Exploring universities' efficiency differentials between countries in a multi-year perspective: an application of bootstrap DEA and Malmquist index to Italy and Poland, 2001-2011

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ABSTRACT

This study employs data envelopment analysis (DEA) to evaluate relative efficiency of a sample of 54 Italian and 30 Polish public universities for the period between 2001 and 2011. The examination is conducted in two steps: first unbiased DEA efficiency scores are estimated and then are regressed on external variables to quantitatively asses the direction and magnitude of the impact of potential determinants. The analysis shows the strong heterogeneity in the efficiency scores within each country, more pronounced than the difference in average efficiency scores between countries. There is evidence that efficiency is determined by revenues' and academic staff's structure: competitive versus non-competitive resources, and the number of professors among academic staff. The study also explores the variation of efficiency and productivity over time, and reveals that while pure efficiency change was similar between the two countries, the efficiency frontier improved more in Italy than in Poland.

Keywords: efficiency, productivity, two-stage DEA, higher education institutions

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1. Introduction

The most recent and promising trend for studying the performance, the productivity and efficiency of universities in Europe is to promoting cross-country comparisons. The necessity of providing a European-level vision for the development of Higher Education (hereafter, HE) has been claimed as one of the key policy challenges for the future (Aghion *et al.*, 2010); and, overall, the setting of transnational objectives into the "Europe 2020 Strategy" required a renewed attention to the European coordination of activities and policies in the HE field (Soriano & Mulatero, 2010). At the same time, the necessity of a wider European space for higher education and research is not a new topic, as the discussion started since the signature of the Bologna Declaration and the implementation of the subsequent Bologna Process (Keeling, 2006); in our days, the international (i.e. European) discourse is simply reinforced by the increasing trends of comparing the performance of HE institutions (hereafter, HEIs) in different countries (on this issue: Dill & Soo, 2005).

A parallel evolution is that, with the advent of more reliable administrative datasets – originally collected for descriptive purposes – academic researchers and analysts can use microdata at the level of single universities to compare their performances and results. To the extent that these datasets are comparable across European countries, this allows undertaking a cross-national assessment of HEIs' relative performances. The present state-of-the-art is well far from this results, however, and using international databases is still a difficult task that require strong theoretical assumptions, methodological rigor and access to the information on the individual institutions' level[1].

[1] Two projects (named AQUAMETH and EUMIDA) were funded by the European Commission, with the aim of collecting data about universities' teaching and research on a routinely and periodically basis (see Bonaccorsi & Daraio, 2007; Bonaccorsi, 2014). Both projects suffered, however, some major limitations: the comparability of microdata was not fully guaranteed, the group of countries was inconsistent over time, the panel of data did not cover all years since the start of the projects, etc.; overall, updating the international dataset resulted as very expensive and time-consuming. Some interesting academic work has been developed with the data from these projects to describe the European HE landscape (Bonaccorsi & Daraio, 2009, Daraio *et al.* 2011); but, because the projects were not transferred to institutional agencies, and remained instead in the hands of the research group, it is not possible to rely on these data for further developing a comparison of HEIs' performance across countries in the next future.

Consequently the empirical studies on HEI's efficiency and productivity that take into account several countries are scarce[2]. In particular, Bonaccorsi *et al.* (2007) compared HEIs from Italy, Spain, Portugal, Norway, Switzerland and the UK. Wolszczak-Derlacz & Parteka (2011) analysed universities from seven European countries in the period 2001 and 2005. They conducted a two-stage DEA analysis first evaluating DEA scores and then regressing them on potential covariates. They found that unit size (economies of scale), number and composition of faculties, sources of funding and gender staff composition are among the crucial determinants of these units' efficiency.

An alternative approach for conducting cross-country studies of universities' efficiency in Europe has been proposed by Agasisti & Johnes (2009), who compared the relative performance of Italian and English HE institutions. The focus on two countries, conducting a *vis-à-vis* comparison of their universities' results, has the limit of providing a narrower picture of the European HE performance; nevertheless, it has two key advantages that make the approach interesting – namely a better ability of selecting highly comparable microdata about teaching and research, and the possibility of using qualitative information about the policy settings (analogies and differences) that can enormously help in interpreting the results.

The present paper follows the latter stream of the literature, and proposes a comparison of efficiency performance of Italian and Polish universities, through the use of the most recent bootstrap Data Envelopment Analysis techniques (Simar & Wilson, 2007) and Malmquist indexes enriched by the second step analysis in which the potential determinants of efficiency scores are evaluated. To the best of our knowledge this is the first paper that explores (evaluate and explain) the dynamics of efficiency and productivity for two important EU countries using a long panel of data (10-year perspective).

Italian and Polish HE systems have some common characteristics that make this comparison meaningful and interesting. First of all higher education sectors are large in both

[2] More common are country specific studies (for some early reviews, see Worthington 2001 and Johnes 2004) but since our paper concentrates on international and intertemporal analysis we do not refer to them directly.

countries with 2 million students in Italy and around 1.7 million in Poland. In both countries there is absence of a binary system of higher education: all HEIs are universities which are public or private in nature, however the former ones are quantitatively more important as far as research and teaching activity are considered (e.g. in both countries the vast majority of students attend the public universities – around 90% in Italy and 76% in Poland).

Conversely, Italian and Polish HE systems differ on a number of aspects that can enrich the ability of investigating the effects of specific regulations or structural characteristics on universities' performances – foremost Polish universities are much more underfunded in comparison to Italian counterparts and their budget rely mainly on the government teaching-related resources (a synopsis of the interesting institutional features that characterise the two HE systems is in the Section 2). Certainly, a source of potentially interesting results derive by the comparison of two important countries from Western and Eastern Europe, as one of the main topics in the present debate is how better integrating HE systems from the two very different parts of Europe.

This paper innovates the existent literature in three main directions. First, while there is a growing attention to the reforms in the Polish HE system (Kwiek, 2012), there are not studies published in international academic journals that describe the performance of Polish HEIs – and this paper fills this gap, also presenting a comparison with one big, important European country like Italy. It is also interesting to check whether Polish HE together with its research productivity is converging towards Western Europe standards. Second, we correlate the efficiency scores of each university (both in a within-country and between-countries analysis) to a set of descriptive characteristics (for instance, their size, the presence of a medical school, the share of public funds etc.) that can help to describe why some institutions are more efficient than others – and how these differences are common across the two countries. Third, the paper considers a quite long panel of data (from 2001 to 2011); while some studies about single countries are starting covering such long periods (i.e. Johnes, 2008 for England, and Garcìa-Aracil, 2013 for Spain), it is the first time that the evolution of HEIs' efficiency over a significant medium run is analysed in a cross-country perspective.

The paper is organised as follows. In the next Section 2, a brief sketch of the main features of the Italian and Polish HE systems is presented. Section 3 contains a description of the methodology and data. Section 4 presents the results. Section 5 hosts the proposition of the main policy implications, and some concluding remarks.

2. Background of Italian and Polish HE

Both Italian and Polish HE systems are characterized by the presence of public and private universities, albeit the vast majority of students (around 90% in Italy and 76% in Poland) attend the former ones. Consequently, the present paper includes, into the empirical analysis, only the data about public universities.

The Italian and Polish universities analysed in this study rely mainly on government funding (60–80% of their budget comes from government). However, the level of finance and pattern of funding (the structure of incomes) are different for both countries.

In Italy, during all the nineties and the first decade of 2000s, the national public funds devoted to universities (*Fondo di Finanziamento Ordinario,* FFO) grew substantially, from around 3.5 to approximately 7.5 billions €; however, public resources started declining in 2010, and the prospective trends are of a further reduction in the next years. Given the contextual decline in the number of students, the expenditure per student only declined between 2008 and 2011, and nowadays seem to grow again, albeit slowly (however, these are nominal figures, while the inflated ones show a decline all over the period). The most part of universities' budgets – especially FFO – is employed for staff salaries, while the remaining is used for developing research activities and teaching initiative in addition to institutional courses.

[Figure 1] around here

An important feature of the Italian HE that is worth to be mentioned is that universities can charge fees. Usually, the level of these fees is quite low (around 1,200€ per year) and covers only a small fraction of the real cost per student; nevertheless, this source of income gained importance in the last years (to contrast the reduction of public funds FFO) and now represents, on average, 15% of the total university budget. This average, however, masks substantial variation, with some universities for which student fees constitute 25% of their income (this means that these institutions charge much higher unit fees); it is likely that the (economic) behaviour of the various universities – especially their responsiveness towards students – is different depending on how much they rely upon students' financial contribution.

Contrary to Italian HE, the Polish public universities are free of charge for full time students (there are some administration fees e.g. for registration, repetition of year etc.). However, the fee is paid by part-time students who are enrolled in public sector (their courses are run during the weekends). The share of revenues from student fees in total revenues of public universities was around 12% in 2012 (15.5% of all teaching revenues, GUS 2013). This proportion is significant especially if we take into account that on the legal bases the higher education is free of charge in public sector. Nevertheless, the share of teaching-related funding (both from budget as well students' fee) having reached its peak in the middle of 2000s is decreasing due to the drop in the number of students in recent years.

Until 2001, Italian students could obtain only one kind of degree (called *Laurea*) at the end of university courses that lasted four or five years depending on the discipline. The Italian HE system was criticized because its inefficiency: despite enrolment rates that were lower than in other important EU countries, a huge proportion of students who started studying at a university actually dropped out – the resulting graduation rates being very low (Triventi & Trivellato, 2008). Last but not least, many students stayed at university much longer than the required time for obtaining the degree (for instance, 7 or 8 years instead of 4 or 5). After 2001, a major reform was implemented to follow the prescriptions of the so called Bologna Process, which required to EU countries to adapt their systems of HE degrees to a Bachelor/Master (BA/MA) structure. Italy implemented this reform quickly and substantially, by obliging all universities to start all the new courses under the BA/MA structure since 2001. The new bachelor resulted very attractive, because it lasts only three years, and many prospective students saw the opportunity to obtain a HE degree in a lower time than previous cohorts; as a consequence, the number of first-year students increased. Contextually, the number of graduates increased steeply in the first years after the reform, because students were allowed to switch from *Laurea* to a new Bachelor course, and many of them (also those who were in the university since a long time) already had a sufficient number of formative credits to obtain a degree. Lastly, the number of graduates also increased after the reform because a higher proportion of students now obtain the degree on time, and in five years they can obtain two degrees (Bachelor and Master) instead of the unique degree (*Laurea*) that existed before the reform (figure 2). Overall, the reform represented a major change that affected radically the numbers of the national HE system (at least in the years immediately after it), and it contributed to increase in the short-medium run both the enrolment and graduation rates (the latter more than the former)[3]; such specific trend must be kept in mind when assessing the efficiency of Italian universities over time, because we define the efficiency concept partly by comparing the number of students and of graduates.

[Figure 2] around here

In the case of Polish HE an enormous growth of the number of graduates and total number of students has been observed since the beginning of nineties till 2005/2006. This process is rooted in the transformation period from centrally-planned to market economy which resulted in expansion of private institutions and growth of part-time students in the public universities. As a consequence of increasing enrolments, universities have become mainly focused on teaching activity (more about transformation period see Kwiek, 2012). Additionally,

[3] These expansion of HE did not benefit all types of students in the same way, as those coming from more disadvantaged socioeconomic background are still underrepresented among first-year university students and, especially, among graduates (Bratti *et al.,* 2008; Triventi & Trivellato 2009) – but this paper does not address this equality problem directly.

due to the non competitive wages in the public institutions, most of the academic staff holds parallel employment in the private universities (according to Kaszubowski & Wolszczak-Derlacz, 2014, about 60% of academic staff have additional income obtained outside home university). All of this erodes the research activity of the Polish HEIs. Due to the demographic changes (drop in the population aged 19-24), since 2006 the number of total students has started to decrease (so far the drop was mainly materialised through the decrease in the number of the part-time students). This (as well as the need to raise research productivity) has initiated the reforms of the Polish HE. The first works started in 2005 and the completely new law has been introduced in 2010-2011. The new law intends to bring back research orientation to the so far teaching focused universities – e.g. through introduction of highly competitive funding mechanisms.

3. Methodology and data

In order to evaluate the efficiency of the higher education institutions (HEIs) we employ Data Envelopment Analysis (DEA) in which efficiency is measured in relation to a nonparametric frontier of efficient units, estimated conditional on observed data. The authors of DEA in currently used form (Charnes *et al.*,1978) refer to the earlier works of Farrell (1957) who defines the efficiency as the success in producing as many as possible outputs from a given set of inputs. Analysed entities are referred to as decision-making units (DMU) as they "decide" either about the inputs or outputs used in the production process. The authors of the DMU's term – Charnes *et al.* 1978), explain that in this way they intended to emphasize that this is an appropriate method to test the efficiency not only of profit bringing companies, but also of many different type of organisations/institutions, e.g.: public enterprises, hospitals, schools, non-profit organizations, programs or even individual people.

We present here only the basic concept of DEA as the detail exposition can be found e.g. in: Cooper *et al.* (2004) or Coelli *et al.* (2005). Below we refer to an output-oriented model with variable return to scale, the model utilised in the empirical part of our analysis.

The activity of given DMU can be described by the production set Ψ of physically possible points (*x*, *y*):

$$\Psi = \{(x, y) \in R_{+}^{N+M} \, | \, \text{x can produce y}\} \tag{1}$$

where: *x* represents a vector of *N* inputs and *y* the vector of *M* outputs.

The efficient DMU operates at the boundary of optimal production (frontier) which in case of output-oriented model $\partial Y(x)$ is defined as:

$$\partial Y(x) = \{y | y \in Y(x), \lambda y \notin Y(x), \forall \lambda > 1\} \tag{2}$$

and the measure of efficiency is found by maximizing achievable output given the level of the inputs:

$$\lambda(x, y) = \sup\{\lambda | (x, \lambda y) \in \Psi\} \tag{3}$$

For the varying returns to scale, the efficiency scores $\hat{\lambda}_{VRS}(x, y)$ can be computed by solving the linear program

$$\hat{\lambda}_{VRS}(x, y) = \sup\{\lambda \Big| \lambda y \leq \sum_{i=1}^{n} \gamma_i y_i ; x \geq \sum_{i=1}^{n} \gamma_i x_i \text{for}(\gamma_1, \ldots \gamma_n) \tag{4}$$

$$\text{such that: } \sum_{i=1}^{n} \gamma_i = 1 \text{and } \gamma_i \geq 0, i = 1, \ldots, n\} \, .$$

In regards to output orientation, a value of DEA efficiency scores ($\hat{\lambda}$) are larger than or equal to one, if $\hat{\lambda} = 1$ than DMU is efficient (characterized by efficiency of 100%, or 1), the inefficiency is indicated by the values greater than 100% or 1.

To obtain statistical properties of the estimated efficiency scores (to estimate the bias and variance, and to construct confidence intervals together with unbiased scores) we follow the bootstrap procedure of Simar & Wilson (2000) which involves generation of pseudo-data and approximation the unknown distribution of efficiency scores by the distribution of bootstrap values[4].

In the empirical part of the paper we also provide evidence about the potential determinants (Z_i) of previously estimated bias-corrected efficiency scores ($\hat{\hat{\lambda}}_i$) where the regression is represented as:

$$\hat{\hat{\lambda}}_i = \alpha + Z_i\beta + \varepsilon_i \tag{5}$$

where ε_i is a statistical noise with left truncation at: $(1 - Z_i\beta)$ since DEA efficiency scores are larger than or equal to one in the output-orientation model. The estimation of regression (5) may cause some statistical problems (e.g. DEA efficiency scores are not observed but estimated and by construction serially correlated, inputs and outputs can be correlation with Z_i) as a result traditional estimation methods (e.g. Tobit model) can be inadequate. The bootstrap truncated regression procedure of Simar & Wilson (2007) is employed here to properly address these limitations[5].

The efficiency changes over time are evaluated on the bases of Malmquist index which measures the change in the total factor productivity of DMU in two periods of time. The concept of Malmquits index derived by Färe *et al.* (1992, 1994) results from efficiency and productivity measurement (Farrell, 1957; Caves *et al.,* 1982) and is rooted in DEA methodology. The productivity changes can be due to the catch-up effect (technical efficiency change (ε_i), DMU approaches efficiency frontier) or/and as the result of frontier shift (change in technology (τ_i)) and Malmquist index can be decomposed as:

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[4] The exact steps to obtain unbiased efficiency scores together with confidence intervals can be found in Simar and Wilson (2000) p. 788-791. In our analysis, all computations have been performed in FEAR: A Software Package for Frontier Efficiency Analysis with R (Wilson, 2008).

[5] The bootstrap truncated regression procedure involves the use of maximum likelihood to estimates of unbiased DEA efficiency scores in order to obtain β coefficients from eq. 5. The original coefficients are confronted with bootstrap parameters (estimated empirically by resampling the original data series) to compute bias-corrected estimates of β as well as percentile bootstrap confidence intervals at a given level of significance. We employ algorithm 2 from Simar & Wilson (2007), pp. 42-43.

$$M_{i,(t_1,t_2)} = \underbrace{\frac{D_i^{t_2}(x_{t_2}, y_{t_2})}{D_i^{t_1}(x_{t_1}, y_{t_1})}}_{(\varepsilon_i)} * \underbrace{\left[\frac{D_i^{t_1}(x_{t_2}, y_{t_2})}{D_i^{t_2}(x_{t_2}, y_{t_2})} * \frac{D_i^{t_1}(x_{t_1}, y_{t_1})}{D_i^{t_2}(x_{t_1}, y_{t_1})}\right]^{1/2}}_{(\tau_i)} \qquad (6)$$

where D_i denotes the efficiency distance function, *x* and *y* are inputs and outputs in periods t_1 and t_2. For example $D_i^{t_1}(x_{t_1}, y_{t_1})$ represents the distance of the *i*th DMU from the period t_1 with the reference to the technology of the same period: t_1, while for $D_i^{t_2}(x_{t_2}, y_{t_2})$ - period t_2 is the reference technology and so on. The calculation of (6) involves the computation of different component distance functions expressed by linear programming problems similar to those defined in eq. (3) and (4) – see Coelli *et al.* (2005) pp. 291-294 for details. Again bootstrap procedure is involved (Simar & Wilson, 1999) to check the statistical properties of the indices and to verify the statistical significance of changes in efficiency and technology. The values of $M_{i,(t_1,t_2)}$ >1 indicate positive TFP growth between periods t_1 and t_2, while values $M_{i,(t_1,t_2)}$ <1 drop in the productivity and if the index is equal the unity than no change in the productivity is detected from time t_1 and t_2.

There are clear advantages of nonparametric DEA approach in relation to traditional methods (e.g. econometric production functions estimated through Stochastic Frontier methods). Key strengths include the property that none or few restrictions are imposed on the production technology and lack of the assumption considering a particular functional form between inputs and outputs. The method is particular useful in case of multiply inputs and outputs were the process of production is influenced by external factors – as in case of higher education. Moreover, due to the bootstrap procedure employed in our study we are able to overcome the main limits of the DEA procedure which, as being deterministic, lacks statistical power.

One critical aspect of DEA methodology is the choice of inputs and outputs. In our analysis we follow the previous studies (see the discussion in Johnes, 2004), however, we are also bounded by data availability. Therefore, the set of indicators that we chosen at the end is completely in line with the best practices in this literature, as inputs it includes: expendiure and number of academic staff while as outputs: the numbers of students and graduates (divided by levels, under/postgraaduates and PhD) and publications[6].

In Italy, we used the administrative data collected by the National Agency for the Evaluation of Universities (ANVUR; www.anvur.org). In particular, the Agency collects every year data from all the universities about the number of students (bachelor, master and PhD), staff, graduates; the most part of this information is also available by subject (even though in this paper we did not used them by subject mix). Also, the Agency hosts the data provided by the universities' statistical offices about the Financial Reports: from this source, we gain information about the overall level of expenditures, students fees, etc.

In Poland there is no common database which provides information about individual HEIs. The non-financial data (academic staff, nonacademic staff, professors, total number of students, graduates, PhD degree awarded) comes from publication of Polish Ministry of Science and Higher Education (*Szkoły wyższe – dane podstawowe*, issues 2002 through 2012). The financial data comes from the individual's institution financial reports which by obligation are published in the Journal of Laws, Monitor Polski B. The number of different departments, year of foundation of given institution and the information whether unit possesses medical departments are taken from the web pages of each HEIs.

For both countries, we collected the data about the publications (articles, proceedings papers, editorial materials, book chapters, book reviews etc.) of the affiliated staff of each of individual university indexed in Web of Science (WoS) database, being a part of the ISI Web of Knowledge.

[Table 1] around here

[6] In recent years, there is also a growing attention to the third mission of universities. However, there is still a lack of agreement about the adequate indicators to measure it and, to the best of our knowledge, the only study that tries to incorporate this type of indicators into efficiency analyses is that of Johnes *et al*, 2008).

In the table 1, we report some descriptive statistics about the inputs and outputs chosen for the analyses, as well as some simple indicators of productivity calculated through them. Overall, Italian universities have much more resources than their Polish counterparts (the real expenditure per student is around 6.4k and 2.7k, respectively), and this is reflected in different available resources for academic staff (the expenditure per unit of academic staff is 191.4k and 43.7k, respectively). The average Italian university is bigger than the Polish one, when looking at the student side (30,000 vs 21,000 students), even though smaller when considering the number of academic staff (1,000 vs 1,400). When considering the teaching outputs, it turns out that on average Italian universities have 4.4k graduates per year, while Polish ones' figures are around 4.1k; remembering that the number of students is one-third lower for the latter, this number suggests a higher ability of Polish universities in teaching efficiency (this intuition is explored later through the appropriate empirical modelling). The numbers about research are instead different, as they show that the average Italian university has almost three times the number of publications than Polish ones (around 1,000 and 350, respectively), and the difference on a per academic staff basis is even wider (0.9 vs 0.2).

4. Empirical analysis

4.1 First step – evaluation of efficiency

We estimate different versions of DEA models depending on the input - output set and assumption considering frontier. In all models the same set of inputs was used, i.e. the number of academic staff and total expenditure, but outputs mix varies according to the adopted model (number of publications, graduates, students and PhD awarded). Additionally, we distinguish between common and country specific frontier – see table 2.

[Table 2] around here

The main results of the DEA empirical analyses are reported in the table 3. The rows report the country-average DEA efficiency scores for each year, the columns are the different models described above, and for both countries we reported the baseline scores as well as the bias-corrected ones (through the bootstrap method outlined in the previous section); the remaining part of comments considers the bias-corrected scores, however. All the estimates show that, on average, inefficiency decreased over time for both countries and no matter the specific model considered. Also, the correlations between the estimates obtained through the different models (table 4) are all statistically significant and quite high in magnitude (ranging from around 0.5 to >0.95), suggesting that the results are quite robust across different specifications of the efficiency analyses. The overall picture is not substantially different in the cases where a common efficiency frontier is assumed or a country-specific one, suggesting that this assumption is not a major determinant of our results.

Polish universities turn out to be more efficient in the models 1 and 2, where the number of PhD awarded is not included among outputs. The positive efficiency differential is driven by two factors. The first factor is that Italian universities are on average richer than Polish counterparts, but their production of outputs (especially teaching outputs) is not proportionally higher; even the higher number of academic staff per Polish average institution does not compensate the higher expenditure of the Italian average institution. The second factor is that Polish universities have, on average, a ratio of transforming students into graduates (i.e. less dropouts, more in-time students, etc.) that is much higher than that in the Italian case. When including doctoral education into the analysis, the results suggest that Italian universities are on average more efficient, and this is probably due to the higher number of PhD degrees awarded while the number of graduate students per institution is quite similar in the two HE systems.

[Tables 3 and 4] around here

The most important result to highlight, however, is the strong heterogeneity in the efficiency scores within each country. In both Italy and Poland, standard deviation of efficiency scores is substantial, ranging between 0.19 and 0.29, and it is higher than the difference in average efficiency scores between countries. This also means that there is not an "average" university in each country in the efficiency perspective, but that there is a wide distribution of efficiency scores within countries that makes differences within-country it more relevant than those between countries. Looking at the figure 3, where the distribution of efficiency scores is reported for both Italian and Polish universities (we report both baseline and bias-corrected scores), it can be understood how the two groups of universities can be compared *vis-à-vis* in terms of relative efficiency, and also that there are not striking differences between the two that make the distribution of efficiency structurally different. Another feature that stresses the importance of taking heterogeneity into account is that, despite an higher level of average efficiency, Polish universities' efficiency scores also have wider tails, suggesting a higher level of heterogeneity within Poland HE than Italian system (this is cross-confirmed by the efficiency scores of Polish universities with lower scores, >3 in some cases).

[Figure 3] around here

In the table 5, we analyse the change in total factor productivity between 2001 and 2011 (the computation is based on an unbiased Malmquist index that considers annual changes), and specifically its decomposition into pure efficiency change and frontier shift. The specific results reported refer to the use of Model 1, but a correlation matrix between the indexes obtained with different models is in the Annex A, and shows that they are qualitatively and quantitatively (Pearson's scores) similar (table A.1). The table 5 does not only report the average Malmquist index (MI) calculated for all universities, as usually done in the literature, but we follow Parteka & Wolszczak-Derlacz (2013) in reporting also the one calculated as the average only for those universities where it is statistically significant (the same holds for the indexes of efficiency change and technology change). In both countries, this choice translates into a slightly higher magnitude of all coefficients; thus, we comment on these adjusted coefficients, which are net of those values that are not statistically significant in describing productivity changes.

On average, Italian universities improved their productivity more than Polish ones (the respective MIs are 1.075 and 1.032). Looking at the components of the synthetic index for the

Italian case, however, an interesting story emerges, as the productivity improvement is all driven by the technology change (1.074) and not by pure efficiency gains (1.038), while the opposite is verified for the Polish universities, where the indexes for technology change and efficiency improvements are 1.030 and 1.050, respectively. The evidence about the shift of efficiency frontier that increased the Italian universities' productivity is also confirmed by Agasisti & Lezzi (2013), and is coherent with previous studies that demonstrated how the adoption of a Bachelor/Master (BA/MA) teaching structure (in following the Process of Bologna) resulted in an immediate improvement of universities' teaching efficiency (Agasisti & Dal Bianco, 2009). A further corroboration of this interpretation stems from the figure 2, where the annual increase in TFP is graphically represented, by country. The wider gap in productivity's improvements is concentrated in the years immediately after the introduction of the Bologna Reform in Italy; since 2005 on, instead, the productivity growth is reducing over time, and now it is somehow specular in the two countries. Also, the relatively low rate of improvement of productivity in both Italy and Poland is in line with that reported by Johnes (2008) for England and by Garcìa-Araril (2013) for Spain, the only two studies that analyse quite a long panel of data of around ten years, as done in the present paper.

[Table 5 and Figure 3] around here

4.2 Second step - determinants of the efficiency

Our task is not only to measure efficiency scores of HEIs but also to check what their possible determinants are. We then conducted a second step analysis in which we treat the efficiency scores (previously estimated) as dependent variable in regression equation. Since the scores are not observable, but have been previously estimated and are censored at 1, to ensure the statistics accuracy of the analysis we employ bootstrap truncated regression method based on the procedure of Simar & Wilson (2007), previously used in Wolszczak-Derlacz & Parteka (2011). The procedure makes possible to obtain unbiased regression's coefficients and valid confidence intervals. Since the values of efficiency scores are larger than or equal to one positive/negative regression's coefficients would mean that due to the rise of the independent variable inefficiency increases/decreases.

In order to provide quantitative evidence on the direction and strength of links between HEI's efficiency and set of possible determinants we fit the following equation which correspond to the eq. (5) from the previous section:

$$DEA_{i,t} = \alpha + \beta X_{i,t} + \varepsilon_{i,t} \tag{7}$$

where: i refers to single HEI, t denotes the time period, $X_{i,t}$ is a matrix of potential determinants of efficiency scores ($DEA_{i,t}$) and $\varepsilon_{i,t}$ is an error term. The basic specification (7) when enriched by other covariates has the following form:

$$DEA_{i,t} = \alpha + \beta_1 Rev\_NonComp_{i,t} + \beta_2 Prof_{i,t} + \beta_3 GDP_{n,t} + B_4 nofac_i + \beta_5 med_i + \\ + \beta_6 yearfound_i + v_t + \varepsilon_{i,t} \tag{8}$$

where the covariates are defined, synthetically:

- $Rev\_NonComp_{i,t}$, - the share of revenues from non-competitive sources, expressed in %;
- $Prof_{i,t}$ - the share of professors in academic staff, expressed in %;
- $GDP_{n,t}$– GDP per capita in euro PPS of the NUTS2 region n, in which the university i is located;
- $nofac_i$ – the number of different departments;
- med_i –dummy variable whether unit possesses medical or pharmaceutical faculty;
- $yearfound_i$ – year of foundation;
- v_t – time dummies.

The choice of independent variables was driven mainly by our general interest in factors that might determine efficiency of HEIs determined by previous studies (e.g. Wolszczak-Derlacz & Parteka, 2011) and data availability. We are especially interested to check whether the source and nature of funding is important for the units' efficiency. We divide the total revenues obtained by units into competitive and non-competitive and we define the first ones as those received through the process of open competitions (e.g. research grants from research agencies). In case of Polish HEIs the non-competitive resources is the shares of governmental funds obtain as a lump sum while for Italian HEIs they are calculated as the difference between total resources and funds from grants and tuition fee. Next we measure the rank structure of the academic staff by the ratio of professors ($Prof_{i,t}$) which allow us to check whether a higher share of professors in the academic body is associated wit higher efficiency of a given unit, thus whether professors are more "efficient" than junior staff especially that in both countries one have to obtain "habilitation" degree to become a full professor. Further, we account for the location of a unit measured by the GDP per capita in euro PPS of the NUTS2 region, in which the university *i* is located (data from Eurostat). Next included variable is the number of different departments ($depart_i$) that can be a proxy for the degree of a unit's interdisciplinarity or/and unit's size. Additionally the variable med_i is a dummy which equals 1 if institution has medicine or pharmacy faculty. Finally, the possible impact of tradition/reputation of a given HEIs on its efficiency is capture by the year of foundation ($yearfound_i$).

The results of the estimation are presented in Table 6 [Panel A]. First, as the dependent variable we employ unbiased DEA scores obtained from the model with assumption of common frontier. We obtain a positive and statistically significant coefficient on the share of non-competitive funds ($Rev\_NonComp_{i,t}$), which indicates lower efficiency (higher inefficiency) for universities with bigger proportion of revenues obtained from non-competitive resources. Then, the next statistically significant variable is the share of professors in academic staff ($Prof_{i,t}$) and its negative sign means that units with higher share of professors are more efficient. The final statistically significant variable is the number of different departments ($depart_i$) which shows that HEIs with a higher number of different faculties have lower DEA scores (which means they are more efficient) indicating the presence of the economy of scope and/or economies of scale. None of the remainder variables: $GDP_{n,t}$; med_i; $yearfound_i$ have statistically significant impact on the efficiency of units. We repeated the same exercise for the DEA scores obtained under the assumption of country specific frontier (right panel of Table 6). Most of the results are very similar as far as the sign and magnitude of coefficients are considered. Additionally, now the $GDP_{n,t}$ becomes statistically significant indicating that the level of development of a given region where the university is located determines its efficiency.

It is also essential to discuss the magnitude of the estimated coefficients to have an idea about their economic significance. The coefficient estimate for $Rev\_NonComp_i$, is 0.028 which indicates that 10% rise in the share of non-competitive resources is associated with an increase in the efficiency score (rise in inefficiency) of 0.28. The interpretation for the share of professors is very similar, but opposite to the sign: 10% increase in the share of professors among academic staff lowers the scores by 0.22 points. In light of the fact that the mean DEA score was about 1.3, an increase in DEA scores of the above mention points is economically noteworthy.

When considering the revenues from competitive sources and fees separately (Table 6, panel B), it seems that universities with higher proportion of fees are more efficient, and this could depend by the fact that they are more responsive towards students' needs and use the money in a more efficient way (for instance, on teaching services that are able to help "producing" more graduates). Therefore, the magnitude of the negative effect of other non-competitive grants is substantially reduced.

We checked the robustness of our finding by employing the efficiency scores obtained by different versions of DEA models (Model 2 and Model 3). The results are presented in Annex (Table A2 and A3). The only noteworthy differences, considers the sign and magnitude of the variable $GDP_{n,t}$ (compare the results from Table 6 and Table A2) and variable $nofac_i$ which when efficiency scores from DEA model 3 are treated as dependent variable loses its statistical significance (compare results from Table 6 and Table A3). In case of GDP per capita we used NUTS 2 categories which might vague some important regional differences that could appear at more disaggregated level e.g. NUTS 3 and might not be seen from the regional perspective.

The number of different departments, as stated before, should be treated as very crude proxy of unit's size as it can also measure economy of scope additionally the variable is time constant so it neglects the changes in university's development. Consequently, in both cases we do not draw strong conclusion about the relationship between these variables and HEIs' efficiency. However, the variable measuring revenues' structure (source of the funds) about which we are mostly interested in, withstands DEA models alterations.

5. Concluding remarks and policy implications

This study employs data envelopment analysis (DEA) to evaluate relative efficiency of a sample of 54 Italian and 30 Polish public universities for the period between 2001 and 2011. The examination is conducted in two step analysis: first unbiased DEA efficiency scores are estimated and then are regressed on external variables to quantitatively asses the direction and magnitude of the impact of potential determinants. The different versions of DEA models are estimated depending on the output set (number of publications, graduates, students and PhD awarded) and assumption considering frontier (common versus country specific frontier). This part of the analysis shows the strong heterogeneity in the efficiency scores within each country, more pronounced than the difference in average efficiency scores between countries. Additionally, it is difficult to point out which country performs better from the efficiency perspective with a definitive judgment: e.g. Polish universities are more efficient in the models where the number of PhD awarded is not included among outputs, while the opposite is true when doctoral education is taken into consideration. However the results are not substantially different in the cases where a common efficiency frontier is assumed or a country-specific one.

Next, the changes in total factor productivity are assessed on the bases of unbiased - Malmquist index and are decomposed into pure efficiency change and frontier shift. On average, inefficiency decreased over time for both countries and no matter the specific model considered. However, in case of Italian institutions the productivity improvement is all driven by the technology change while the opposite is verified for the Polish universities, where the indexes for technology change and efficiency improvements are 1.030 and 1.050, respectively.

Finally, the second step analysis is conducted in which we treat the efficiency scores (previously estimated) as dependent variable in regression equation. Since the scores are not observable, but have been previously estimated and are censored at 1, to ensure the statistics accuracy of the analysis we employ bootstrap truncated regression method based on the procedure of Simar and Wilson (2007). The results of this part indicate: (a) higher efficiency of universities with bigger proportion of revenues obtained from competitive resources (competitive resources defined as those received through the process of open competitions e.g. research grants from research agencies); (b) the proportion of funding from students' fee is associated positively with units' efficiency; (c) there is evidence that higher number of professors among academic staff improve the efficiency; (d) neither a dummy variable for medical faculty nor the year of foundation of given institution have robust statistically significant impact on the efficiency of units.

Due to the appropriate methodology and rich microdata panel we are able to provide new insights into activities of HEIs from two countries where the sector of HE is sizable and to draw some robust conclusions. More specifically this study has a number of policy implications, some of which refers to both countries, and some stem from the comparison and apply to a specific case.

When considering a common efficiency frontier, it emerges that there are high-performing units in both countries, and these institutions are comparable in terms of absolute and relative performance. Thus, it seems that structural, country-level factors are less important in affecting performance than the individual universities' actions and activities. This result is important it opens the doors to potential European level recommendations and policy suggestions that can be applied to universities in different countries – for instance, about the opportunity of increasing competitive funding of HE institutions.

At this stage, the positive productivity shock due to the introduction of a BA/MA structure (Bologna Process) seems to have operated in Italy, much less in Poland (see frontier shift in table 5), despite the overall number of graduates increased in both countries (in Poland it has been accompanyed by a significant increase of the number of students). One potential explanation is the timing of implementation, earlier in Italy. Future analyses can show if the effects will be that strong also in Poland in the next years or if this country's HE system "absorved" the reform without obtaining substantial structural productivity gains.

Polish universities should rethink the structure and results of PhD education; our results show that, when including the variables about PhDs into efficiency analyses, the relative efficiency of Polish institutions substantially decline. In other words, while they produce a higher value for money for undergraduate and graduate education when compared to Italy, they still suffer efficiency problems in PhD segment of the formative offer, and the policy effort should be devoted to increase graduation rates at this level. The objective is challenging: the number of PhD degrees (average per institution) is today 50% of that provided by Italian universities.

Italian universities should revise the way in which they employ own resources. Albeit they have less academic staff than their Polish counterparts, they spend more per unit salary and for other activities without obtaining better results in terms of graduation rates and publications. In this perspective, the efficiency challenge consists in understanding which are the managerial practices that help Polish universities in "producing" relatively more graduates with less; comparing some good practices in the two countries, in a benchmarking spirit, can be a fruitful exercise for future research.

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Table 1. Descriptive statistics

	ITALY (N=54)			
	Mean	Min	Max	Std. Dev
Expenditure in 1,000 EUR*	195,000	22,000	1,730,000	175,000
Academic staff	1,027	113	4,950	877
Students	30,076	5,183	139,937	24,841
Graduates	4,428	261	21,517	3,777
Doctoral students	611	0	5,040	563
PhD degree awarded	191	0	2,095	233
Publications**	991	2	5,549	1,028
Expenditure per academic staff in 1,000 EUR	191.47	102.07	1337.47	63.18
Expenditure per student in 1,000 EUR	6.43	1.75	45.92	2.61
Publications per academic staff	0.89	0.02	2.15	0.42
Graduates per academic staff	4.56	1.34	11.13	1.52
	POLAND (N=30)			
	Mean	Min	Max	Std. Dev
Expenditure in 1,000 EUR*	64,500	7,144	243,000	43,900
Academic staff	1,413	287	3,642	744
Students	21,262	4,495	46,282	9,974
Graduates	4,122	732	10,887	2,163
Doctoral students	674	0	3,021	629
PhD degree awarded	94	0	510	81
Publications**	367	1	1,810	345
Expenditure per academic staff in 1,000 EUR	43.73	6.92	72.41	10.58
Expenditure per student in 1,000 EUR	2.73	0.44	5.36	0.93
Publications per academic staff	0.22	0	0.63	0.13
Graduates per academic staff	3.09	1.4	8.01	1.06

Notes:

* Values expressed in real terms, reference year: 2011

**All publications (articles, proceedings papers, editorial materials, book chapters, book reviews etc.) listed in Web of Science core collections: Science Citation Index Expanded (SCI-EXPANDED), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference Proceedings Citation Index- Science (CPCI-S), Conference Proceedings Citation Index- Social Science & Humanities (CPCI-SSH), Book Citation Index– Science (BKCI-S), Book Citation Index– Social Sciences & Humanities (BKCI-SSH), Current Chemical Reactions (CCR-EXPANDED) and Index Chemicus (IC).

Table 2. The different DEA models at a glance

	Inputs	Outputs
First set of models: common frontier		
	Inputs	Outputs
Model 1	Expenditure in Euro, number of academic staff	Publications, graduates
Model 2		Publications, students
Model 3		Publications, graduates, PhD degree awarded
Second set of models: country-specific frontier		
	Inputs	Outputs
Model 4	Expenditure in Euro, number of academic staff	Publications, graduates
Model 5		Publications, students
Model 6		Publications, graduates, PhD degree awarded

Table 3. Efficiency scores – a summary

Panel A. Italy

	DEA scores						DEA unbiased scores					
	Common frontier			Country specific frontier			Common frontier			Country specific frontier		
Model	1	2	3	4	5	6	1	2	3	4	5	6
						ITALY						
2001	1.367	1.325	1.189	1.311	1.315	1.17	1.486	1.43	1.293	1.434	1.44	1.265
2002	1.283	1.2	1.218	1.215	1.196	1.157	1.388	1.271	1.321	1.313	1.279	1.248
2003	1.355	1.265	1.202	1.322	1.261	1.165	1.476	1.35	1.292	1.453	1.366	1.254
2004	1.261	1.241	1.128	1.243	1.231	1.113	1.353	1.317	1.2	1.345	1.322	1.187
2005	1.275	1.225	1.153	1.234	1.213	1.124	1.375	1.305	1.237	1.33	1.304	1.195
2006	1.332	1.255	1.143	1.303	1.248	1.125	1.44	1.341	1.218	1.43	1.35	1.195
2007	1.307	1.229	1.195	1.296	1.222	1.183	1.408	1.304	1.282	1.416	1.31	1.277
2008	1.228	1.169	1.178	1.216	1.169	1.172	1.303	1.235	1.254	1.307	1.241	1.257
2009	1.211	1.149	1.157	1.196	1.148	1.149	1.292	1.208	1.238	1.28	1.211	1.229
2010	1.192	1.16	1.098	1.166	1.16	1.092	1.263	1.224	1.156	1.235	1.229	1.146
2011	1.167	1.13	1.111	1.162	1.129	1.111	1.234	1.205	1.17	1.235	1.19	1.174
Mean	**1.271**	**1.214**	**1.161**	**1.242**	**1.208**	**1.142**	**1.365**	**1.29**	**1.242**	**1.343**	**1.295**	**1.221**
Min	1	1	1	1	1	1	1.046	1.041	1.041	1.037	1.035	1.036
Max	2.158	2.543	1.913	2.158	2.543	1.85	2.332	2.695	2.012	2.34	2.724	1.96
Std.Dev	0.259	0.228	0.194	0.24	0.226	0.176	0.265	0.234	0.195	0.246	0.236	0.176

Panel B. Poland

	DEA scores						DEA unbiased scores					
	Common frontier			Country specific frontier			Common frontier			Country specific frontier		
Model	1	2	3	4	5	6	1	2	3	4	5	6
							POLAND					
2001	1.269	1.164	1.255	1.258	1.154	1.244	1.409	1.269	1.367	1.391	1.242	1.377
2002	1.281	1.124	1.254	1.262	1.119	1.238	1.405	1.202	1.374	1.386	1.189	1.362
2003	1.196	1.115	1.163	1.19	1.108	1.157	1.318	1.202	1.263	1.275	1.171	1.258
2004	1.167	1.116	1.118	1.153	1.104	1.107	1.261	1.194	1.19	1.234	1.167	1.178
2005	1.214	1.137	1.198	1.192	1.118	1.181	1.315	1.219	1.285	1.29	1.183	1.288
2006	1.221	1.143	1.194	1.183	1.107	1.166	1.324	1.221	1.267	1.271	1.164	1.254
2007	1.199	1.126	1.154	1.152	1.097	1.129	1.302	1.2	1.248	1.231	1.154	1.207
2008	1.135	1.131	1.135	1.101	1.111	1.098	1.215	1.201	1.213	1.159	1.177	1.16
2009	1.21	1.121	1.195	1.13	1.092	1.109	1.291	1.182	1.275	1.197	1.145	1.175
2010	1.218	1.164	1.199	1.118	1.104	1.095	1.298	1.231	1.259	1.185	1.162	1.151
2011	1.145	1.335	1.138	1.061	1.139	1.051	1.214	1.417	1.194	1.102	1.206	1.087
Mean	**1.205**	**1.152**	**1.182**	**1.164**	**1.114**	**1.143**	**1.305**	**1.231**	**1.267**	**1.247**	**1.178**	**1.227**
Min	1	1	1	1	1	1	1.048	1.037	1.042	1.032	1.037	1.028
Max	2.802	2.37	2.747	2.802	2.37	2.747	3.07	2.572	2.945	3.041	2.499	2.979
Std.Dev	0.281	0.191	0.259	0.268	0.169	0.245	0.296	0.197	0.267	0.281	0.17	0.259

Note: DEA unbiased scores obtained by bootstrap method following Simar & Wilson (2000)

Table 4. Correlations between different DEA models

	DEA scores						DEA unbiased scores					
	Common frontier			Country frontier			Common frontier			Country frontier		
Model	1	2	3	4	5	6	1	2	3	4	5	6
1	1											
2	0.64	1										
3	0.82	0.52	1									
4	0.96	0.62	0.78	1								
5	0.62	0.97	0.49	0.64	1							
6	0.79	0.51	0.95	0.82	0.52	1						
1	0.99	0.62	0.8	0.96	0.61	0.78	1					
2	0.61	0.99	0.49	0.59	0.96	0.48	0.61	1				
3	0.81	0.51	0.99	0.78	0.48	0.95	0.81	0.49	1			
4	0.95	0.6	0.76	0.99	0.63	0.8	0.96	0.59	0.76	1		
5	0.59	0.95	0.45	0.61	0.99	0.48	0.59	0.96	0.45	0.61	1	
6	0.78	0.49	0.94	0.81	0.5	0.99	0.78	0.47	0.95	0.81	0.47	1

Note: all Pearson coefficients significant at 1% level

Table 5.Trends in productivity (M), efficiency and technology in Italian and Polish HEIs, based on annual changes for 2001-2011 period

	Malmquist (TFP)	Efficiency change	Technology (frontier shift)
Italy			
Number of all indexes	540	540	540
Average value of all indexes	*1.070*	*1.023*	*1.051*
Number of statistically significant indexes	495	311	330
Average value for statistically significant indexes	*1.075*	*1.038*	*1.074*
Number (and %)of statistically significant improvements	431	187	238
	80%	35%	44%
Poland			
Number of all indexes	300	300	300
Average value of all indexes	*1.029*	*1.019*	*1.012*
Number of statistically significant indexes	272	131	112
Average value for statistically significant indexes	*1.032*	*1.050*	*1.030*
Number (and %) of statistically significant improvements	187	76	70
	62%	25%	23%

Notes: The values are considered as statistically significant assuming the conventional 10% level. Results are based on Model 1 (two inputs: expenditure and academic staff; two outputs: publications, graduates); a common efficiency frontier is imposed.

Table 6 [Panel A]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources including Revenues from fees

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	0.027***	0.0204	0.0318	0.028***	0.0208	0.0332
$Prof_{i,t}$	-0.022***	-0.0335	-0.0104	-0.021***	-0.0329	-0.0085
$GDP_{n,t}$	-0.143	-0.2871	0.0037	-0.157**	-0.3047	-0.0017
$depart_i$	-0.009*	-0.0223	0.0035	-0.011*	-0.0246	0.0025
med_i	-0.039	-0.1366	0.0617	-0.004	-0.1067	0.1018
$yearfound_i$	0.000	-0.0002	0.0001	0.000	-0.0003	0.0001

Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions. Constants are not reported. Year dummies included in all models. Results from Model 1 (DEA Model 1: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, graduates).

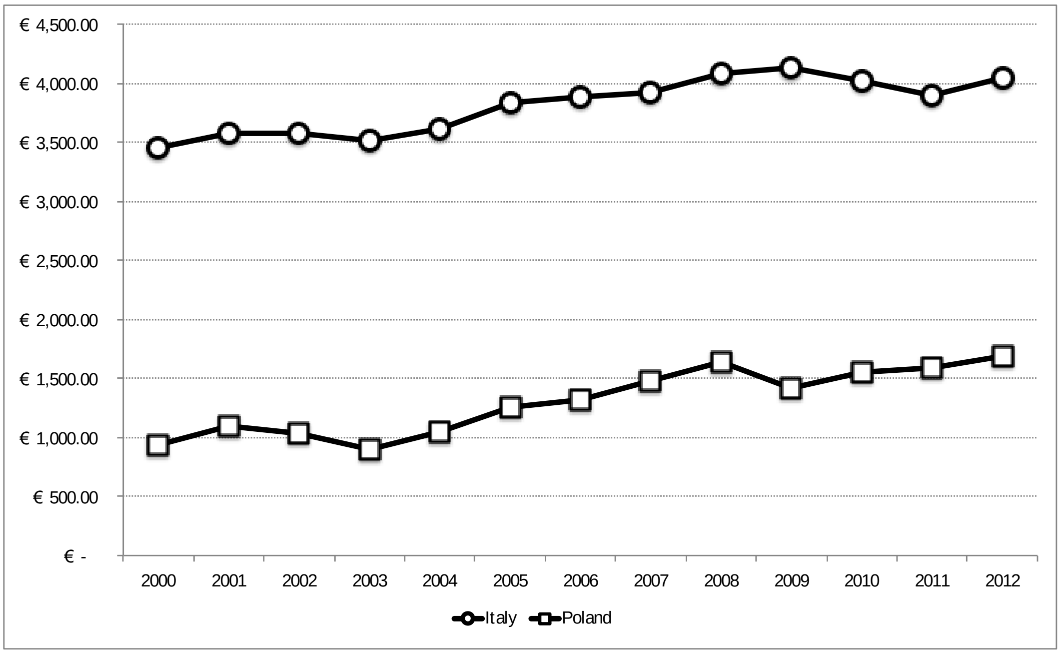
Table 6 [Panel B]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources and Revenues from fees separately

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	0.009***	0.0034	0.0138	0.008***	0.0031	0.0136
$Prof_{i,t}$	-0.008*	-0.0174	0.0010	-0.006*	-0.0156	0.0031
$GDP_{n,t}$	-0.163**	-0.2816	-0.0292	-0.156**	-0.2779	-0.0190
$depart_i$	-0.012**	-0.0232	-0.0002	-0.013**	-0.0246	-0.0008
med_i	-0.050	-0.1287	0.0359	-0.022	-0.1038	0.0620
$yearfound_i$	0.000	-0.0002	0.0001	0.000	-0.0002	0.0001
$Revenues\_Fee_{i,t}$	-0.027***	-0.0339	-0.0179	-0.028**	-0.0359	-0.0189

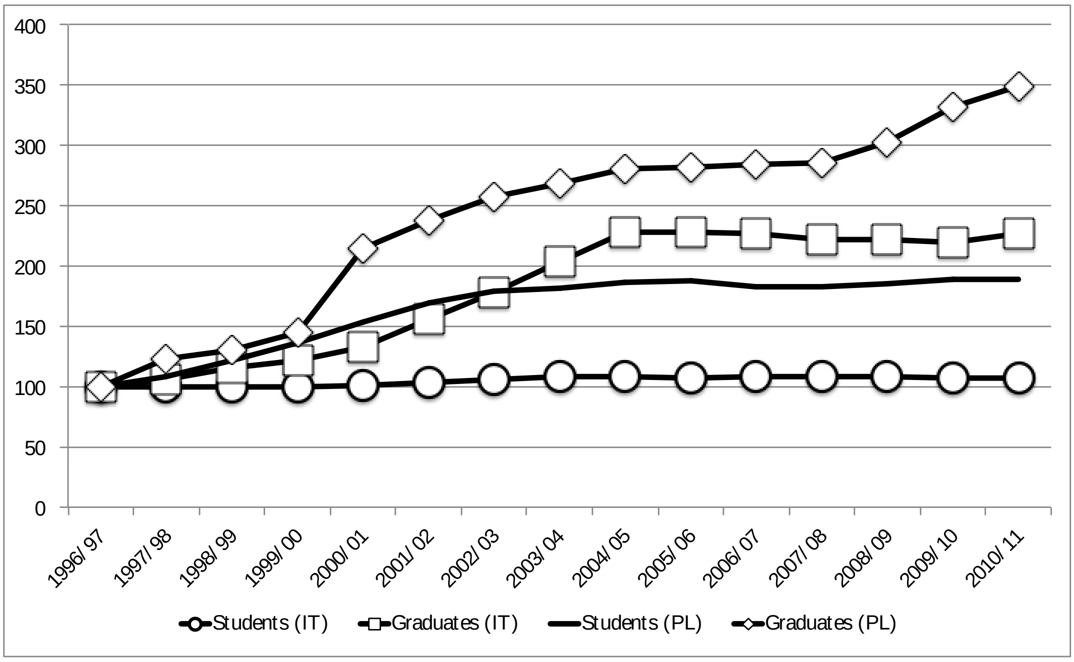
Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstraping interactions. Constants are not reported. Year dummies included in all models. Results from Model 1 (DEA Model 1: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, graduates).

Figure 1.
Public spending per student in both countries, nominal terms – only public universities (2000-2012)



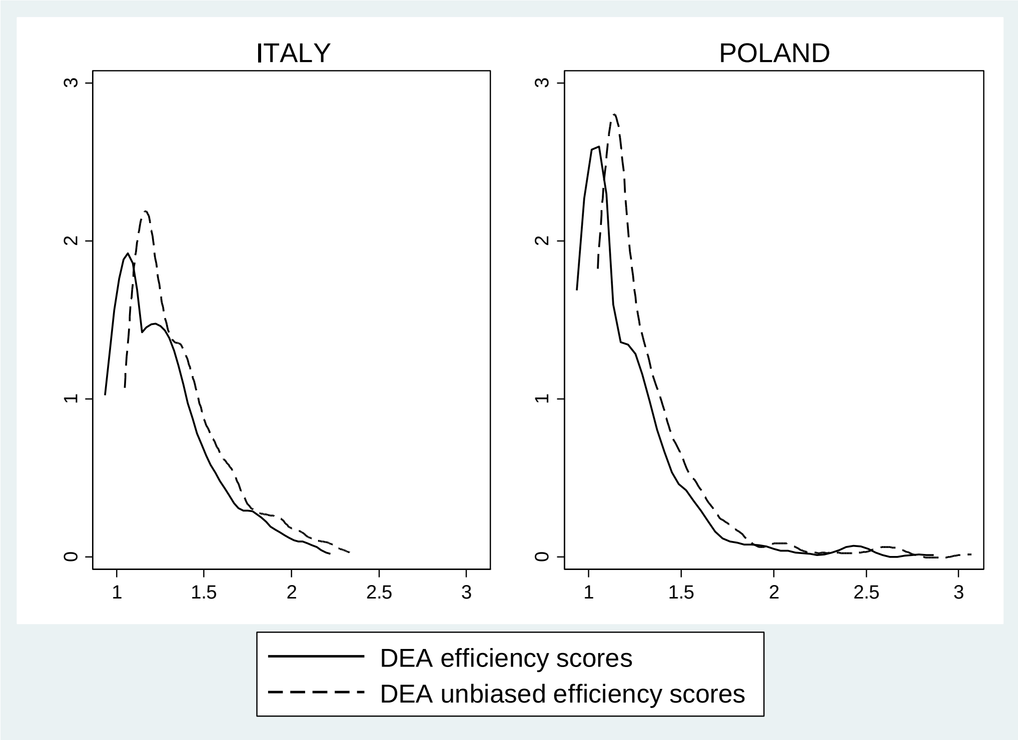
Source: authors' elaboration. For Italy based on Italian State's Financial Reports, various years, for Poland Central Statistical Office (GUS, 2013).

Figure 2.
The number of students and graduates, 1996/97 – 20110/11 – only public universities (index numbers: 1996/97 =100)



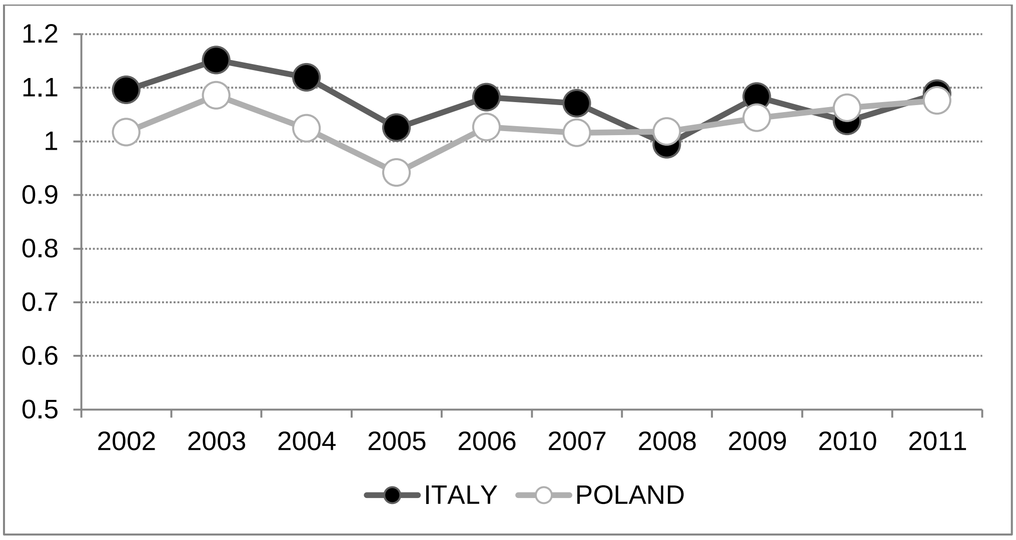
Source: authors' elaboration. In case of Italy - Ministry of Education's Statistics Office, various years, for Poland: Central Statistical Office (GUS, 2013).

Figure 3.
The distribution of efficiency scores by country (all years pooled) obtained from Model 1



Notes: all the elaborations are obtained with the assumption of a common efficiency frontier.

Figure 4. Average changes in productivity (Malmquist indexes), by country and year



Notes: results based on Malmquist indexes that are statistically significant at 10% level. Results are based on Model 1 (two inputs: expenditure and academic staff; two outputs: publications, graduates); a common efficiency frontier is imposed.

Annex

Table A.1 Pairwise correlations between Malmquist indexes based on different DEA models (Pearson coefficients)

	Malmquist indices						Malmquist unbiased indices					
	Common frontier			Country frontier			Common frontier			Country frontier		
Model	1	2	3	4	5	6	1	2	3	4	5	6
1	1											
2	0.65	1										
3	0.31	0.48	1									
4	0.98	0.66	0.31	1								
5	0.64	0.99	0.47	0.66	1							
6	0.25	0.41	0.96	0.26	0.42	1						
1	0.99	0.66	0.31	0.97	0.65	0.24	1					
2	0.65	0.99	0.46	0.65	0.98	0.4	0.66	1				
3	0.36	0.48	0.99	0.36	0.47	0.95	0.35	0.47	1			
4	0.98	0.66	0.32	0.99	0.67	0.26	0.98	0.67	0.36	1		
5	0.64	0.98	0.46	0.66	0.99	0.41	0.65	0.99	0.46	0.67	1	
6	0.25	0.42	0.96	0.26	0.43	1	0.25	0.41	0.96	0.27	0.41	1

Notes: Malmquist unbiased indexes are obtained by bootstrap methods following Simar & Wilson (1999). All Pearson coefficients are significant at 1% level.

Table A2 [Panel A]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources including Revenues from fees, efficiency scores from DEA Model 2

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	0.014***	0.0086	0.0181	0.017***	0.0113	0.0218
$Prof_{i,t}$	-0.008*	-0.0175	0.0023	-0.004	-0.0143	0.0063
$GDP_{n,t}$	0.227**	0.0854	0.3518	0.250***	0.1001	0.3843
$depart_i$	-0.030***	-0.0424	-0.0159	-0.035***	-0.0486	-0.0195
med_i	-0.182***	-0.2660	-0.0880	-0.171***	-0.2584	-0.0760
$yearfound_i$	0.000	-0.0003	0.0001	0.000	-0.0003	0.0000

Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions. Constants are not reported. Year dummies included in all models. Results from Model 2 (DEA Model 2: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, students).

Table A2 [Panel B]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources and Revenues from fees separately, efficiency scores from DEA Model 2

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	-0.002	-0.0065	0.0042	0.001	-0.0043	0.0076
$Prof_{i,t}$	0.001	-0.0081	0.0100	0.005	-0.0052	0.0139
$GDP_{n,t}$	0.228***	0.0887	0.3562	0.264***	0.1139	0.4026
$depart_i$	-0.033***	-0.0454	-0.0193	-0.038***	-0.0509	-0.0221
med_i	-0.183***	-0.2583	-0.0912	-0.174***	-0.2506	-0.0794
$yearfound_i$	0.000	-0.0003	0.0000	0.000	-0.0003	0.0000
$Revenues\_Fee_{i,t}$	-0.025***	-0.0331	-0.0154	-0.026***	-0.0348	-0.0154

Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions. Constants are not reported. Year dummies included in all models. Results from Model 2 (DEA Model 2: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, students).

Table A3 [Panel A]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources including Revenues from fees, efficiency scores from DEA Model 3

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	0.021***	0.013	0.028	0.021***	0.0120	0.0296
$Prof_{i,t}$	-0.043***	-0.059	-0.025	-0.050***	-0.0677	-0.0283
$GDP_{n,t}$	0.088	-0.121	0.273	0.081	-0.1536	0.2877
$depart_i$	0.004	-0.014	0.020	0.002	-0.0181	0.0203
med_i	0.011	-0.124	0.154	0.035	-0.1166	0.1992
$yearfound_i$	0.000	0.000	0.000	0.000	-0.0002	0.0004

Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions. Constants are not reported. Year dummies included in all models. Results from Model 3 (DEA Model 3: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, graduates, PhD degree awarded).

Table A3 [Panel B]

The determinants of efficiency scores (truncated regression), when considering Revenues from competitive sources and Revenues from fees separately, efficiency scores from DEA Model 3

Variable	Common frontier			Country frontier		
	Bias adjusted coefficients	95% Bootstrap confidence intervals		Bias adjusted coefficients	95% Bootstrap confidence intervals	
		Low	High		Low	High
$Rev\_NonComp_{i,t}$	0.000	-0.0054	0.0062	0.000	-0.0059	0.0060
$Prof_{i,t}$	-0.020***	-0.0303	-0.0077	-0.022***	-0.0333	-0.0092
$GDP_{n,t}$	0.043	-0.1059	0.1897	0.041	-0.1123	0.1952
$depart_i$	-0.001	-0.0144	0.0111	-0.003	-0.0165	0.0105
med_i	-0.003	-0.0954	0.0950	0.007	-0.0912	0.1102
$yearfound_i$	0.000	0.0000	0.0003	0.000	-0.0001	0.0003
$Revenues\_Fee_{i,t}$	-0.029***	-0.0375	-0.0185	-0.029***	-0.0378	-0.0177

Notes: * Value of zero does not fall within 90% confidence interval,** Value of zero does not fall within 95% confidence interval, *** Value of zero does not fall within 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions. Constants are not reported. Year dummies included in all models. Results from Model 3 (DEA Model 3: inputs: expenditure (total costs) in Euro and number of academic staff, outputs: publications, graduates, PhD degree awarded).