregated indicators at national level, that shed little light on institutional differences and on the impact of institutional models on performance.

In order to explore the most complex issues in S&T and HE, a new generation of indicators is needed. We have proposed an approach based on the collection of administrative microdata at university level, and the construction of several positioning indicators.

These new indicators can be used for purposes of comparability across countries, but also to foster institutional learning, competition and strategic focusing of individual universities.

The original approach has been developed within the umbrella of the European Network of Excellence PRIME. The next stages of the research involve the following steps:

- Enlarging the census of universities to new countries (Hungary, The Netherlands and partially France have completed data collection at the end of 2006; Germany, Finland, and Australia, will join in 2007);
- Enlarging, whenever possible, the range of variables, including indicators of quality (citations of publications; student placement ratios; survey-based data on quality of services), of regional context, of third mission (patents, patents of academic inventors, licensing, industrial contracts, spin-off creation), of subject mix;
- Cross-validating national data using other sources.

While research on new indicators and new techniques will go ahead for the next years, it is clear that at some point an institutional effort to standardize and homogenize data collection at national and European level will be needed. It will be a great goal for a research team to have explored at high risk a subject that may be of interest for a large audience of stakeholders.

*

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References

AMARAL, A., JONES, G. A., KARSETH, B. (Eds) (2002), *Governing Higher Education: National Perspectives on Institutional Governance*. Dordrecht, Kluwer Academic Publishers.

BARRÉ, R. (2006), *Towards a European STI Indicators Platform (ESTIP)*, Position Paper presented at the second PRIME annual conference, Paris, February 2006.

BONACCORSI, A. (2007), Explaining poor performance of European science: Institutions versus policies, *Science and Public Policy*, 34 (5) : 303–316.

BONACCORSI, A., DARAIO, C. (2004), Econometric approaches to the analysis of productivity of R&D systems. Production functions and production frontiers, In: H. F. MOED, W. GLÄNZEL, U. SCHMOCH (Eds), *Handbook of Quantitative Science and Technology Research*, Kluwer Academic Publishers, pp. 51–74.

BONACCORSI, A., DARAIO, C. (Eds) (2007A), *Universities and Strategic Knowledge Creation. Specialisation and Performance in Europe*, Cheltenham, Edward Elgar.

BONACCORSI, A., DARAIO, C. (2007B), Theoretical perspectives on university strategy, In: BONACCORSI & DARAIO (2007A).

BONACCORSI, A., DARAIO, C. (2007C), Universities as strategic knowledge creators: Some empirical evidence, In: [BONACCORSI & DARAIO, 2007A].

BONACCORSI, A., DARAIO, C., LEPORI, B., SLIPERSAETER, S. (2007D), Indicators on individual higher education institutions: Addressing data problems and comparability issues, *Research Evaluation*, 16 (2) : 66–78.

BONACCORSI, A., DARAIO, C., SIMAR., L. (2006), Size, scope and trade-off in the productivity of universities: an application of robust nonparametric methods to Italian data. *Scientometrics*, 66 (2) : 389–410.

BONACCORSI, A., DARAIO, C., SIMAR, L. (2007), Productivity and efficiency of European universities. Exploring trade-offs in the strategic profile, In: [BONACCORSI & DARAIO, 2007A].

CAZALS, C., FLORENS, J.P., SIMAR, L. (2002), Nonparametric frontier estimation: a robust approach, *Journal of Econometrics*, 106 : 1–25.

CLARK, B. R. (1983), *The Higher Education System: Academic Organization in Cross-National Perspective*. Berkeley, The University of California Press.

CRESPI, G. (2007), The UK knowledge production function, In: [BONACCORSI & DARAIO, 2007A].

D'ANGELO, C. A., PUGINI, F., ABRAMO, G. (2006), La misurazione della produttività scientifica delle università italiane attraverso una metodologia bibliometrica-non parametrica, In: *Reti, servizi e competitività delle imprese*, XVII Riunione Scientifica AiIG, Aracne Roma.

DARAIO, C., SIMAR, L. (2005), Introducing environmental variables in nonparametric frontier models: A probabilistic approach, *Journal of Productivity Analysis*, 24 (1) : 93–121.

DARAIO, C., SIMAR, L. (2007), *Advanced Robust and Nonparametric Methods in Efficiency Analysis. Methodology and Applications*. New York, Springer.

EHRENBERG, R. G. (2004), Econometric studies of higher education, *Journal of Econometrics*, 121 : 19–37.

ESTERLE, L., THEVES, J. (2005), Analysis of the different European systems for producing indicators, paper presented at the *Lisbon Workshop on S&T Indicators Production*, Lisbon 22–23 September 2005.

EUROPEAN COMMISSION (2003), *Third European Report on Science & Technology Indicators*. Brussels, European Commission.

EVIDENCE LTD (2006), *The Quality Base of UK Science*. Mimeo, June.

FILIPPINI, M., LEPORI, B. (2007), Cost structure, economies of capacity utilization and scope in Swiss Higher education institutions, In: [BONACCORSI & DARAIO, 2007A].

GODIN, B. (2005), *Measurement and Statistics on Science and Technology: 1920 to the Present*. London, Routledge.

GRILICHES, Z. (1994), Productivity, R&D, and the data constraint, *American Economic Review*, 84 (1) : 1–23.

HICKS, D. (2004), The four literatures of social science, In: [MOED & AL., 2004 : 473–496].

HUISMAN, J., KAISER, F. (Eds) (2001), *Fixed and Fuzzy Boundaries in Higher Education. A Comparative Study of (Binary) Structures in Nine Countries*. Den Haag, Adviesraad voor het Wetenschapsen.

JONGBLOED, B., LEPORI, B., SALERNO, C., SLIPERSAETER, S. (2005), *European Higher Education Institutions: Building a Typology of Research*, CHINC report, IPTS, Seville.

KING, D. (2004), The scientific impact of nations. What different countries get for their research spending, *Nature*, 430 : 311–316.

KYVIK, S. (2004), Structural changes in Higher Education systems in Western Europe. *Higher Education in Europe*, 29 (3) : 393–409.

KYVIK, S., SKOVDIN, O.-J. (2003), Research in the non-university higher education sector – tensions and dilemmas. *Higher Education,* 45 : 203–222.

LAREDO, P. (Ed.) (2003), *Observatoire Recherche Angevine. Sinthèse Enquete 2002.* Paris, Technopolis France.

LEPORI, B., BENNINGHOFF, M., JONGBLOED, B., SALERNO, C., SLIPERSAETER, S. (2007), Changing models and patterns of higher education funding: some empirical evidence. In: [BONACCORSI & DARAIO, 2007A].

MARCHETTI, C. (1989), The Nobel saga, *Technology Review*, Italian edition, March.

MARSH, L. C. (2004), The econometrics of Higher Education: editor's view, *Journal of Econometrics*, 121 : 1–18.

MCCORMICK, A. C. (2004), The 2005 revision of the Carnegie Classification System. Presentation to the Washington Higher Education Secretariat. Washington D.C. June 8, 2004. Available online at: http://www.carnegiefoundation.org/Classification/future.htm

MUSSELIN, C. (2004), Towards a European academic labor market? Some lessons drawn from empirical studies on academic mobility. *Higher Education*, 48 : 55–78.

MUSSELIN, C. (2005), *Le Marché des Universitaires. France, Allemagne, Etats-Unis*. Paris, Presses de la Fondation National des Sciences Politiques.

NEAVE, G., VAN VUGHT, F. A. (1994), *Government and Higher Education Relationships Across Three Continents*. Oxford, Pergamon Press.

SLIPERSAETER, S. (2005), Comparisons of methodological approaches for determining research intensity at higher education institutions, paper presented at the *Lisbon Workshop on S&T Indicators Production*, Lisbon 22–23 September 2005.

SLIPERSAETER, S., LEPORI, B., JONGBLOED, B., SALERNO, C. (2005), *Collecting Institutional Level Data for European Higher Education Institutions: Evidence from the CHINC Project*, CHINC report.