A scaling approach to tackle the heterogeneity of HEIs

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Introduction

The assessment of the performance of Higher Education Institutions (HEIs) at the micro (institutional), meso (regional) and macro (country) level is an important and recurrent question in the higher education's policy debate. The modernisation agenda for Higher Education in Europe (European Commission, 2016) identifies the relevance of creating effective governance and funding mechanisms for higher education among the five key priorities for this sector. It is underlined the importance to ensure greater flexibility and autonomy for institutions to specialise more easily, promoting better educational and research performance while fostering excellence within higher education systems.
Different models of governance (Agasisti and Catalano, 2006; Capano et al. 2015) are applied by policy makers trying to improve the *systemic* performance of Higher Education.
However, the analysis of the performance of HE systems is far from being easy to deal with. One of the main critical issue to address properly the assessment of the performance, in a multi-level (systemic) perspective, is the consideration of the *heterogeneity* of the HEIs involved.
Among the heterogeneity factors of HEIs, the disciplinary specialization or *subject mix* is considered one of the most relevant (López-Illescas et al. 2011, Daraio et al. 2011).

Main objective of the study

Recently, Bonaccorsi et al. (2017) extend the results of Ruocco and Daraio (2013) to the evaluation of bibliometric indicators of Social Sciences and Humanities (SSH) and propose a scaling approach as a tool for *indirect qualitative-quantitative comparative analysis* across heterogeneous disciplines. In this paper we (i) demonstrate that the distributions of total enrolled students (ENR STUDENTS) of European HEIs in four main fields of education (ENG, MED, NAT, SSH) follow a Log-Normal master curve, (ii) estimate the scaling factors that work like *rates of substitution* to compare the education production across different fields on a common ground and (iii) propose to use the estimated *scale factors* to make appropriate *normalizations* before running systemic performance assessment and comparison.

Data

The data analysed come from the European Tertiary Education Register (ETER) which is a database that provides a core set of data on 2,239 HEIs in 31 European Research Area countries for the years 2011-2014. Most ETER data can be freely downloaded from the project website (http://eter.joanneum.at/imdas-eter/).

Method and results

Following Ruocco and Daraio (2013) the distributions of the total enrolled students (including ISCED 5 to 7 students, average 2011-2013), called ENR STUDENTS hereafter, aggregated in four broad fields of education ENG (Engineering and Technology), MED (Medicine), NAT (Natural Sciences) and SSH, have been assumed as a Log-Normal:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma x}\exp\left\{-\frac{1}{2\sigma^2}\left[\ln\left({}^{x}/_{\xi}\right)\right]^2\right\}, \quad (1)$$

and the rankings (in percentile, then with a maximum value equal to 100) of ENR STUDENTS have been fitted with a cumulative Log-Normal distribution:

$$F(x) = 50 + 50\mathrm{erf}(\frac{ln\left({}^{x}/_{\xi}\right)}{\sqrt{2}\sigma})\}, \quad (2)$$

where:

$$\mathrm{erf}(.) = \frac{2}{\sqrt{\pi}}\int_0^{(.)} e^{-t^2}\,dt. \quad (3)$$

These functions depend on two parameters, the *scale factor*, ξ, which is a kind of *exchange rate* to compare heterogeneous categories of students (namely ENG, MED, NAT and SSH), and the parameter σ, or *shape* parameter, that should be close to one if the compared categories are similar, that is, in the case of *universality* of their underlying distribution. See Figure 1.
Table 1 shows the results of the estimates, obtained by applying a non-linear fit algorithm (Levemberg-Marquardt). For each field of education (ENG, MED, NAT, SSH), the table shows the value of the estimated scale parameter ξ, its Standard Error (S.E.), the standard deviation (σ) and its S.E.; and

finally the statistics of the reduced Chi-square and the Adj. R-square.

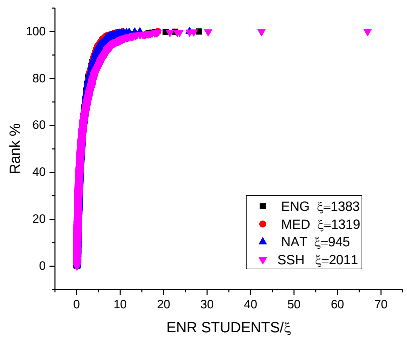
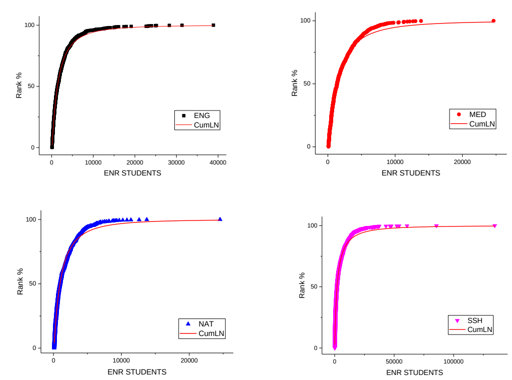


Figure 1. Cumulative *scaled* distributions of ENR STUDENTS by field of education (ENG, MED, NAT, SSH). The figure shows the distributions (Eq. 2) of ENR STUDENTS by fields of education divided by their respective scale parameters, ξ whose values are reported in the legend of the figure.

The *scale* parameter ξ, acts like a kind of *exchange* rate to compare the heterogeneous categories of students. The standard deviation (σ) estimated are all close and around one, showing that we are in presence of *universality*. Finally, it is worth noting that we have a very high fit for all the considered categories, as all the Adjusted R-Squares are almost equal to one. This result confirm that ENR STUDENTS have a Log-Normal distribution across the different fields of education considered. Figure 2 illustrates the obtained fit.

Field Edu.	ξ i (S.E.)	σ (S.E.)	Reduced Chi-Sqr	Adj. R-Square	N
ENG	**1383 (2.25)**	1.258 (0.003)	1.491	0.998	979
MED	**1319 (3.19)**	1.246 (0.003)	2.674	0.997	782
NAT	**945 (2.27)**	1.272 (0.003)	2.898	0.997	889
SSH	**2011 (3.93)**	1.561 (0.003)	2.524	0.997	1763

Table 1 Results of the fit by Field of Education of the Enrolled students.



Note: The red curve represents the fit to the Log-Normal cumulative distribution (Eq. 2).

Figure 2. Fit of the cumulative distributions of ENR STUDENTS by fields of education.

Discussion and conclusions

The results of this analysis show that to make appropriate comparisons it is important to consider the heterogeneity of the disciplinary mix of education. The estimated *scale* parameters by field of education represent sound *thresholds* for comparing the different categories of enrolled students among HEIs and at the country level.
The scaling approach we propose in this paper could be an interesting tool to analyse and tackle the different sources of heterogeneity of HEI systems included in multi-level models of performance where country level statistical data are combined with micro-level institutional data. It is worth then to further corroborate and apply the scaling approach proposed here to implement appropriate normalization strategies in multi-level systemic performance evaluation models.

Acknowledgments

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