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The growth process of higher education institutions and public policies

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A B S T R A C T

This paper investigates the growth over time of the size of higher education institutions (HEIs), as measured by the number of academic staff, and its association with HEI and country attributes. We analyze a sample of 837 HEIs from 18 countries derived from the European Tertiary Education Register (ETER) and from the European Micro Data dataset (EUMIDA) for the years 2008 and 2012. Our analysis shows that (1) HEIs growth is largely proportional to their size, leading to a nearly log-normal distribution of size (Gibrat's law), even if small institutions tend to grow faster; (2) the growth of the number of students and HEI's reputation level positively influences HEI growth. Consequently (3) small HEIs need a lower level of reputation and less growth of students to continue growing over time, while only highly reputed HEIs are able to maintain a large size over time. Our results are relevant to understand the extent to which cumulative effects lead to a lasting concentration of resources in the HE system and whether public policies are able to redistribute resources based on merit.

1. Introduction

The growth of the higher education system is a subject that has received little attention from the scientific community. There are only a few studies that address this process at the system's level, by looking at the growth and number of universities over several decades (Bonaccorsi & Daraio, 2007; Riddle, 1993) and at the growth of overall student enrolment (Schofer & Meyer, 2005). This may be explained by the lack of reliable data on individual HEIs, but this subject can be explored in more detail with the development of databases such as the European Micro Data (EUMIDA) and the European Tertiary Education Register (ETER), two projects supported by the European Commission and realized in close cooperation with EUROSTAT whose aim was to establish a comparable dataset of European Higher Education Institutions in Europe (Lepori et al., 2014).

The topic is of theoretical and practical relevance. First, an extensive literature review demonstrated that the growth process of many types of organizations is driven by cumulative advantage, where the growth rate is largely independent of size, leading to a highly skewed distribution of organizational size (Gibrat's law; Mitzenmacher, 2004). Such cumulative effects are well known in the science system, where a power-law distribution has been found for paper citations, researchers' productivity and impact (e.g. Katz, 1999, 2000; van Raan, 2006a, 2008a,b, 2013). Therefore, it is important to analyze whether this effect can also be found in the growth of HEI size over time.

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Second, in most European countries, public policies increasingly allocate funding to HEIs based on performance, by increasing the share of competitive funds and by linking the level of core allocation to the number of students and to some measure of research performance (Auranen & Nieminen, 2010; Geuna & Martin, 2003; Jongbloed & Vossensteyn, 2001). Yet, cumulative effects imply that large HEIs have more opportunities – for example they acquire more students – and therefore, performance-based allocation would reinforce the existing hierarchy rather than redistributing resources based on merit. An analysis of how resources are redistributed over time and whether this leads to differential growth is clearly required.

In this paper, we analyze the growth of a sample of 837 HEIs in 18 European countries between 2008 and 2012, using total academic staff as a measure of organizational size. This is the first study of its type, according to our knowledge of the literature. We include a set of variables at the country and at the organizational level that may influence organizational growth.

First, we present descriptive statistics on the variables considered, highlighting the skewness of their distribution.

Second, we show that the distribution of HEI size, at a given point of time, is nearly log-normal, therefore providing evidence that Gibrat's law might play a role in explaining organizational growth. We also perform distributional analysis of the increase in total academic staff between 2008 and 2012, focusing on differences between countries and on the identification of fast-growing HEIs.

Third, we run multi-level regressions to predict size in 2012 as a function of size in 2008, of HEI characteristics (growth of the number of students, reputation, HEI type) and of the change in national investment in tertiary education.

In the discussion section, we provide an interpretation of these results in terms of the model of growth of HEIs, highlighting the interplay between cumulative effects and performance-based allocation and its implication for the resulting distribution of organizational size within HE systems. Lastly we point to some future extensions of our research.

2. Theoretical framework

2.1. Size distribution and growth processes

Several phenomena in the world and in society are not characterized by a normal distribution of the variable of interest *at a given point in time* – like organizational size, number of species, paper citations – but by a right-skewed distribution, where the values for a small number of observations are much larger than the median and account for a large proportion of total scores. Such distributions can frequently be fitted by a log-normal distribution, where the logarithm of the variable is distributed normally, or by a power law distribution of the form $p(x) = c \times x^{-\alpha}$, where $p(x)$ is the proportion of observations with score x (Newman, 2005). The two distributions are very similar in shape, except that a log-normal distribution has a less fat tail of extreme values, making difficult, in some situations, to decide which distribution is a better fit for empirical data.

The power law has been found in several contexts: to measure the usage frequency of words in various languages (Zipf, 1949); in the number of papers a researcher writes (Coile, 1977); in the impact of the papers measured by the number of citations (Perc, 2010; Price, 1965); in the number of visitors to sites of the World Wide Web (Adamic & Huberman, 2000), in the number of species per genus of mammals (Willis & Yule, 1922) and in income distribution of companies (Okuyama, Takayasu, & Takayasu, 1999).

The log-normal distribution has been used in: fitting molecular weight distributions (Monteiro, 2015; Shin-Ya, Yoshizawa, Hong, Lee, & Kajiuchi, 2003); fitting the coefficients of friction and wear distributions (Steele, 2008); fitting the g-index and the h-index distributions for researchers (Perc, 2010) and in fitting the file size distribution of publicly available data files on the Internet (Gros, Kaczor, & Markovic, 2012). In economics, there is extensive evidence that the size distribution of firms in many fields displays a log-normal distribution (Ijiri & Simon, 1967).

These distributions can be linked to simple generating processes, where the growth over time of individuals or organizations is in proportion to their current size, as the outcome of some form of cumulative advantage (Mitzenmacher, 2004).

A log-normal distribution can be generated from Gibrat's law, which states that the probability distribution of a firm's growth rate is independent from the firm's size (Mansfield, 1962). The growth of individual firms is dependent on their profitability as well as on other factors that are dependent on the quality of the firm's management, the availability of the inputs and the economic environment. The combined effect of these factors will lead to a probability distribution of the rates of growth for firms of a given size. If that distribution is the same for all size-classes of firms, the size distribution of firms converges to a log-normal distribution.

More precisely, Gibrat's law can be expressed as follows:

$$Size_t = (1 + \varepsilon) \times Size_{t-1} \quad (1)$$

where ε is a random variable with mean m and variance σ accounting for variation in the growth rate among HEIs. Provided the selected time difference is short and therefore ε is sufficiently small:

$$\log(Size_t) = \log((1 + \varepsilon) \times Size_{t-1}) \approx \log(Size_{t-1}) + \varepsilon \quad (2)$$

When repeating this process for n times from a starting time t_0, we get:

$$\log(Size_{tn}) \approx \log(Size_{t_0}) + \varepsilon_1 + \varepsilon_2 + \cdots + \varepsilon_n \quad (3)$$

When m grows large, the starting size becomes irrelevant, and provided ε_i are independent, the right size converges as a consequence of the central limit theorem to a normal distribution with mean $n \times m$ and variance $n \times \sigma$. In this process, the random variation in the growth rates among HEIs generates large size differences independent from the initial conditions.

Over time, several studies of firms' growth based on Gibrat's law have been performed (Adams, Andersson, Hardwick, & Lindmark, 2014; Audretsch, Klomp, Santarelli, & Thurik, 2004; Becchetti & Trovato, 2002; Ijiri & Simon, 1967; Lensink, van Steen, & Sterken, 2005), but also in the cities' growth (Gonzalez-Val, Lanaspa, & Sanz-Gracia, 2013; Gonzalez-Val, Lanaspa, & Sanz-Gracia, 2014; Resende, 2004; Rozenfeld et al., 2008), in the growth dynamics of universities enrolments (Havemann, Heinz, & Wagner-Dobler, 2004) and in the growth dynamics of university research (Plerou, Amaral, Gopikrishnan, Meyer, & Stanley, 1999).

The generating processes for power-law distributions are very similar (Mitzenmacher, 2004). This process, known as the Yule process, assumes that in a system where we have a collection of objects (e.g. papers or cities) each object has an associated property of k (number of citations or population) with an initial value of k_0. Each time a new object appears, it is considered that the probability of getting a new citation (in the case of papers) is proportional to the number it already has (Newman, 2005). In both cases the generating mechanism is growth over time being proportional to current size, but in the power-law case there is minimum threshold of increment, while the growth is represented as continuous in the lognormal case.

We consider Gibrat's law as a reasonable first approximation of the growth process of HEIs. HEIs have different characteristics, quality and levels of efficiency, which influence their ability to acquire resources and, therefore, their growth. Yet, it can be assumed that some of the key determinants are proportional to their current size: student intake will largely be proportional to the amount of educational offerings, while acquisition of research funds will be largely proportional to the number of research staff. Therefore:

H1. The size distribution of HEIs is expected to be log-normal and the HEI growth rate is expected to be independent from its current size.

2.2. Organizational characteristics

A more refined strategy for studying HEI growth should take into account that HEIs may differ in their ability to acquire external resources. In European countries, HEI funding is mostly composed of State allocations, either in the form of block grants or project funds, and is driven by two major criteria, i.e. educational and research performance (Jongbloed & Lepori, 2015).

Educational allocation is mostly based on the number of students, while research allocation is increasingly based on international reputation and on the competition for project funds (Abramo & D'Angelo, 2015; Auranen & Nieminen, 2010; Geuna & Martin, 2003; Hicks, 2012; Jongbloed & Vossensteyn, 2001; Strehl, Reisinger, & Kalatschan, 2007). In many countries, both still include a share of historical allocation based on past activities and size.

Concerning education, some HEIs might be able to attract more students by offering courses that better suit their interests and the requirements of the labour market, by providing more favourable study conditions or simply because of their higher reputation.

Concerning research, HEIs might increase their level of research core funding by increasing scientific productivity and reputation, as these play a (varying by country) role in the allocation of the core State budget (Hicks, 2012; Jongbloed & Lepori, 2015). In getting project funds, the HEI's research reputation plays a central role (van den Besselaar & Leydesdorff, 2009). It is therefore expected that higher levels of reputation will lead to the acquisition of more resources, and therefore, a growth in size.

However, when studying the influence of research reputation on the growth of HEIs, we have to consider the importance of size-dependent cumulative advantages in the acquisition of resources (Katz, 1999, 2000; van Raan, 2006a,b, 2008a). Therefore, a large share of this effect might already be accounted for by the HEI's current size.

H2. The rate of growth of HEIs increases with their international reputation and with the growth of the number of students.

Finally, many European HEI systems are characterized by the presence of different legally-defined types of HEIs (Kyvik & Lepori, 2010), including doctorate-awarding universities and so-called Universities of Applied Sciences (UASs), which are more teaching-oriented and perform limited research activities (without the right to award a doctorate).

While in countries like the UK, HEIs with the legal status of universities but a similar profile as UASs exist (as a remnant of the binary system which existed before 1992), we are interested in the *legal* distinction since it implies different access to resources: in most countries, national regulations provide that UASs are mostly funded based on student numbers and have limited access to research funding. On the contrary, HEIs like the UK Polytechnics have the right to acquire core research funds (allocated competitively through the Research Excellence Framework); hence, reputation might also drive their growth if these HEIs are able to increase their reputation.

We therefore expect that the growth process is driven by different factors depending on the HEI type.

H3. University growth is influenced by the number of students and by research reputation, while growth of UASs is influenced essentially by the number of students.

2.3. Country characteristics

HEIs are embedded in countries with very different higher education policies. On the one hand, statistical data display lasting differences in levels of public investment, with a group of medium-size countries allocating more resources to higher education (Jongbloed & Lepori, 2015). On the other hand, there are differences among countries in the criteria adopted to distribute funds to HEIs, with countries like the UK, the Netherlands and Norway having moved towards performance allocations while other countries retained funding systems largely based on history and the current levels of expenditures.

H4. The growth rate of HEIs increases with increasing public investment in higher education at the national level.

It would go beyond the scope of the current study and of the data available to investigate the impact of different national funding allocation systems on the HEI growth rate (and particularly, on the importance of student numbers and reputation in determining HEI growth).

3. Methods and data

3.1. Sample

The sample is composed of 837 HEIs from 18 European countries, Belgium, Bulgaria, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Finland, Ireland, Italy, Lithuania, Malta, the Netherlands, Norway, Poland, Spain, Sweden and Slovakia. It has been derived from the European Micro Data dataset (EUMIDA) for the year 2008 and from the European Tertiary Education Register (ETER) database for the year 2012 (ETER is the follow-up of EUMIDA). These datasets cover most of the HEIs in European Union countries plus Norway and Switzerland. EUMIDA and ETER provide data at the individual HEI level for total academic staff, students, graduates and other organizational features. Most definitions and sources are the same for the two datasets, therefore data can be considered as reasonably comparable.

ETER and EUMIDA data are provided by National Statistical Authorities from official statistical databases and are based on a common methodological manual, which follows standard definitions in educational statistics. The data have been extensively checked and cleaned for mistakes and comparability problems (refer to the ETER website http://eter.joanneum.at/imdas-eter/). Nevertheless, some comparability problems exist concerning staff data: the most important being differences in the perimeter of employees considered in each country, different levels of inclusion for PhD students, and in a few cases, data in headcounts rather than in full time equivalents.

In the sample used we are considering 91% of total academic staff in 2012 in these 18 countries and 87% of total students.

3.2. Variables

3.2.1. Dependent variable

Our dependent variable, i.e. HEI size, was measured using total academic staff.

Size_2012-Total Academic Staff in full time equivalents retrieved from ETER for the year 2012.

3.2.2. Independent variables

HEIs-level

Size_2008—Total academic staff in full time equivalents, retrieved from EUMIDA for the year 2008.

GrowthStudents—Ratio between total undergraduate students (levels 5 to 7 of the International Standard Classification of Educational Degrees ISCED) in 2012 and their number in 2008.

Reputation—As a measure of reputation of a given HEI, we use the product of the Normalized Impact (NI) and the total number of documents published, divided by total academic staff in 2008. The NI and the total number of publications were retrieved from the Global Scimago Institutions Ranking (Global SIR) for the year 2011, which is based on the scientific documents published between 2005 and 2009 and indexed in Scopus. From the Global SIR we have data for 313 HEIs, while the remaining HEIs–as they published less than 500 documents during the considered period–are not included in the Global SIR. As the reputation index considered here is a combination of both volume and impact, we considered that if a given HEI has less than 500 papers in the considered period, then its reputation can be set to zero.

Organization type—This categorical variable represents the type of HEI: 2—university of applied science (UAS); 1—universities and 0—others.

In the ETER database, HEIs are considered “universities” if they display a largely academic orientation, have the right to award a doctorate and can bear the full name of “University”. “Universities of Applied Sciences” (UASs) are professionally oriented HEIs, mostly without the right to award a doctorate, in countries where they constitute a legally recognized HEI type (“binary systems”; Kyvik, 2009). HEIs that do not match any of the above descriptions are classified as “others”, as they are normally small institutions of art and music academies or military schools (Lepori et al., 2014).

3.2.3. Control variables

In our dataset, some of the HEIs experienced deep changes from the year 2008 to 2012. We specifically deal with cases where the highest degree delivered by the HEI increased from bachelor to master or from master to PhD, since this is expected to influence the volume of activities.

ChangeDegree. Dummy variable that was set to 0 if the HEI maintains the highest degree delivered from 2008 to 2012 and 1 if the highest degree delivered increased.

3.2.4. Country-level variables

At the country level we consider the growth of the investment in tertiary education.

GrowthInvestment—ratio between the total investment in tertiary education, in constant prices, for 2011 and 2008. Data were retrieved from EUROSTAT.

3.3. Statistical analysis

First, we perform a descriptive analysis at the country and HEI level in order to investigate the distribution of variables and provide preliminary evidence on their correlations.

Second, we analyze the distribution of total academic staff in 2012 for the set of HEIs in order to study the size distribution at a given point of time. We also analyze the distribution of the growth rate in order to investigate its association with size, differences by countries and to identify fast-growing HEIs.

Third, we run a regression to predict academic staff in 2012 from the level in 2008 and from HEI and country characteristics. Since the HEIs are embedded in countries with different characteristics, we adopt a multi-level model as this allows us to take into account the influence of both levels and within-country correlations (Rabe-Hesketh & Skrondal, 2008). The main goal here is to study the growth process over time.

To test Gibrat's law, we first estimate the following equation:

$$\frac{\text{Size}_{ijt}}{\text{Size}_{ijt-1}} = \alpha \text{Size}_{ijt-1}^{\beta_1 - 1} \tag{4}$$

The parameter α is a scale factor representing the overall growth of the size of the HEI system; β_1 has been inserted in order to test empirically whether the Gibrat's law holds ($\beta_1 = 1$, see H1).

Since we are also analysing the impact of HEI and country factors on the HEI growth rate – after taking into account the size effect – when introducing these factors, Eq. (4) becomes (as the baseline is a reputation equal to 0):

$$\frac{\text{Size}_{ijt}}{\text{Size}_{ijt-1}} = \alpha \times (\text{Growth Students})_{ij} \times (1 + Reputation)_{ij} \times (\text{Organization type})_{ij} \times (\text{Change Degree})_{ij} \times (\text{Gowth Investment}_j) \times \text{Size}_{ijt-1}^{\beta_1 - 1} \tag{5}$$

Applying the logarithmic transformation we obtain:

$$\begin{aligned} \log(\text{Size}_{ijt}) &= \beta_0 + \beta_1 \log(\text{Size}_{ijt-1}) + \beta_2 \log(\text{Growth Students})_{ij} + \beta_3 \log(1 + Reputation)_{ij} \\ &+ \beta_4 \log(\text{Organization Type})_j + \beta_5 (\text{Change Degree})_{ij} + \beta_6 \log(\text{Growth Investment})_i \\ &+ \mu_{it} + \mu_{ijt} \end{aligned} \tag{6}$$

where Size_{ijt} is total academic staff for the HEI j within country i at time t, Size_{ijt-1} is the total academic staff for the HEI in the previous period of time, β_0 is the constant growth ratio ($\log \alpha$), β_1 is the effect of past size on the subsequent rate of HEIs' growth, β_2 and β_3 are the effect of educational and research performance, β_4 gives information on different growth rates by organization type, β_5 represents the effect of changing the highest degree delivered, β_6 is the effect of public investment, μ_{it} is a random term at country level and μ_{ijt} is a random term at the HEI level.

H1 is supported if β_1 is not significantly different from 1, H2 is supported if β_2 and β_3 are significantly greater than 0, while H4 is supported if β_6 is significantly greater than 0. To test H3, we run distinct regressions by type of HEI and we analyze whether coefficients of students' growth and reputation are different.

4. Results

4.1. Descriptive statistics: HEIs and country level data

The descriptive statistics in Table 1 show that HEI variables have a skewed distribution with a median value much lower than the average, reflecting the presence of a few cases with scores well above the average. The high standard deviations suggest large variability.

The medians and standard deviations for organizational size in both years (2008 and 2012) are very close. The average value is two times the median, suggesting that size distributions are right skewed. The median growth of HEI size from

Table 1
Descriptive statistics (837 HEIs and 18 countries).

Variable	Mean	Median	Standard deviation	Maximum	Minimum
Size_2012	813.62	392.00	1019.39	5998.90	10.00
Size_2008	738.00	336.00	938.35	6571.00	7.00
GrowthStaff	1.24	1.12	0.82	18.55	0.29
GrowthStudents	1.23	1.11	1.12	23.41	0.27
Reputation	1.63	0.00	3.07	40.58	0.00
GrowthInvestment	1.07	1.06	0.12	1.43	0.83

Table 2
Correlation matrix for the variables in the study (variables log transformed).

	Size_2012	Size_2008	GrowthStudents	Reputation	GrowthInvestment	GrowthStaff
Size_2012	1					
Size_2008	0.973**	1				
GrowthStudents	−0.057	−0.131**	1			
Reputation	0.716**	0.707**	−0.057	1		
GrowthInvestment	−0.172**	−0.190**	0.200**	−0.150**	1	
GrowthStaff	−0.041	−0.272**	0.329**	−0.076*	0.107**	1

** $p < 0.01$.
* $p < 0.05$.

2008 to 2012 was 12%. The very high standard deviation, maximum and minimum values, suggests large variability, i.e. the presence of fast-growing HEIs and HEIs that have lost a large percentage of their staff.

On average, the total number of students increased by about 23% from 2008 to 2012. There are 80 HEIs with a growth rate above 50%. These HEIs are mainly small and young, 57 out of 80 have a total academic staff below 500 FTEs, and 34 were created after 1990.

63% of the HEIs have a reputation equal to zero, most of them being small institutions. Reputation is above 4.5 for about 17% of the HEIs. This group includes mostly large institutions, only 7 of them having less than 500 FTEs of academic staff.

Looking to country variables, the investment in tertiary education increased by 7% on average. The highest increase (43%) was observed for Malta (only one HEI), while in Bulgaria, Italy and Lithuania the investment decreased between 2008 and 2012. The small standard deviation shows that differences between countries in terms of investment increases in tertiary education are not very large.

The correlation table (Table 2) shows that, expectedly, academic staff in 2012 is highly correlated to 2008, displaying the stability of HEI size over the considered period; moreover, the growth rate of staff is negatively correlated with 2008 size, suggesting that small HEIs grow more rapidly than large ones. The growth rate is also positively correlated with the growth in the number of students, but the correlation with HEI reputation is very small and negative. An increase of total academic staff is related to an increase in the investment in tertiary education, but the correlation is small.

Among independent variables, there is a correlation of 0.7 between 2008 size and reputation but this correlation drops to 0.3 if HEIs with zero reputation are left out. As already discussed in the literature, there is therefore some scaling effect in that the number of citations grows more rapidly than the number of publications (van Raan, 2008a, 2013), which in our sample is correlated to 0.84 to size. The effect of setting reputation equal to zero is discussed in Section 4.3. The correlation between reputation and growth of the number of students is not significant.

4.2. Size distribution

In our setting, it is important to distinguish between the growth process (over time) and the observed size distribution (at a given point in time); if the growth process is driven by cumulative advantage, larger HEIs will grow more rapidly leading to a right-skewed distribution of the size at a given time. Below we present the results of examining cross-sectional distributions.

In 2012, the median size of HEIs in the sample was slightly below 400 FTEs, with a high standard deviation of 1000 FTEs and maximum size of about 6000 FTEs (see Table 1). The sample includes 42 HEIs with total academic staff above of 3000 FTEs, 319 HEIs between 500 and 3000 and 476 HEIs below 500 (205 of which are in Germany). From the set of small institutions, 37% were created before 1990 and 71% are UASs or HEIs classified as “others”. Most of the small institutions are focused on a single domain, particularly in Arts, Music, Dance, Economics, Theatre, Theology and Physical Sciences.

The data show that the size distribution is skewed. 14.5% of the total academic staff in FTEs is concentrated in HEIs with a size lower than 500 FTEs and 60.17% in HEIs with a size between 500 FTEs and 3000 FTEs. This means that medium and large HEIs concentrate most of the staff; however, the very large HEIs (above 3000 FTEs) account only for a limited proportion of staff.

The cumulative probability distribution shows that the log-normal distribution fits reasonably well with the empirical data (Fig. 1), the *r* square being 0.998. However, the log of total academic staff does not pass the Kolmogorov–Smirnov and

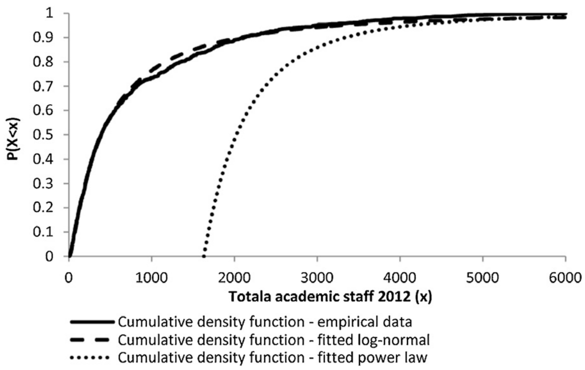

Fig. 1. Cumulative density function for the empirical data, adjusted log-normal and power law cumulative distributions.

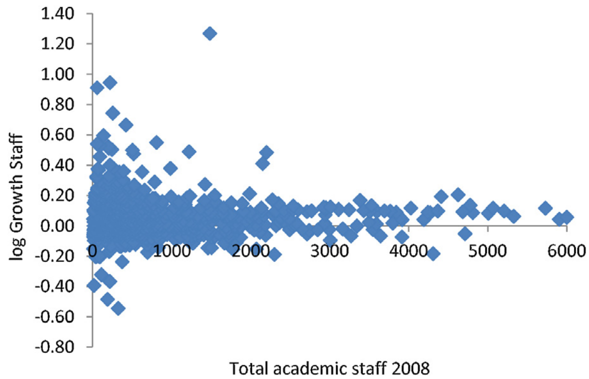

Fig. 2. Relative growth rate as a function of size in 2008.

the Shapiro–Wilk tests for normality ($p < 0.01$). Deviations are observed for institutions of a large size (large values of total academic staff) and at some point for institutions with a total academic staff between 1000 FTEs and 1800 FTEs.

Since the power law distribution is very similar in shape to the log-normal distribution, we also tested its fit to the data. There are several studies in the literature that show that the power law applies only on the tail of the distribution, i.e. for values greater than a minimum x_{min}. Therefore, in determining the parameters we used an approach that combines maximum-likelihood fitting methods with goodness-of-fit tests based on the Kolmogorov–Smirnov statistic and likelihood ratios (Clauset, Shalizi, & Newman, 2009). Comparing the complementary cumulative density function for the empirical data and for the fitted power law ($\alpha = 3.21$ and $x_{min} = 1631$FTEs), we see that the power-law distribution does not provide a good fit for the data over most of the size distribution.

4.3. Growth rates

As suggested by Table 1, several HEIs experienced large changes in their size between 2008 and 2012. 70% of the HEIs have experienced an increase in size. The sample includes 32 HEIs that more than doubled their size and 105 HEIs that increased their size by more than 50%. In 2008, only 132 of them had a total academic staff above 1000 FTEs. Therefore, there is some descriptive evidence that small HEIs tend to grow faster, while a growth rate above 1000 FTEs academic staff seems to be independent from size (see Fig. 2).

As demonstrated by Fig. 3, there are large differences among and within countries in HEI growth. Large heterogeneity is observed for Cyprus (only 6 HEIs), Germany, Italy, Ireland and Slovakia (with three outliers). In the Czech Republic, Spain, Italy and Lithuania more than half of the HEIs experienced a decrease in total academic staff. In these countries, investment in tertiary education decreased by about 9% and 3% in Italy and Lithuania respectively, while in Spain it increased only by 0.2%. The country with the highest median relative growth rate is Bulgaria (49%).

35 outliers can be identified, most of them in Germany and Italy. These outliers are either very small or young HEIs, or HEIs that changed the highest level of degree delivered.

4.4. Models

Table 3 presents the regression results using total academic staff in 2012 as a dependent variable, and as a baseline the type of organization defined as “universities”. This regression allows us to study the growth process over time.

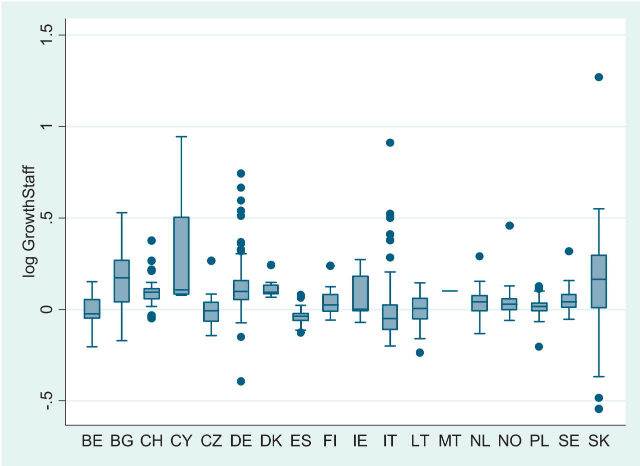

Fig. 3. Boxplots of the relative growth rate of the total academic staff between 2008 and 2012 for the 837 HEIs in 18 countries. Malta only has one HEI.

Table 3
Results for the multilevel regression.

Variables	Empty model		Model 1. Size model		Model 2. HEI variables		Model 3. Country and HEIs variables		Model 4. Country and HEIs variables plus control	
	Coefficients	SE	Coefficients	SE	Coefficients	SE	Coefficients	SE	Coefficients	SE
Growth Investment							0.136	0.359	0.129	0.355
Size_2008			0.994**	0.005	0.965**	0.007	0.965**	0.007	0.967**	0.007
GrowthStudents					0.288**	0.024	0.287**	0.025	0.288**	0.025
Reputation					0.058**	0.013	0.058**	0.013	0.058**	0.013
ChangeDegree									0.013	0.008
Type = other					−0.047**	0.012	−0.047**	0.012	−0.047**	0.012
Type = UAS					0.018+	0.009	0.018+	0.009	0.013	0.010
Constant	2.652**	0.053	0.070*	0.021	0.111**	0.023	0.109**	0.024	0.103**	0.024
Random effects, (variance; standard errors)										
Country level	0.038	0.016	0.004	0.012	0.003	0.001	0.003	0.011	0.003	0.010
HEIs level	0.275	0.014	0.006	0.002	0.005	0.0003	0.005	0.0020	0.005	0.0020
Log likelihood	−642.06		870.46		970.80		970.81		966.18	
AIC	1290.12		−1732.92		−1925.60		−1923.74		−1912.37	

** $p < 0.001$.
* $p < 0.05$.
+ $p < 0.1$.

The empty model shows that the share of variance at the country level is only about 12%.

The size only model (model 1) explains 97.8% of the variance, showing that past size already provides a very good prediction of current size (as expected over a short period of time). The past size coefficient is not significantly different from 1 (the confidence interval encompasses the value 1) and therefore, the results are in agreement with the Gibrat's law (H1).

However, when the variables at the HEI level are considered (model 2), the fit of the model improves; the total initial variance explained is higher and the Akaike Information Criteria (AIC) is smaller than for the size model. The coefficients of reputation and student growth are positive and significant, confirming the hypothesis that the growth rate increases with the increase of the number of students and the level of reputation (H2). In this model, the coefficient of past size is significantly below 1, implying that small HEIs grow more rapidly. Finally, "other" institutions grow less than "universities", while UASs grow more rapidly, but the difference is only marginally significant.

In the country model (model 3), the coefficient of the growth of investment at the national level is not significant, refuting our H4. This result might be due to the short period considered (2008–2012), which translates into limited growth in investment and limited country differences.

The standardized measure of effect size (computed as the product of the regression coefficient with the standard deviation of the corresponding variable) is 0.57 for size, 0.04 for students' growth and 0.18 for reputation (Model 2). These results show that, as expected, past size has the larger impact on (absolute) growth, while reputation is more important than growth in the number of students.

Table 4
Median values for HEI characteristics by type.

Organization type	Size_2012	Size_2008	Reputation	GrowthStudents	GrowthStaff
Others	79.00	72.00	0.00	1.12	1.09
Universities	763.31	708.00	1.64	1.07	1.09
Universities of applied science	229.50	183.50	0.00	1.19	1.19

A number of robustness tests were performed.

First, we tested whether setting reputation to 0 for HEIs not included in the Scimago Institutions Ranking might bias our results. Separate regressions where run for HEIs in the SIR (including the reputation variable) and for HEIs not in the SIR. In the first regression, the growth of students is no longer significant, while the coefficient of reputation decreased but remained significant, implying that the growth process is driven by past size and international reputation for these HEIs. In the second regression, the coefficient of student's growth remained significant. The coefficient of past size remained very stable in both regressions. This supports the insight that growth processes differ between research universities and other HEIs (see below Section 4.5).

We further tested a more refined approximation of reputation for HEIs not included in the Global SIR, where the expected number of publications is computed from the number of staff (the two are correlated to 0.84 in our sample); when this figure is below 500 (the threshold for inclusion in the Global SIR), we used it, while when it was higher we set the number of publications to 500. For these HEIs, we computed reputation using 1 as a measure of Normalized Impact. The regression results do not differ significantly from those presented in Table 3, except for a small increase in the reputation's coefficient.

Second, we tested for the effect of subject mix on our results, since European HEIs have different subject composition (Lepori, Baschung, & Probst, 2010). This might influence our results in two ways: first, mechanisms of growth might be different depending on disciplinary composition, since HEIs receive different levels of funding for students by field, and the availability of research funding differs. Second, our reputation indicator is to some extent dependent on subject mix, since the coverage of bibliometric databases varies by field and scientific productivity differs by field. We therefore inserted the proportion of students in social sciences and humanities as an additional control. This control is not significant and has no significant impact on the other coefficients, except reducing somewhat the reputation coefficient.

Finally, we tested the robustness of the model using the jackknife methodology and tested for the stability of the model's coefficients when some countries are left out of the sample. This is particularly important since some countries comprise a large share of the observations. The high correlation between the predictions obtained using the resampling method and the initial predictions shows that the model is robust in relation to the set of HEIs. The study of the stability of the variable's coefficients when a given country is left out showed that the coefficients for the variables with significant impact do not change drastically (variation coefficient between 0.7% for Size_2008 and 18.7% for the constant). Therefore, our results are robust in respect to the set of countries and HEIs considered.

4.5. Differences between HEI types

Differences in the mission and activities of HEI types suggest that they have different growth processes. As demonstrated by Table 4, organizational characteristics and growth rates are indeed different.

The HEIs classified as "others" have the lowest size, while for the UASs and "others" the median value of reputation is zero, as expected since these institutions are mainly teaching oriented and have very limited research activities.

UASs display the highest growth both in the number of staff and of students, as expected since they are relatively recent institutions (about 47% of the UASs in our sample were created after 1990), which are developing rapidly and are strongly focused on education. Most group differences are statistically significant, except differences in staff growth between "universities" and "others" (Kruskal Wallis test).

Separate regressions support our hypothesis on differences in the growth process: H3 (Table 5).

For "universities", the coefficient of past size is below 1, implying that small "universities" tend to grow faster than large "universities", while for UASs the coefficient is not different from 1. Both for "universities" and UASs the coefficient of students' growth is positive and significant, but for the latter it is much larger. On the contrary, reputation is significant only for "universities". In this set we have 40% of the universities with a reputation equal to zero.

5. Discussion

In interpreting our findings, several limitations have to be kept in mind. First, we observed growth over a short period of only four years, meaning that our results cannot necessarily be generalized to long-term processes. Yet, growth of staff over the considered period has been substantial (24% in the aggregate) and, more importantly, we observed a large variance among HEIs (see Table 1). Second, the HEI growth process is characterized by endogeneity, in particular for the association between HEI size and reputation; our empirical design does not allow for disentangling such interactions.

Third, our explanatory variables have some limitations. Some issues might affect the measure of total academic staff at the individual level (HEI), but these limitations are not considered significant in an analysis where the distribution of size

Table 5
Regression models for UASs and "universities".

Variables	Universities				UASs			
	Empty model		Model 5		Empty Model		Model 6	
	Coefficients	SE	Coefficients	SE	Coefficients	SE	Coefficients	SE
Size_2008			0.942**	0.008			1.010**	0.010
GrowthStudents			0.054*	0.022			0.524**	0.041
Reputation			0.081**	0.013			−0.020	0.060
Constant	2.876**	0.057	0.183**	0.025	2.406**	0.063	0.009	0.041
Random effects (variance; standard errors)								
country level	0.040	0.050	0.004	0.011	0.150	0.060	0.008	0.025
HEIs level	0.211	0.015	0.003	0.002	0.387	0.018	0.003	0.003
Log likelihood	−314.16		642.79		−120.55		334.91	
AIC	634.31		−1273.58		247.11		−657.83	

* $p < 0.05$.
** $p < 0.001$.

ranges from dozens of FTEs to over 6000 FTEs. Moreover, since all models use the ratio of size between two years for the same HEI, part of the effect is netted out.

The reputation indicator was obtained using the scientific production indexed and cited in the Scopus database. There are several international bibliometric databases (Scopus and Web of science being the more important), with a different coverage of the scientific literature. However, we do not consider this a strong limitation as there is a high overlap between the literature indexed in both databases (Vieira & Gomes, 2009) and Scopus provides the best coverage of the literature in several scientific domains (Gavel & Iselid, 2008; Meho & Rogers, 2008; Norris & Oppenheim, 2007). Indeed, we computed the variable reputation using data from the Leiden Ranking (based on the Web of Science) and from Global SIR (based on Scopus); for a subsample of HEIs included in both rankings, the correlation between the two scores was about 0.9.

A major limitation was lacking data on staff for the year 2012 for two large European countries, i.e. France and the UK. When these data will become available, the sample will be larger and it will be possible to test more refined models in order to analyze the impact of national policies on HEI growth.

The size only model (model 1) shows that HEI growth over the considered period is proportional to past size as predicted by Gibrat's law. Not only does past size predict quite precisely the current one, as it would be expected over a short period of time; there is also no empirical evidence that the growth rate differs by HEI size. The exceptions are small HEIs, which indeed might grow rapidly as shown by Fig. 2 and by the analysis of outlier cases. But data show that as soon as they reach a size of around 1000 FTEs of staff, their growth becomes proportional to their size.

These findings are consistent with the literature on cumulative growth, as well as with the analysis of the current size distribution, which is close to a log-normal one. While of course HEIs might be born with different sizes and resources, for example as associated with their geographical position, cumulative growth processes generate over time a log-normal distribution, particularly in a rapidly expanding system like higher education.

The model, including students' growth and reputation (model 2 in Table 3) provides a more precise prediction, even if the improvement is not very large (from 97.8% to 98.2% of total variance), displaying how much of the growth process is already accounted for by the Gibrat's law. Therefore, differences among HEIs in their ability to acquire students and in their reputation–beyond those already associated with their size–explain part of their growth, as it would be expected given that public funding of HEIs nowadays includes a performance-based component in most European countries.

Two questions are relevant in this context, i.e. the implications for the growth processes of individual HEIs on the one hand, and the implication for the overall size distribution on the other hand.

At the individual level, a coefficient of past size below 1 implies that smaller HEIs grow more rapidly and that, for each combination of the growth of students and of reputation, there will be a size threshold above which HEIs will not grow any more. This is consistent with the observed size distribution, which suggests some level of ceiling (see Fig. 1).

In Fig. 4, the expected growth rate of academic staff for several values of reputation and growth of students is computed (referring to universities).

Fig. 4 displays how small institutions grow faster than large ones for every combination of the growth of students and reputation; HEIs below 1400 FTEs of academic staff continue to grow even with zero reputation and a stable number of students. This threshold obviously depends on the overall growth of the size of the HEI system, as expressed by the constant term. However, already with 500 FTEs the growth rate is below 4%, i.e. well below the median in our sample.

As we increment the level of reputation (plot A) and the growth rate of students (plot B), the decreasing effect of past size is mitigated even for "universities" of a large size. With a reputation of 1.63 (the average in the sample), an HEI with 500 FTEs of academic staff reaches a growth of 10% and with a reputation of 5 a growth of 15%. With a reputation of 5 and a size of 3000 FTEs, the growth rate is still 8%.

However, for "universities", reputation is correlated with actual size (Table 2) and, therefore, most large "universities" also have a high level of reputation and will increase their size, while most HEIs with zero reputation are small or belong to the non-university sector. Therefore, our model demonstrates empirically how differences in reputation translate into

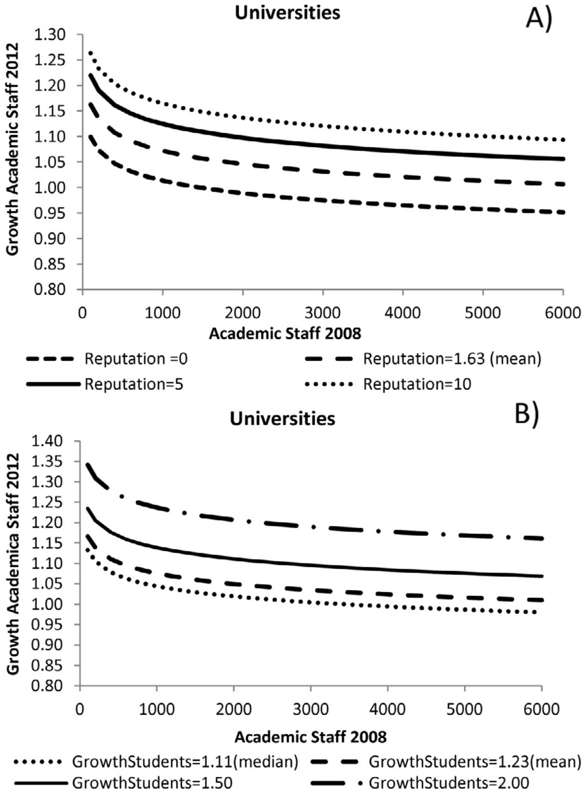

Fig. 4. Evolution of the size of the HEIs from 2008 to 2012 for different values of reputation and if the total number of students does not increase (plot A), respectively for different growth rates of students and reputation equal to zero (plot B).

differences in growth rates, accounting for the observed correlation between reputation and size. Of course, it is likely that cumulative effects also work in the other direction, i.e. that reputation increases with size as well, further strengthening the cumulative effect.

The number of students has a similar effect, but the impact is more limited since a very high growth rate would be required. An increase of more than 11% (median value) is necessary for compensating the decreasing effect of past size for institutions with a total academic staff above 3000 FTEs. Universities of this size have thousands of students, therefore such an increase in the number of students might be difficult to achieve. This displays the difference between growth processes based on reputation and students: for the former, HEIs grow more based on their *current* reputation, leading to cumulative effects, while for the latter, HEIs grow more based on the *increase rate* of the number of students (which is not correlated with the current number).

When taking into account cumulative effects, the size model and the HEI model provide complementary insights. The size model shows how growth is proportional to past size, while the HEI model shows how differences in reputation, and in the acquisition of students, generates variance in the growth process. The latter is essential, since without such a variance, cumulative growth would simply magnify differences in initial size (like in the Yule process).

Therefore, the fact that differences in reputation and in the ability to recruit students among HEIs leads to different growth rates is essential to yield the observed distribution. With enough time, this process is effective in wiping out historical differences in resource endowments and generating the observed association between size and levels of reputation. Moreover, an increasing impact of such factors in the growth rate implies more inequality in the distribution of size, as it increases the variance of the log-normal distribution.

These remarks are relevant to understand the impact of public funding allocation on the distribution of HEI size and resources. A purely historical allocation (constant growth rate) would increase inequality in resources borne from history; however, introducing variation in the growth rate depending on some performance elements is effective in wiping out such differences and concentrating resources in the highest performing HEIs, provided such mechanisms work for a sufficiently long period of time (over which the size of the system increases substantially). In other words, when the HEI system grows rapidly, a mix of historical allocation and performance-based allocation, as practiced in most European countries, is an effective way of redistributing resources, whereas under conditions of austerity, historical differences are maintained and stronger redistribution policies might be required.

Finally, separate regressions highlight differences in the growth model between HEI types (Table 5). For “universities”, the growth in the number of students counts little in terms of resourcing, but reputation is central, whereas the differential growth of UASs is associated with increasing numbers of students. This mechanism would seem effective in promoting a concentration of resources in the more reputed HEIs for the university sector and in those HEIs being able to recruit large numbers of students for the UAS sector. A closer consideration of differences in funding mechanisms between the HEI sector would be in place here, as such differences might be essential to promote differentiation, despite isomorphic tendencies (Kyvik & Lepori, 2010).

6. Conclusions

Our study added to the literature by introducing Gibrat's law into the universe of higher education and by showing that educational and research performance play a role in explaining a HEIs' relative growth rate as measured by total academic staff.

The empirical results showed that Gibrat's law largely explains the growth process over the considered period of time and that the growth rate is not significantly dependent on size, with the exception of small HEIs. At the same time, the educational and research performance, measured respectively by the growth of the number of students and by international reputation, influences HEI growth. This was expected given that funding mechanisms for higher education in most countries involve a mix between historical mechanisms (based on past size) and performance-based allocation (based on number of students and international reputation).

We also identified differences between the growth processes of "universities" and "universities of applied sciences" (UASs). For "universities", growth is driven by past size and by reputation, while the increase in the number of students plays a very limited role; this implies that only highly reputed "universities" are able to maintain their size over time, therefore leading to the observed association between size and reputation. On the contrary, the growth process of UASs is mostly driven by the increase in the number of students, as it would be expected given their educational orientation. Different growth processes, associated with different missions and funding mechanisms, are likely to foster the differentiation of profiles between HEI types.

Our results also help to disentangle how the interaction between funding allocation mechanisms and cumulative processes determine the observed distribution of resources within higher education systems. While purely historical allocation would simply magnify differences inherited from the past, the presence of a competitive component generates differences in growth rates, which are then magnified by cumulative processes and wipe out historical differences over time, even in the presence of a large component of historical allocation, under the condition that the size of the whole system increases rapidly. More competitive funding regimes will lead to a higher concentration of resources.

Two limitations of our study also open important avenues for future research. First, we observed the growth process over a short period of only four years; therefore, it is difficult to generalize findings to the long-term growth of HEIs. Longer panel data would allow a deeper analysis of a number of important issues: first, to disentangle the (reciprocal) association between size and reputation; second, to ascertain whether some HEIs perform systematically better than others over time, once taken into account the size effect; third, to assess the time to equilibrium after changes in the composition of higher education, like the creation of a new sector of higher education or a policy of mergers.

Second, the structure of European higher education systems differs strongly (Kyvik, 2004; Lepori & Kyvik, 2010), but also the level of competition in the allocation of public funds (Jongbloed & Lepori, 2015), with some countries introducing Performance-based Research Funding Systems (PRFSs; Hicks, 2012), like the UK Research Excellence Framework (REF). This is expected to generate differences in the HEI growth process between countries and time periods, which would shed more light on the link between public policies and the HEI growth process.

Author contribution

Conceived and designed the analysis: Elizabeth S. Vieira and Benedetto Lepori.
Collected the data: Elizabeth S. Vieira.
Contributed data or analysis tools: Elizabeth S. Vieira and Benedetto Lepori.
Performed the analysis: Elizabeth S. Vieira.
Wrote the paper: Elizabeth S. Vieira and Benedetto Lepori.

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