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The Transient and Persistent Efficiency of Italian and German Universities: A Stochastic Frontier Analysis*

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Abstract

Despite measures on the European level to increase the compatibility between the HE sectors of the member states, the recent literature exposes variations in their efficiencies. To gain insights into these differences we split the efficiency term according to the two management levels each university is confronted with. Utilizing a recent advancement in the method to measure efficiency, we separate short-term (transient) and long-term (persistent) efficiency, while controlling for unobserved institution specific heterogeneity. While the first term reflects the efficiency of the individual universities working within the country, the second term echoes the influence of the country specific overall HE structure. The cross-country comparison displays if the overall efficiency difference between countries is related to individual performance of their universities or their HE structure. This allows more purposeful policy recommendation and expands the literature regarding the efficiency of universities in a fundamental way. Choosing Italy and Germany as two important illustrative examples we can take advantage of a novel dataset including characteristics of institutions in both countries for an exceptional long period of time from 2001 to 2011. We show that the Italian universities exhibit a higher overall efficiency value than their German counterparts. With the individual universities working at the upper bound of efficiency in both countries, the overall inefficiency as well as the gap between the countries is caused by persistent, structural inefficiency. To expedite a true European Area of Higher Education future measures should hence aim at the country specific structure, not solely at affecting the activities of single universities.

JEL classification: C14, C23, D61, I22, I23, H52

Keywords: Stochastic Frontier Analysis, Persistent Inefficiency, Higher Education, Costfunction, Italy, Germany

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1. Introduction

The 1998 initiated Bologna Process set in motion a process that has radically changed Higher Education (HE) in Europe. Measures, like the modernizing of degree structures and the strengthening of quality assurance mechanisms are aiming to increase the compatibility of the HE sector of the individual countries[1]. The envisaged European Higher Education Area (EHEA) is supposed to increase the mobility of students as well as graduates and at the same time boost the competitive- as well as attractiveness of the European universities to the rest of the world. Nevertheless, the latest Bologna implementation process report by the EU Commission states "[…] that more needs to be done. While it is obvious, that countries are moving in the same direction, they do so at widely varying pace." (European Commission (2015), S. 3). Despite the efforts on the European level, the HE structure is by its very nature, defined and variant at country level and reflects national-historical as well as cultural peculiarities. This variation is confirmed by the literature regarding the efficiency of the HE sector, with several cross-country studies showing noteworthy differences in the efficiency of institutions between countries [see Wolszczak-Derlacz and Parteka (2011), Agasisti and Pohl (2012), Bolli et al. (2016)].

To gain insights on these efficiency differences we argue that one ought to look at the two management levels each university is confronted with and separate two types of efficiency: on one side, the efficiency of the individual universities working within the country, and on the other side the efficiency which is caused by the country specific, overall HE structure. While the first term displays how the individual universities operate with the available resources within the HE sector, the second term reflects its structural characteristics, representing the country specific mechanisms for funding and competition. A blending of both types of efficiency could lead to a misrepresentation of the overall efficiency of a country, if the HE structure creates a highly productive surrounding but the universities themselves are poorly managed, or vice versa. Against this background, the research question of this paper is formulated as follows: *Are efficiency differences between countries related to the individual performance of the universities working within the HE sector or the HE structure?*

To answer the raised research question, we utilize a recent advancement in the method to measure efficiency. Kumbhakar et al. (2014) proposed a model that allows to distinguish between transient and persistent inefficiency. As displayed by the given names, the interpretation of both terms is thereby commonly time related. While transient inefficiency is interpreted in the context of a chosen year (short term), persistent inefficiency indicates long-term operational problems, since it echoes the effects of unobserved, but changeable factors, which vary across institutions but are constant over time. We argue that with an application to the HE sector the methodology

[1] From this point on the HE sector refers to the whole system of the respective country, including the HE structure as well as the HE Institutions.

allows an even farther-reaching interpretation, given through the levels of management responsibility. Universities commonly possess the autonomy to respond to annual changes, as for example to a variation in student numbers. Transient efficiency, reflecting these annual changes, therefore presumable occurs at the institutional level. Long-term objectives are in contrast commonly defined at a higher level, with the state as investor regulating fundamental factors like the long-term growth of institutions. Persistent efficiency, being a constant factor, therefore relates to the state specific HE structure and shows its influence on the institutions. Short- and long-term efficiency of the HE sector can thus be seen as indexes, representing to a given extend, an *institutional* and a *structural efficiency*[2]. The advantage of the specification is even greater when comparing the efficiency between two countries. The comparison of both terms can show on which level the in the literature demonstrated efficiency differences between countries occur, allowing more purposeful policy implications.

We explore the developments for an exceptional long period of time (11 years from 2001 to 2011) in two large European HE Countries: Germany and Italy. The limitation to two countries is thereby deliberate, with the aim to concentrate on the new approach to compare the efficiency of the HE sector and the demonstration of its advantages. Equally deliberately chosen are the countries themselves. While they are both greatly involved within the Bologna Process, demonstrating their efforts for a high level of comparability and mobility between them, they both exhibit distinct country specific differences in HE structure (discussed in subsequent sections of this paper). The two countries, working on similar goals but exhibiting distinct structural characteristics, can therefore be considered particularly interesting cases to analyze potential convergence effects emerging from transnational reforms.

Our findings are important for expanding the literature about the cross-national comparison of universities' efficiency that, despite its relevance, is still in its infancy [Wolszczak-Derlacz and Parteka (2011)]. It is innovative because it is the first time that the efficiency of the HE sector is separated according to the management level of the institutions, within a cross-country comparison. The comparison of both types of efficiency can show if one HE structure is preferable to another and facilitates the subsequent deduction of convergence objectives. The present paper can be seen as a starting point, demonstrating the advantages of the approach as well as the necessity to apply the method on a broader sample. The new interpretation also opens up new opportunities for analysis in other similar structure areas, especially in the public sector.

The remainder of the paper unfolds as follows. A short literature review is given in the next section (§2), followed by a closer look at the method of econometric analysis (§3). Afterwards the characteristics of the HE sectors in Italy and Germany are discussed (§4) and the dataset is presented (§5). The results are then displayed and related to the country characteristics (§6).

[2] Onwards the terms persistent and structural as well as transient and institutional efficiency are used simultaneous.

A sensitivity analysis validates the argumentation (§7), before the resulting policy implications are debated (§8). A concluding section draws together the main findings and makes some suggestions for future research.

2. Literature Review

Although the influence of the HE structure on the performance of universities is an undoubtedly insightful topic, only few studies have made attempts to evaluate it. One existing literature strand thereby regards the question which factors determine the autonomy of universities [see Volkwein and Malik (1997)] and how this autonomy influences the quality of the institutions output [see Volkwein (1986)]. A recent study by Aghion et al. (2010) analyses how it affects the performance of the entities, measured by patenting and international university research rankings. They demonstrate that autonomy and competition among US and European institutions are positively correlated with the university output. To our knowledge no attempt has yet been made to evaluate the HE structure in the context of an efficiency analysis, looking at input as well as output, comparing the *structural efficiency* of two countries, evaluating their preferability. Doing so in the context of two countries within the European Union also has the advantage of suggesting policies at the international level.

In contrast, the efficiency analysis of HE Institutions is more common, applying one of the main methods, namely the Data Envelopment Analysis (DEA) or the Stochastic Frontier Analysis (SFA). While the first studies measuring efficiency in the HE sector focused solely on carefully selected faculties of institutions within one country [see Johnes and Johnes (1995)] the focus quickly widened. Recent studies not only examine universities in their entirety but also inspect private and specialized colleges. Since then, a limited, but recurring sample of countries has been covered, focusing on different aspects of the HE Institutions and applying varying methods[3]. Besides the better availability of data, the development was driven by the advancements in the measurement of efficiency, giving more attention in particular to the heterogeneity between institutions. Since universities usually evolved in a historic context, the institutions feature different locations and are therefore, among other things, confronted with regional specific labor market conditions. To account for such permanent and unchangeable university specific differences, which should evidently not be included in the efficiency measurement, primal studies made the examined sample as homogeneous as possible, focusing on similar institutions. But, due to the difficulty of doing so, lately options were proposed to account for these differences within the econometric specification itself. In the prominent proposal by Greene (2005) heterogeneity among institutions is incorporated and measured by a university-specific, time-invariant component in the estimation equation. The advancement was applied among others by Johnes and Schwarzenberger (2011),

[3] For a review of empirical studies utilizing frontier efficiency measurement techniques in education, see Worthington (2001) and De Witte and López-Torres (2017).

who control for such structural differences and show that heterogeneity is an important factor when evaluating German universities, and by Agasisti & Johnes (2010) for the same purpose in the context of Italian HE.

While the analysis of institutions became swiftly customary, the comparison of efficiency between countries was assumed to be unfeasible for a long time, driven by the barriers represented by the lack of comparable data. Just lately studies comparing different HE sectors emerged, with the comparison of European countries being the most common. Amongst other authors looking at two countries, Agasisti and Johnes (2009) relate the efficiency of Italian universities to English, while Agasisti and Pohl (2012) compare them to German institutions. Using broader data Bolli et al. (2016) look at entities in eight European countries for the exceptional long period from 1994-2006. At this stage of the literature, however, no studies have proposed a method to incorporate the heterogeneity of institutions in cross-country comparisons.

In the present paper, we move to the most recent methodical development, a novel specification of the SFA, which distinguishes between varying short-term (transient) and stable long-term (persistent) efficiency. While the transient term reflects changes that occur in a given year, the persistent term echoes the effects of surrounding factors such as management as well as other unobserved, changeable factors that vary across institutions but are constant over time. The first estimation specification to include the idea of transient and persistent efficiency was proposed early on by Kumbhakar and Heshmati (1995). Unfortunately, the authors neglect the idea of heterogeneity across institutions and assume that the measured time-invariant component is entirely due to long term inefficiency. Therefore, it has only been utilized in selected areas, especially in the agriculture sector [see for example Ahmad and Bravo-Ureta (1996)] but it has not been applied for the measurement of efficiency in the HE sector. The drawback of the specification was amended more recently in a specification by Kumbhakar et al. (2014)[4]. The model allows to distinguish between the two types of efficiency, while controlling for heterogeneity of institutions. Although it has been applied to the HE sector of single countries, it has not been utilized in a cross-country comparison. Looking at the US, Titus et al. (2016) shows that cost inefficiency tends to be persistent rather than short term in the local HE sector. Gralka (2016) confirms this results for German universities and concludes that a comprehensive change of the university structure seems to be necessary to increase efficiency. The fact that a persistent inefficiency component is prevalent in the HE sector of both countries, can be seen as a first indication that long-term factors could also be a reason behind efficiency variations between nations, validating the relevance of the present analysis.

Apart from the cross-country perspective, we extend the findings from the aforementioned studies by the argument that the novel methodology allows a wider interpretation when applied to

[4] Along with Kumbhakar et al. (2014) similar models where developed simultaneously by Colombi et al. (2014) and Filippini and Greene (2016).

the HE sector, given by the distinct management levels. While universities respond to annual changes, long-term objectives are commonly defined at a higher level, with the government as investor steering the fundamental factors. Transient efficiency, reflecting annual influences, therefore presumable occurs at the institutional level and represents an *institutional efficiency*. In contrast, persistent efficiency, being a constant factor, reflects the influence of the higher level, representing a *structural efficiency*. The comparison of both types of efficiency can show if the efficiency differences between countries are driven by the state specific administrative design of the HE sectors or the individual performance of the universities working within.

Our findings are therefore important for expanding the literature about the cross-national comparison of universities' efficiency that, despite its relevance, is still in its infancy [Agasisti and Johnes (2009); Wolszczak-Derlacz and Parteka (2011), De Witte and López-Torres (2017)]. It additionally complements the studies by Titus et al. (2016) and Gralka (2016) where, given the fact that the studies consider single countries, the implications can be interpreted only at managerial level (factors that can be addressed by universities' decision makers) and not also at policy level (design of the system's governance features, which lie in the hands of policy-makers).

3. Methodology

By now, the SFA that originates from the study of Aigner et al. (1977) can be seen as a standard approach to evaluate efficiency in a variety of research areas, including the HE sector. Within the HE Literature, a cost function is thereby customarily used to estimate efficiency [Eagan and Titus (2016)]. Derived from microeconomic cost theory, the cost function is the mathematical representation of the relationship between the total costs of producing a given level of outputs from a specific set of inputs. In other words, a cost function is a boundary describing the lowest cost at which an institution can produce a set of outputs[5]. The deviation from the boundary, the often-called "frontier", is picked up by the additional error term. In the specification by Kumbhakar et al. (2014) the error term is split into four components. Besides the customary term representing the statistical noise, a term to account for the heterogeneity is included. Heterogeneity thereby refers to structural differences, which are persistent, not changeable and occur at the individual level. A classic example for heterogeneity is the age or the specific location of the institutions, which determine the available labor supply. In the context of a cross-country comparison it is important to keep in mind that heterogeneity is assumed to be individual specific. The term therefore controls for unique university characteristics, not for overall country differences. The error term additionally comprises the mentioned two efficiency terms, separating transient and persistent efficiency and, following the afore-given argumentation, representing *institutional* and *structural efficiency* in the context of the HE sector. Both terms are again individual specific, with

[5] To verify the assumption for the present dataset, a skewness test on the OLS Residuals was conducted and found to be significant, providing support for the cost frontier specification of the model.

an assigned term for each university. While *institutional efficiency* changes annually and reflects the actions of the university itself, *structural efficiency* is constant and shows the influence of the HE structure on the individual institution. The variation of the second term is thereby consistent with the argumentation, since the institutions exhibit varying agreements with the states, get different fundings and possess varying extends of autonomy.

In line with the literature we consider teaching and research as the primary activities and outputs produced by the HE Institutions[6]. These two outputs (Q_{jit}) are evaluated with respect to the main input, the expenses of the institutions. The first output variable teaching is represented by the total number of students from bachelor and master courses (or equivalent), differentiated across the three subject group's science, non-science and medicine[7]. The research output is measured by third-party funding. The approximation of research through third party funding is common in the literature. One can argue that the funding provides a quality adjusted measure, since it reflects the market value of research [Johnes (1997), Worthington (2001)]. The outputs are compared to the sum of annual personnel and other current expenditures of institutions, deducted by research grants and revenues ($\mathrm{C_{it}}$)[8]. Costs as well as third-party funds and the number of students are normalized by the number of graduates, following Kempkes and Pohl (2010)[9].

A scaled translog function is assumed for the present analysis. This choice is in line with a variety of studies, including the earliest and most recent analysis of university costs by Koshal and Koshal (1999), Stevens (2005) and Bolli et al. (2016). Orientating at Christensen and Greene (1976) and applying the novel specification by Kumbhakar et al. (2014) the translog cost function has the following form:

$$ln\, C_{it} = \alpha_0 + \sum_{j=1}^{4} \beta_j\, ln\; Q_{jit} + \frac{1}{2}\sum_{j=1}^{4}\sum_{k=1}^{4} \beta_{jk}(ln\, Q_{jit}\, ln\, Q_{kit}) + \varepsilon_{it} \qquad \textit{with} \qquad (1)$$

$$\varepsilon_{it} = v_{it} + \rho_i + [\mu_i + \tau_{it}]$$

where *i* denotes universities and *t* the time period, covering the years 2001 to 2011. The term α_0 which captures the constant and β are unknown parameter vectors to be estimated. The additional four components which are comprised in the error term are the ones of interest.

[6] For a comprehensive review of the literature and the considered variables see De Witte and López-Torres (2017).

[7] Non-science subjects are courses related to art, economics, law, sport and culture. General science contains mathematics, natural sciences, agricultural, forest sciences and engineering. Medicine includes human and health science as well as veterinary medicine.

[8] The inclusion of the subject group medicine could lead to a bias of the efficiency results due to the fact that they are part of the general health provision and therefore exhibit inflated cost. We account for the matter by implementing the subject as a separated group. Additionally, one can argue that the goal of the present study is not the interpretation of an absolute level of efficiency but a comparison of efficiency levels between two countries.

[9] Country Dummies where deliberately not included in the regression, since this would imply that countries significantly differ in their technology of producing the output, an assumption which does not hold in the HE context.

The term v_{it} accounts for statistical noise and the term ρ_i is a random institution effect that captures heterogeneity between institutions. The overall inefficiency term u_{it} is divided into the persistent (long-term, constant) part μ_i and the transient (short-term, changing) component τ_{it}. Ranging between 0 and 1, a higher value indicates higher efficiency.

A multistep procedure is used to estimate efficiency [see Kumbhakar et al. (2014)][10]. While the strategy is complex and greatly dependent on the underlying distributional assumptions, its advantages lie in the improved accuracy regarding the time-invariant component and the additional information that can be gained. The interested reader can look at the Technical Annex T1 for a closer description on the multistep procedure, and Badunenko and Kumbhakar (2016) for a detailed discussion of the relatively new model and a simulation.

4. Italy and Germany

To address the raised research question, we explore the developments of universities' efficiency in two deliberately chosen European HE Countries: Italy and Germany. While they are both greatly involved within the Bologna Process, demonstrating their efforts for a high level of comparability and mobility between them, they both exhibit key, country specific differences in the HE structure. The two countries, working on similar goals but exhibiting distinct structural differences, can be considered particularly interesting cases to analyze potential convergence effects emerging from transnational reforms. When asking if efficiency differences between the two countries are driven by the HE structure or the individual performance of the universities, it is insightful to keep the three main differences between the countries in mind.

The supervision of the universities by the government can be seen as the greatest deviation. Although the institutions in both countries have their own functional autonomy, the Italian universities are regulated and funded by the central government, while the German institutions are financed and controlled by the federal states. Thereby both systems have frequently discussed advantages as well as disadvantages [see Enders (2004)]. While central systems benefit from a wider expertise, they are often confronted with the accusation of being too gross to account for the individual needs of regions. In contrast concerns are raised in federal systems regarding the quality and comparability of the education subsystems as well as the resulting degrees.

The second largest difference can be seen in the overall composition of the HE sector. Responding to the strong growth in student numbers as well as the changing needs for skilled labor most European countries expanded their university dominated HE sector in the 60s. Novel institutions where founded with the main purpose to offer a wide spectrum of vocational training,

[10] It can be argued that the four error component model is inefficient relative to a simulated maximum likelihood estimation method (for a discussion see Heshmati et al. (2016)). We deliberately choose the component model due to its relative straight forward estimation procedure, compared to the simulated maximum likelihood method as well as the possibility to verify the estimation result in every step.

combining theory and practical work [Kyvik (2004)]. Widely varying models of HE sectors emerged, with Italy and Germany choosing different alternatives [Scott (1995)]. Italy now represents the classic case of a university-dominated system with universities and university-level specialized colleges being the only HE Institutions. Organizations offering vocational programs such as nursing, are not considered as HE establishments[11]. In contrast Germany established a binary system of HE Education, where "Fachhochschulen" complement universities. The "Fachhochschulen" have the principal objective to provide education, but not research or research training. The graduates receive the same formal title, differentiating themselves from university graduates only through the place of study. The institutions are often multidisciplinary, vocationally oriented and usually suit the regional economy in their subject range. The German government therefore chose to create a clear and distinct alternative to the universities, with "Fachhochschulen" focusing on the more practical subjects instead of the traditional academic studies. Given the established differences between universities and "Fachhochschulen", in this paper only the first type of institutions is included in the empirical analysis, with the aim of granting the comparability with their Italian counterparts.

The third difference that ought to be mentioned is linked to the funding mechanisms of the institutions. With the main part of funding in both countries being based on objective data (such as the number of students) and the gradually implementation of variable amounts based on quality (through performance based funding), the overall funding mechanisms of both countries are becoming more similar. Nevertheless, a main difference still exists in the levying of tuition fees. Italian universities charge a high all-purpose fee, with the exact amount depending on the income of the parents. In contrast, the German institutions only levy a small amount, which is independent of the household income and directly linked to subsidies of local transport and student meals etc.[12] Additionally, the German government provides interest free student loans to households below a certain threshold ("Bafög").

It is relevant to keep in mind, that both countries have undergone changes in the course of the Bologna declaration, starting in 1999, foremost introducing the new Bachelor and Master qualifications in the EU countries. In Italy the four to five year "Laurea" degree was changed to a three year first degree ("Laurea") as well as a possible second degree ("Laurea specialista"). Likewise, Germany introduced the new qualifications, replacing the five year "Diplom" by a three year ("Bachelor") and an optional two year degree ("Master"). The introduction of the new qualifications in both countries was, amongst other measures, accompanied by an additional

[11] Some short professional programs were integrated within universities in 1990 under the title "Diploma Universitario". However they were implemented in limited numbers and not regarded as attractive by students or academic staff mostly due to the missing degree recognition on the labor market [Kyvik (2004)].

[12] General tuitions fees were introduced in seven of the sixteen German states in 2005, but where abolished shortly after, in particular as a result of great public pressure and changes in government. In addition, several states exhibit special fees, aimed at those whose studies are taking longer than the required time and second degrees, which are independent of the first degree.

harmonization provision, aimed to strengthen the mobility of students. Courses where modularized and aligned with the European Credit Transfer System (ECTS) as a unit of measurement for the curricula.

The efficiency of institutions in both countries has been analyzed using varying approaches. Looking at Italian universities Agasisti (2016) amongst others showed that the institution raised their efficiency in the period between 2001 and 2011. In comparison Kempkes and Pohl (2010) as well as Johnes and Schwarzenberger (2011) displayed that the German universities work at a constantly high level of efficiency. While the idea of persistent inefficiency was not applied to the Italian HE sector, Gralka (2016) revealed that inefficiency of the German institutions is mainly caused by long term factors. We complement the study by Agasisti and Pohl (2012) as well as Lehmann et al. (2016) who compared Italian and German institutions, using the Data Envelopment Analysis (DEA) and showed that, while universities from the latter country are more efficient, the Italian universities are catching up. These two studies, however, did not include any distinction between country-specific differentials of efficiency, an element that can instead contribute to explain the relative performance of institutions in the two countries.

5. Data

The panel data set, representing the two countries, covers the years from 2001 to 2011 and represents 55 out of 61 Italian and 70 of the 75 German public universities[13], providing a comprehensive view of the HE Landscape in both countries. Institutions specializing in some fields only, like fine arts and medicine, are dropped from the sample. Distance learning university are also excluded. The data were provided by the Federal Statistical Offices of the two countries[14]. All monetary variables are deflated to the year 2011. Descriptive statistics are reported in Table 1. The values are similar to Kempkes and Pohl (2010) and Johnes and Schwarzenberger (2011) who look at Germany, as well as Barra et al. (2015) looking at Italy and Bolli et al. (2016), who consider selected European countries[15]. While Italian universities, with an average of around 29,700 students per university, are slightly larger than their German counterparts, with 17,800, their allocation into the three largest subject groups is similar over the whole period (see Figure 1). The largest share of students is enrolled in non-science subjects, followed by science and medicine. The number of graduates are in line with the distribution of students between countries as well as among subject groups. The only exception is the subject group medicine, where

[13] The following universities are excluded, mainly due to merges within the timeframe: U Duisburg-Essen, Brand. TU Cottbus-Senftenberg, HafenCity U Hamburg, U Kiel, U Lübeck and Università di Camerino, Stranieri di Perugia, Stranieri die Siena, Università di Trento, Sissa Trieste, Università degli Studi di Urbino Carlo Bo.

[14] Both datasets have been used previously in separate efficiency analysis and where merged for the following analysis, see Agasisti (2011) and Gralka (2016).

[15] The difference in the displayed costs compared to the study by Agasisti and Pohl (2012) are due to different definition of cost. The present study assumes that third party funding should be excluded from the overall cost since it represents an output.

Table 1 - Descriptive Statistics

2001-2011	**Italy** (n=55)		**Germany** (n=72)	
	Mean	Std. dev.	Mean	Std. dev.
Students, Non-Science	17,509.94	15,644.58	10,627.55	8,234.58
Students, Science	10,824.04	10,175.08	5,956.43	4,664.84
Students, Med	1,377.54	1,476.65	1,241.28	1,616.84
Graduates, Non-Science	2,487.14	2,362.83	1,257.53	939.29
Graduates, Science	1,731.40	1,757.63	737.30	611.64
Graduates, Med	156.45	170.75	239.10	321.80
Third-party funding[a]	10,448.47	12,343.19	53,788.85	50,548.31
Costs [a]	182,423.40	166,402.00	161,823.50	114,412.40
Costs per student	*6,065.23*	*2,524.45*	*15,497.49*	*10,451.40*
Costs per graduate	*43,451.46*	*18,900.68*	*124,090.80*	*82,828.73*

Source: Federal Statistical Office of Germany and Italy; own calculations.
[a] In 1,000 €, 2011 prices.

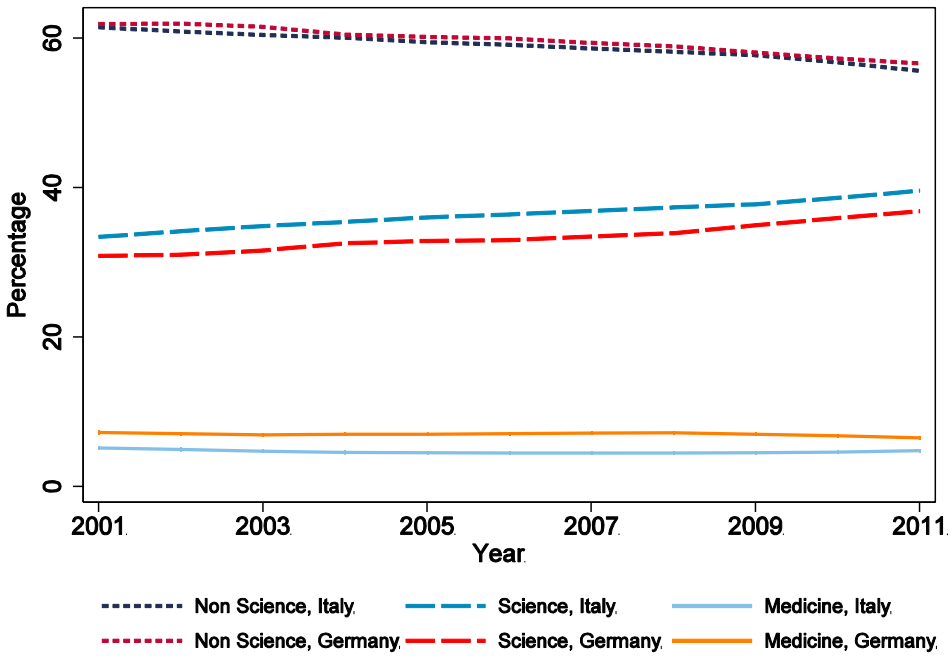
Germany exhibits a higher graduation rate. In contrast the second considered output variable, the research income, is substantially lower with around 10 million euros at Italian universities than at the German institutions with around 56 million euros. Additionally, it is relevant to note that German universities were able to raise their funding considerably, while the overall amount is stable for Italy in the regarded timeframe. The current expenditures sum up to around 182 million euros annually in Italy and 162 million in Germany. These sums stay steady throughout the regarded time frame. A rather prominent characteristic of the descriptive statistics, which is in line with the literature, is that for each variable, the standard deviation is close to the mean. This indicates a considerable degree of heterogeneity among institutions.

Apart from the look at the relative distribution of students to the subject groups, it is interesting to investigate if the HE sector of both countries differ as a whole and to look at the institutions' distribution within country as a measure of internal heterogeneity. To examine this subject, we clustered the sample in three groups according to the five main factors of interest: annual cost, third party funding and students separated for each subject group for the year 2011[16]. Figure 2 shows the resulting clusters, with each examined university displayed according to their cluster and the total number of students. The figure distinguishes three distinct university types. The first group only consists of Italian universities, which are by far the biggest institutions in the sample[17].

[16] The choice to cluster into three groups is thereby deliberate. In an analysis regarding the horizontal differentiation of the German HE sector Ehrhardt and von Kotzebue (2016) identify three to four main groups of universities. In line with our results they also ascertain one large, homogeneous group of institutions, a second smaller one and third containing mainly outliers.

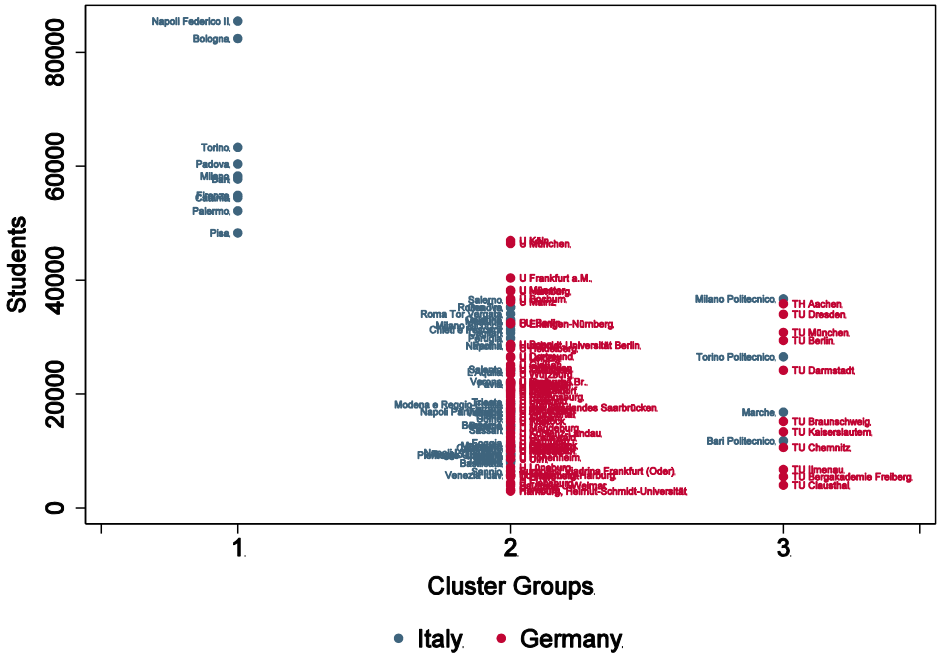
[17] Due to its great size, the university *Roma La Sapienza* was excluded from the graph but belongs to the first group.

Figure 1 - Students by Subject Group (Percentage)



Source: Federal Statistical Office of Germany and Italy; own calculations.

Figure 2 - Evaluated Cluster and Students (2011)



The fact that the Italian HE structure seems to allow institutions to grow bigger, can be seen as a first main difference between the two considered HE structures, presumable influencing the *structural efficiency*[18] of the whole system. The second group consists of almost all German and the majority of Italian institutions. The third cluster is distinct again and depicts technical universities from both countries[19]. With thirteen institutions, the German HE sector consists of a higher number of technical oriented universities than the Italian, which encompasses four. Summarizing, the cluster analysis shows that, while the majority of institutions in the Italian and German HE sector seem to be similar, a clear difference is located in the size of universities. This demonstrates the relevance of the present research question as well as the importance to account for the seemingly stronger heterogeneity of Italian institutions in the efficiency estimation.

6. Results

The Stochastic Frontier Analysis specification by Kumbhakar et al. (2014) was employed to measure transient and persistent efficiency of the Italian and German HE sector. The estimated cost equation is reported in the Appendix, Table A.1. The coefficients of the outputs and inputs behave well in the sense that the values are in line with theoretical expectations. A further interpretation of the results in the table is not advisable, owing to the presence of quadratic and interaction terms. The implications of the cost function for economies of scale and scope in university production are not the main thrust of this study and are therefore not considered in any depth, while future research could be devoted to this scope. Table 2 presents the mean efficiency values for the estimated model. The mean efficiency values for each university can be found in the Appendix, Table A.2. With an estimated overall efficiency of 0.708, the mean efficiency of the Italian HE sector lies distinctly above the mean value of German institutions with 0.510. The high

Table 2 - Efficiency Values

	Mean efficiency	**Std. Dev.**	**Minimum**	**Maximum**
Italy, Overall	0.708	0.097	0.384	0.910
Italy, *Transient*	0.904	0.033	0.497	0.975
Italy, *Persistent*	0.783	0.102	0.459	0.940
Germany, Overall	0.510	0.158	0.194	0.853
Germany, *Transient*	0.901	0.033	0.638	0.983
Germany, *Persistent*	0.565	0.172	0.223	0.907

Source: Own calculations.

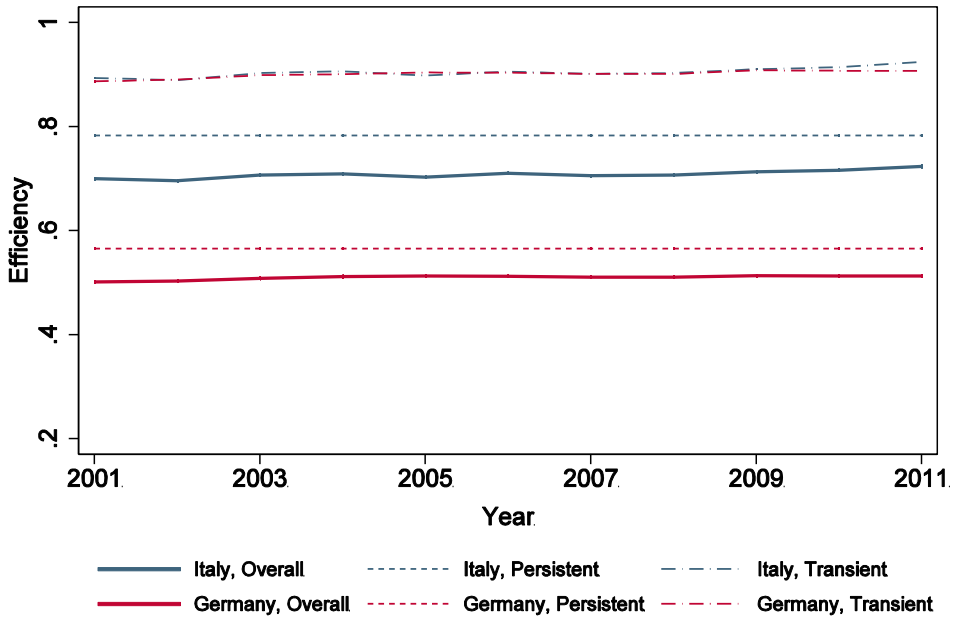
[18] This could be driven, amongst other factors, by the central government in Italy. Diversity efforts of the federal states in Germany presumably lead to a more evenly distributed funding, probably due to risk aversion.

[19] The cluster analysis originally assigned six technical universities to the third group. For the later use of the clusters in the interpretation of the results we choose to allocate all technical universities to the group.

and similar short-term *institutional efficiency* shows that universities in both countries work at the upper bound of efficiency possibility. Instead, the inefficiency and therefore the overall disparity between the two HE sectors is driven by long-term *structural inefficiency*. Italian universities exhibit a higher persistent efficiency than their German counterparts leading to the overall higher efficiency value. Figure 3 confirms that this result holds true over the whole timeframe. The figure also displays that the *institutional efficiency* varies over time, with each country performing best, confirming the proximity of this term for both countries. Drawing a first conclusion, the results indicate that, while the individual institutions work efficient, the HE structure in both countries needs improvement to obtain significant efficiency gains. The Italian HE structure leads to a higher performance than the German, causing the overall gap between the states.

This outcome confirms the results by Titus et al. (2016) for teaching oriented master institutions (in the United States) as well as the study by Gralka (2016) for German public universities, showing that inefficiency in each country is driven by the persistent term. Nevertheless, the comparison of two countries within one analysis allows to take a further essential conclusion, the *structural efficiency* not only drives the overall inefficiency in single countries but also the differences in efficiency between them. The in-comparison contradicting results to the study by Agasisti and Pohl (2012), who conclude that German universities are more efficient, are driven by methodological as well as content-related differences. The authors apply a DEA and therefore consider different as well as multiple inputs. Additionally, they miss the opportunity to control for heterogeneity of institutions, which according to the data examination is an important issue. Furthermore, the study is characterized by a different time frame as well as variable choice and definition.

Figure 3 – Efficiency over Time



Subsequent to the short analysis of the absolute values and development of efficiency over time, a more thorough assessment of the results is necessary. Therefore, Figure 4 gives the kernel distribution of the estimated efficiency values for both countries. The distributions are well shaped. The picture confirms the finding that the estimated values for the Italian universities are higher than the efficiency of the German institutions, driven by the persistent term. The figure also verifies the close correlation of the transient efficiency in both countries. It is additionally important to verify whether the efficiency results are definite. The plot of the confidence interval in Figure 5 shows that the method can clearly discriminate between the highest and lowest performing universities in both countries. Therefore, there are no objections in this context regarding the usage of a methodological approach that assumes inefficiency in production.

Figure 4 – Kernel Density

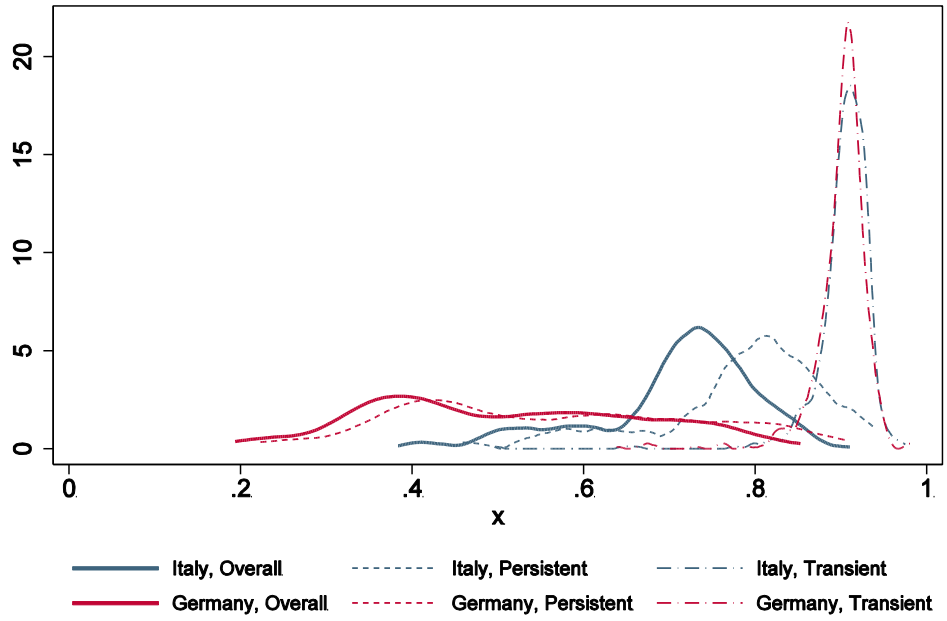
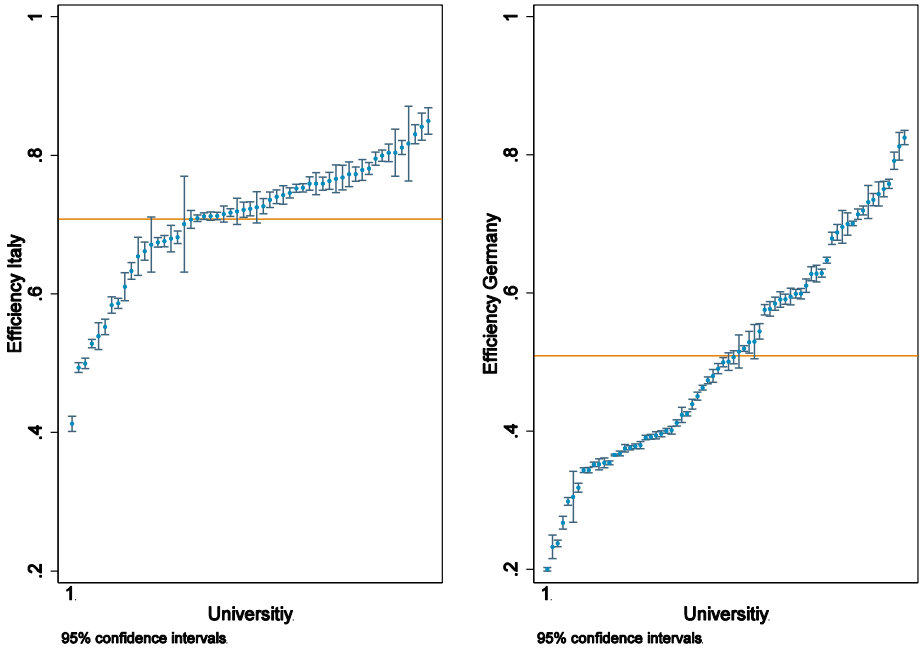


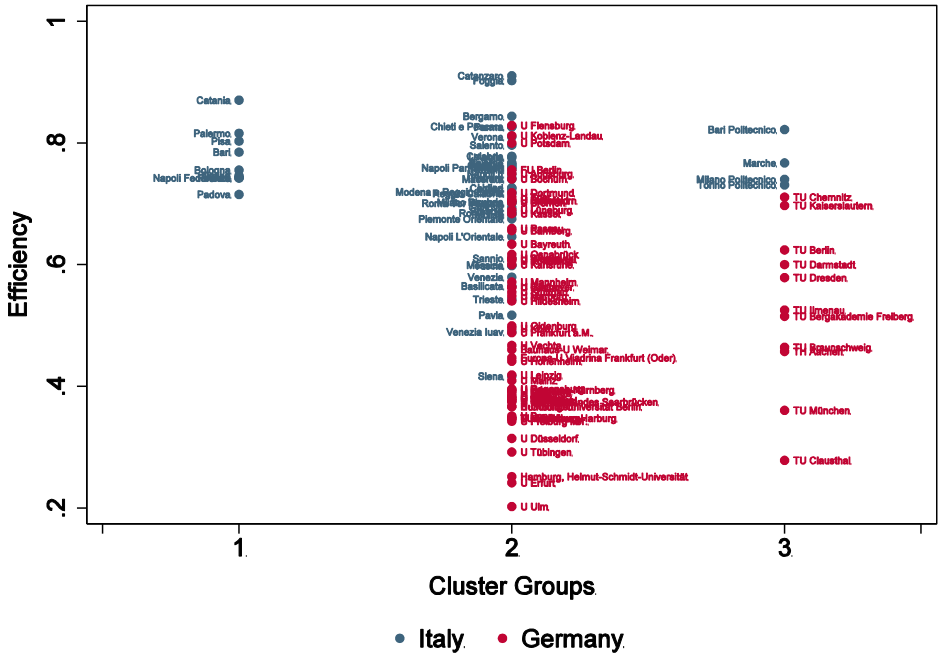
Figure 5 – Efficiency Score and associated 95 percent Confidence Interval by University



Having estimated the efficiency values for each institution it is insightful to connect them to the clusters we obtained in the data evaluation. The grouping according to the annual cost, third party funding and students lead to three distinct groups, the first containing the largest institutions of the sample (all located in Italy), the second encompassing almost all German and the majority of Italian universities and the third including the technical institutions. Figure 6 shows the three determined groups in relation to the estimated efficiency for the year 2011. In all three cases, the Italian institutions exhibit a higher efficiency than the German universities, confirming the previous drawn result. The biggest universities are characterized by an overall high efficiency value showing that the allowance for universities to grow in the Italian HE sector can be evaluated positively, most likely for the ability of these institutions to benefit from significant economies of scale. The second group relates closely to the kernel distribution of Figure 4, showing that Italian universities not only exhibit a higher mean efficiency but also indicating that the lower bound of efficiency is higher than the limit for the German institutions. The technical universities in the third group are in comparison widespread along the efficiency scale, with the Italian institutions being more efficient than the German ones again.

Knowing that the overall inefficiency in both countries is caused by the persistent term and seeing in Figure 4 and Figure 6 that the distribution of efficiency values in the German HE sector is more widespread, a concluding look at both terms of efficiency for each institution is insightful. Figure 7 and Figure 8 display them for the year 2011 sorted by the persistent term. The figures

Figure 6 – Evaluated Cluster and Efficiency (2011)



illustrate that the universities with low persistent efficiency are not necessarily the ones with the lowest transient efficiency and vice versa. This indicates that individually efficient working institutions can possess a low overall efficiency value driven by the *structural efficiency*, reflecting an undesirable influence of the HE structure. In addition, it is obvious that, while the *institutional term* seems to vary at a certain efficiency level, the *structural term* shows a stronger disparity among the institutions. The variation is thereby larger in Germany than in Italy. While both countries exhibit institutions with high *structural efficiency*, the German universities feature a lower value. The German HE structure therefore seems to influence the institutions to a more diversified and in some cases more disadvantageous extent.

Figure 7 – Efficiency per Italian Institution

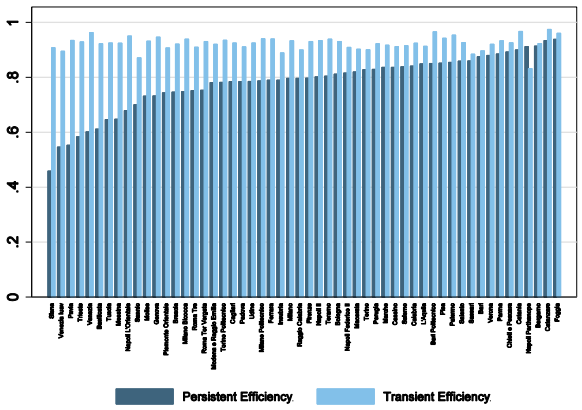
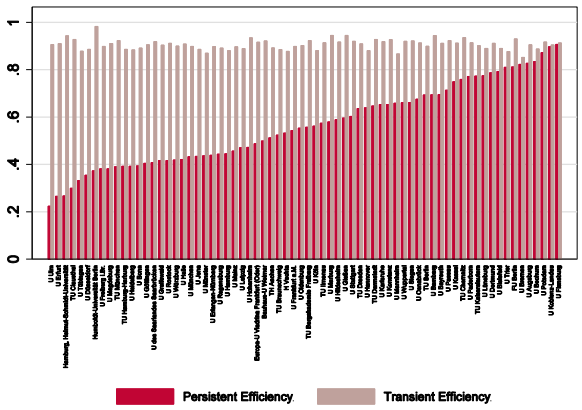


Figure 8 – Efficiency per German Institution



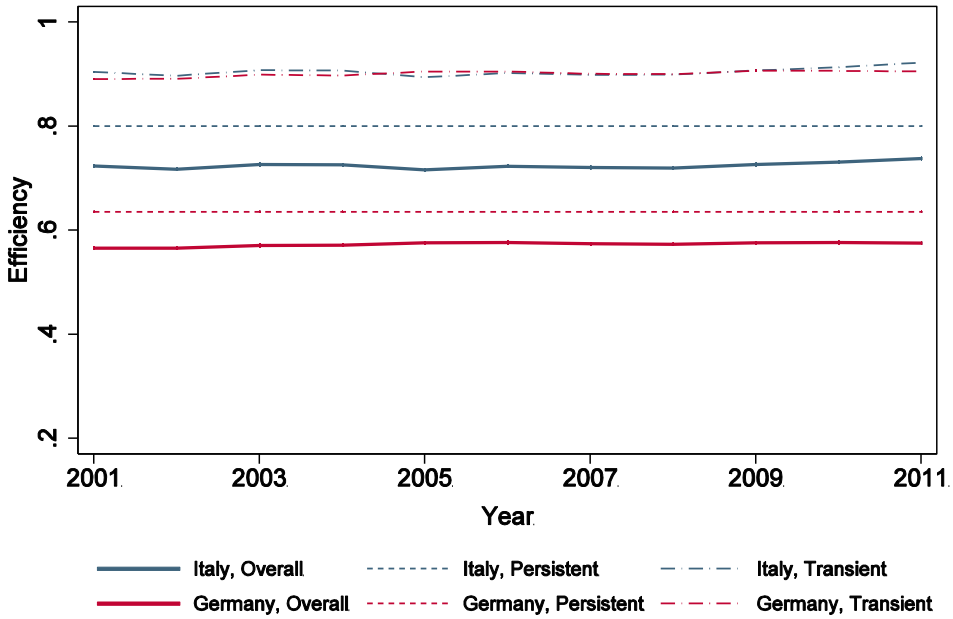
7. Sensitivity Analysis

To illustrate potential biases caused by the selection of variables, time frame and method, we also test three further variations of the specification. Firstly, since Agasisti and Haelermans (2016) show that it is important to take into account the different political incentive systems of each considered country, we examine if the outcome differs when teaching is represented by graduates instead of students. Secondly, the robustness of the results is checked by splitting the timeframe into two periods. Lastly, we test if the heterogeneity assumption in our specification influences the presented overall results.

7.1 Students vs Graduates

While it is a common assumption within the efficiency analysis to represent teaching by the total number of students differentiated across subject groups the output can likewise be represented by the graduates of a university [see Agasisti and Haelermans (2016) for a detailed discussion]. The descriptive statistics in Table 1 demonstrate that, similar to the distribution of students, Italy has more graduates in science and non-science subjects. Looking at the relation of students to graduates only the subject group medicine differs, with Germany possessing more graduates in the absolute as well as the relative comparison. Since Agasisti and Haelermans (2016) show that the inclusion of one or the other teaching output can lead to strongly different results, we examine if and how our results change if graduates instead of students are encompassed in the regression. The results of the SFA specification, including graduates instead of students, by Kumbhakar et al. (2014) are graphically represented in Figure 9. While the results slightly change, with German institutions becoming relatively more efficient, the overall results

Figure 9 – Graduate Model

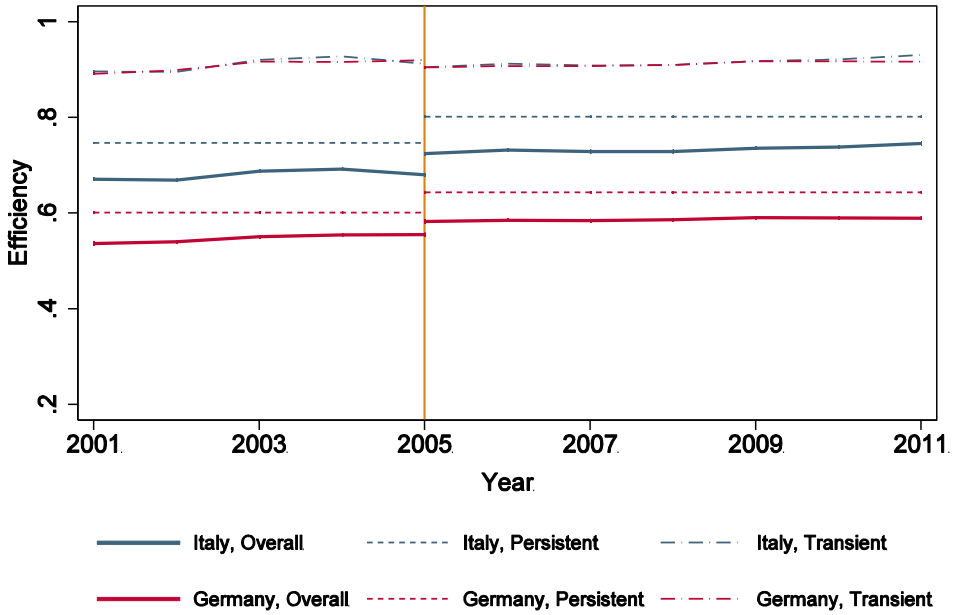


remain unaffected (Italy 0.724 / Germany 0.572). Italian universities are more efficient than their German counterparts, this situation being driven by the persistent term of efficiency. We can therefore conclude that the results are robust to different specifications of the teaching output of the institutions.

7.2 Timeframe

Due to the assumption that the persistent term of efficiency is stable over the whole-time period one can assume that the mean value depends on the considered time frame. The robustness of the results is therefore additionally tested by splitting the sample into different, unequally long periods, similar to the procedure by Abbott and Doucouliagos (2009). While the first time frame covers the years 2001-2005, the second represents the years 2005-2011. Again, the overall efficiency only varies slightly and is comparable to the values of the baseline model. The mean efficiency values for the split sample are slightly higher (Italy 0.680 and 0.733 / Germany 0.547 and 0.587) than the value for the entire time frame (Italy 0.708 / Germany 0.510). Due to the dependence of the efficiency values from the overall sample, small variations are to be expected. Figure 10 additionally shows that while the estimated transient efficiency of the first timeframe is similar to the second, the persistent and overall terms are slightly lower in the first period. However, the estimation shows definite similarities to the baseline model, and the main result of the estimation remains unchanged, that is, Italian universities are more efficient than their German counterparts, driven by the persistent term of efficiency. It can therefore be derived that the findings are also robust with regard to the considered time period.

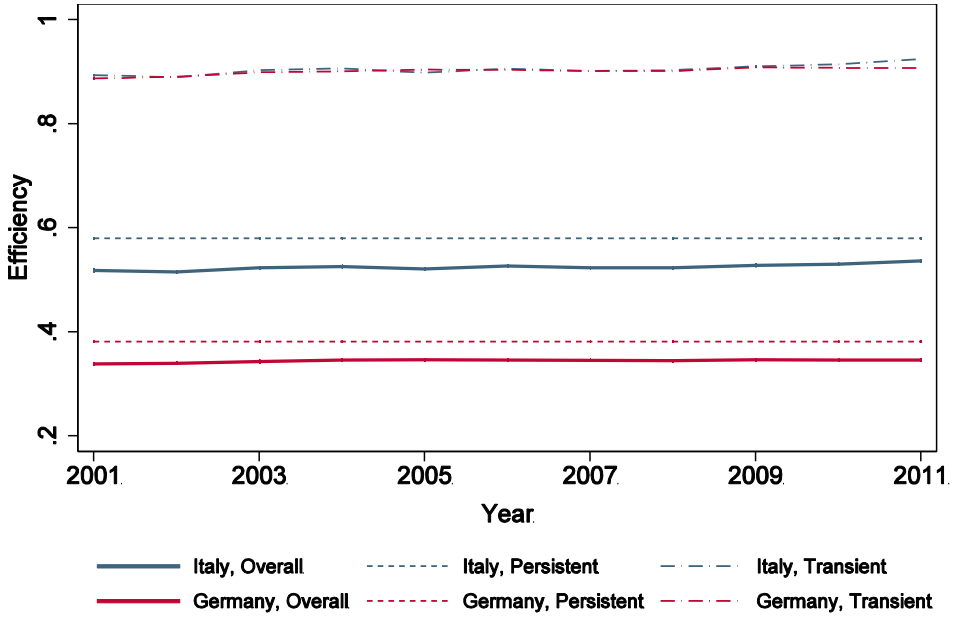
Figure 10 – Timeframe



7.3 Heterogeneity

Given the fact that the specification by Kumbhakar et al. (2014) accounts for heterogeneity, controlling for institutional long-term characteristics, the question can be raised, if one accidently picks up a share or the complete structural differences between countries, which is supposed to be measured. To deal with these challenges, the specification by Kumbhakar and Heshmati (1995) is additionally estimated and compared to the foreshown results[20]. The difference between the two specification lies within the assumption regarding heterogeneity. The earlier model contains only one time-invariant parameter in the estimation, namely persistent efficiency. Heterogeneity is compound in the efficiency term, assumable leading to an overall relatively low estimated efficiency value. If our assumption is right and heterogeneity is only accounted for at the individual level in our preferred specification, one would expect that the estimated values of the earlier specification are lower (since unchangeable factors are still included in the efficiency term) and the overall results to be unchanged. Figure 11 shows the estimated results and confirms the theoretical expectations. The efficiency values are lower for both countries, showing that heterogeneity is an important factor in both HE sectors. The mean efficiency of the Italian HE sector lies distinctly above the mean value of German institutions (Italy 0.524 / Germany 0.344), driven by the persistent term of efficiency. Our results are therefore robust even when different assumptions about the role of universities' heterogeneity are made.

Figure 11 – Kumbhakar and Heshmati (1995)



[20] Estimation Equation can be found in the Technical Appendix T2.

8. Policy and Research Implications

The results presented in this paper must be read in the light of the afore-identified characteristics of the HE sector of both countries. Since the differences between the countries relate strongly to the respective HE structure, they can mainly be observed in the *structural efficiency*. As debated in Section 4 the supervision of universities, by a central government or the federal states, is the greatest deviation between the two considered countries and expectedly affects the efficiency considerably. The cluster analysis showed that the Italian HE sector allows institutions to grow bigger, which could at least partly be driven by the fact that a federal system presumably leads to a more evenly distributed funding and therefore more evenly sized institutions. The federal system could also be seen as a cause for the stronger variation of the *structural efficiency* in the German HE sector, with federal governments managing institutions in varying ways and aiming for dissimilar long-term goals. The second major difference relates to the composition of the HE sector. While the Italian universities service all students, German high school graduates can choose between “Fachhochschule” and university for their study. This could explain the higher number of students at Italian universities as well as their bigger size. The third difference is linked to the levying of tuition fees, with Italian universities charging a high all-purpose fee. Taking into consideration the higher costs, Italian high-school graduates who decide to go to university presumably have a higher graduation probability than their German counterparts. This is reflected in the descriptive statistics of Table 1 showing a higher graduation rate for Italian science and non-science students. The higher rate at which Italian students complete their tertiary education degree can be a factor that can affect the overall efficiency of operations at least for the teaching activities.

The implications that can be drawn from the present study are threefold, with a research as well as general and country specific policy perspective. Firstly, the present paper makes an important extension to the literature, showing that it is necessary to separate two types of efficiency, to account for the two management levels of universities. The application of the novel specification by Kumbhakar et al. (2014) allows to separately evaluate the individual HE Institutions and the overall HE structure of the countries HE sector. This is of particular interest whenever the HE sectors of different countries are compared. If the focus of assessment is on the efficiencies of the individual universities within different states, it is necessary to account for the influence of the HE structure and not only the operations of the individual institutions. If in turn the HE structure is to be evaluated, one should control for the efforts of the individual institutions within the assessed country. Statements regarding either, the individual institutions or the HE structures, are only possible if the efficiency term is separated. To show the advantages of the new specification and point out our argumentation, we limited the present study to two countries. The results confirm our line of reasoning and show the necessity to evaluate a broader sample of

countries. Future studies would also benefit from a richer data set, particular in regard to the personnel composition and the wage level of institutions. In addition, extending the analysis to other countries can be a valuable direction to extend the drivers of efficiency of European HE systems.

Secondly, drawing a line to the introduction and the motivation of this study, the results also have clear policy implications. While there only seems to be a small efficiency potential for the management of universities, there are great possibilities to raise the efficiency by structural improvements. To expedite a true European Area of Higher Education future measures should therefore aim at the country specific structure, not at the universities. Differences in the HE structures of EU member states have to be identified, confronted and evaluated in context of the *structural efficiency*. In this perspective, there is probably a growing room for studies that analyze the determinants of efficiency of HE systems as a whole, in the spirit of early studies conducted by Agasisti (2011) and Pereira and Aubyn (2009).

Thirdly, while the universities in both evaluated countries work equally efficient, the Italian HE structure seems to be preferable to the German. Independent of European convergence goals this has a clear implication for German policy makers. To see which factors of the HE structure have to be adjusted to raise efficiency, a thorough assessment of the structural differences between the two states and an evaluation of their possible influences on the *structural efficiency* is necessary.

9. Conclusion

In light of recent European measures to increase the compatibility of the HE sectors between countries and the parallel demonstrated variations in their efficiency, the present study examines two sources of inefficiency. Utilizing a recent methodologically advancement by Kumbhakar et al. (2014) the efficiency term is split, according to the management levels of universities. We consider transient efficiency, of the individual universities working within the country and persistent efficiency, which is caused by the country specific overall HE structure. While the first term displays how the institutions operate with the available resources within the HE sector, the second term reflects its structural characteristics, representing the country specific mechanisms for funding and competition.

To answer the question whether efficiency differences between countries are related to the individual performance of the universities working within the HE sector or the HE structure, we explore the developments in two large European HE Countries (Germany and Italy) for an exceptional long period of time. We demonstrate that both countries exhibit a high and similar short-term *institutional efficiency*, showing that universities in both countries work at the upper bound of efficiency. Instead, the inefficiency and therefore the overall disparity between the two HE sectors is driven by long-term *structural inefficiency*. The country specific characteristics seem

to influence the universities to a strong and disadvantageous extend. We show that Italian institutions exhibit an average higher *structural efficiency*, with an overall relatively similar influence for each university. The German institutions display an in-contrast lower mean efficiency value, with a more varied influence for each university.

Our findings are important for expanding the literature about the cross-national comparison of universities' efficiency that, despite its relevance, is still in its infancy [Wolszczak-Derlacz and Parteka (2011)]. It is innovative because it is the first time that the efficiency term is split according to the management level of the institutions, within a cross-country comparison of the HE sector. It shows if one HE structure is preferable to another and facilitates the subsequent deduction of objectives. But, as pointed out by De Witte and López-Torres (2017) one should be aware that efficiency (doing things right), should ideally not be seen separately from effectiveness (doing the right things). It has to be noted that the present study, as most efficiency analysis before, is not able to make statements about the quality of education or the equality of learning outcomes.

The present paper can be seen as a starting point, demonstrating the advantages of the approach as well as the necessity to apply the method on a broader sample. The novel interpretation also opens up the possibility for new analysis in other similar structure areas, especially in the public sector.

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Appendix

A.1 - Regression Results

		Kumbhakar et al. (2014)	
TPF		0.415***	(0.037)
Stud, Sc		0.350***	(0.037)
Stud, NSc		0.349***	(0.037)
Stud, Med		0.222***	(0.023)
TPF2		0.045***	(0.004)
Stud2, Sc		0.044***	(0.004)
Stud2, NSc		0.059***	(0.004)
Stud2, Med		0.021***	(0.003)
Stud, Sc	* TPF	-0.003	(0.002)
Stud, NSc	* TPF	0.009***	(0.003)
Stud, Med	* TPF	0.002	(0.001)
Stud, Sc	Stud2, NSc	-0.052***	(0.006)
Stud, Sc	Stud2, Med	-0.003	(0.003)
Stud2, NSc	Stud2, Med	-0.014***	(0.003)
Constant		-1.702***	(0.146)
σ_u^2 *from step 2*		0.018***	
σ_v^2 *from step 2*		0.027***	
σ_u^2 *from step 3*		0.346***	
σ_v^2 *from step 3*		0.031***	
No. of observations		1375	
No. of institutions		125	

Source: Own calculations.

Note: *p=0.01, **p=0.005, ***p=0.001; Std. Err. in parentheses.
The estimation results are from the baseline model, first step.

Abbreviations: TPF = Third Party Funding.

A.2 – Average Efficiency per University

University	Country	Overall	*Transient*	*Persistent*
Bari	italy	0.795	0.908	0.876
Bari Politecnico	italy	0.766	0.900	0.851
Basilicata	italy	0.552	0.903	0.612
Bauhaus-U Weimar	germany	0.451	0.903	0.499
Bergamo	italy	0.830	0.909	0.914
Bologna	italy	0.736	0.906	0.812
Brescia	italy	0.676	0.906	0.746
Cagliari	italy	0.712	0.908	0.784
Calabria	italy	0.763	0.907	0.841
Cassino	italy	0.759	0.908	0.837
Catania	italy	0.804	0.894	0.900
Catanzaro	italy	0.841	0.901	0.934
Chieti e Pescara	italy	0.811	0.909	0.893
Europa-U Viadrina Frankfurt (Oder)	germany	0.439	0.901	0.488
FU Berlin	germany	0.732	0.901	0.812
Ferrara	italy	0.715	0.906	0.790
Firenze	italy	0.723	0.906	0.797
Foggia	italy	0.850	0.905	0.939
Genova	italy	0.654	0.893	0.733
H Vechta	germany	0.480	0.902	0.532
Hamburg, Helmut-Schmidt-Universität	germany	0.233	0.872	0.267
Humboldt-Universität Berlin	germany	0.305	0.818	0.373
Insubria	italy	0.717	0.908	0.790
L'Aquila	italy	0.768	0.904	0.850
Macerata	italy	0.743	0.906	0.820
Marche	italy	0.759	0.908	0.836
Messina	italy	0.586	0.905	0.648
Milano	italy	0.721	0.906	0.796
Milano Bicocca	italy	0.671	0.897	0.748
Milano Politecnico	italy	0.701	0.890	0.787
Modena e Reggio Emilia	italy	0.709	0.908	0.781
Molise	italy	0.662	0.904	0.732
Napoli Federico II	italy	0.740	0.907	0.816
Napoli II	italy	0.727	0.906	0.802
Napoli L'Orientale	italy	0.610	0.898	0.679
Napoli Parthenope	italy	0.817	0.896	0.912
Padova	italy	0.712	0.908	0.785
Palermo	italy	0.773	0.904	0.855
Parma	italy	0.804	0.908	0.885
Pavia	italy	0.500	0.903	0.553
Perugia	italy	0.753	0.908	0.829
Piemonte Orientale	italy	0.674	0.907	0.744
Pisa	italy	0.773	0.907	0.852

Reggio Calabria	italy	0.719	0.903	0.796
Roma La Sapienza	italy	0.746	0.908	0.821
Roma Tor Vergata	italy	0.680	0.903	0.753
Roma Tre	italy	0.682	0.906	0.752
Salento	italy	0.779	0.906	0.859
Salerno	italy	0.759	0.905	0.839
Sannio	italy	0.633	0.904	0.701
Sassari	italy	0.781	0.908	0.860
Siena	italy	0.412	0.899	0.459
TH Aachen	germany	0.463	0.904	0.512
TU Bergakademie Freiberg	germany	0.501	0.898	0.558
TU Berlin	germany	0.629	0.906	0.694
TU Braunschweig	germany	0.474	0.904	0.524
TU Chemnitz	germany	0.688	0.905	0.760
TU Clausthal	germany	0.267	0.892	0.300
TU Darmstadt	germany	0.585	0.904	0.647
TU Dresden	germany	0.576	0.905	0.636
TU Hamburg-Harburg	germany	0.352	0.897	0.392
TU Ilmenau	germany	0.520	0.905	0.574
TU Kaiserslautern	germany	0.696	0.900	0.773
TU München	germany	0.352	0.901	0.390
Teramo	italy	0.725	0.901	0.805
Torino	italy	0.752	0.908	0.828
Torino Politecnico	italy	0.707	0.905	0.782
Trieste	italy	0.528	0.904	0.584
Tuscia	italy	0.584	0.903	0.646
U Augsburg	germany	0.751	0.907	0.828
U Bamberg	germany	0.628	0.904	0.694
U Bayreuth	germany	0.628	0.904	0.695
U Bielefeld	germany	0.719	0.908	0.793
U Bochum	germany	0.758	0.908	0.835
U Bonn	germany	0.354	0.899	0.394
U Bremen	germany	0.743	0.903	0.823
U Dortmund	germany	0.714	0.907	0.787
U Düsseldorf	germany	0.318	0.897	0.355
U Erfurt	germany	0.238	0.895	0.265
U Erlangen-Nürnberg	germany	0.396	0.902	0.439
U Flensburg	germany	0.825	0.909	0.908
U Frankfurt a.M.	germany	0.490	0.903	0.543
U Freiburg i.Br.	germany	0.343	0.901	0.381
U Gießen	germany	0.530	0.889	0.596
U Greifswald	germany	0.375	0.901	0.416
U Göttingen	germany	0.366	0.903	0.405
U Halle	germany	0.380	0.902	0.421
U Hamburg	germany	0.401	0.901	0.445
U Hannover	germany	0.577	0.903	0.639
U Heidelberg	germany	0.354	0.902	0.393

U Hildesheim	germany	0.529	0.898	0.589
U Hohenheim	germany	0.424	0.897	0.472
U Jena	germany	0.392	0.903	0.434
U Karlsruhe	germany	0.591	0.905	0.653
U Kassel	germany	0.679	0.906	0.749
U Koblenz-Landau	germany	0.812	0.905	0.897
U Konstanz	germany	0.591	0.904	0.654
U Köln	germany	0.507	0.902	0.562
U Leipzig	germany	0.425	0.903	0.471
U Lüneburg	germany	0.700	0.904	0.775
U Magdeburg	germany	0.344	0.901	0.381
U Mainz	germany	0.412	0.903	0.456
U Mannheim	germany	0.595	0.903	0.659
U Marburg	germany	0.515	0.888	0.580
U München	germany	0.391	0.903	0.433
U Münster	germany	0.394	0.902	0.437
U Oldenburg	germany	0.500	0.904	0.553
U Osnabrück	germany	0.611	0.904	0.675
U Paderborn	germany	0.701	0.908	0.772
U Passau	germany	0.647	0.907	0.714
U Potsdam	germany	0.791	0.908	0.872
U Regensburg	germany	0.401	0.903	0.444
U Rostock	germany	0.376	0.902	0.417
U Siegen	germany	0.599	0.905	0.662
U Stuttgart	germany	0.545	0.903	0.603
U Trier	germany	0.735	0.907	0.810
U Tübingen	germany	0.298	0.898	0.332
U Ulm	germany	0.200	0.896	0.223
U Wuppertal	germany	0.599	0.906	0.661
U Würzburg	germany	0.378	0.902	0.419
U des Saarlandes Saarbrücken	germany	0.368	0.902	0.408
Udine	italy	0.713	0.908	0.785
Venezia	italy	0.539	0.896	0.602
Venezia Iuav	italy	0.494	0.903	0.547
Verona	italy	0.800	0.909	0.880

Technical Annex

T.1 Kumbhakar, Lien and Hardaker (2014)

The model by Kumbhakar et al. (2014) is specified as:

$$c_{it} = \alpha_0 + f(x_{it}, \beta) + \varepsilon_{it} \quad \text{with} \quad (2)$$

$$\varepsilon_{it} = v_{it} + \rho_i + \mu_i + \tau_{it}$$

$$v_{it} \sim iid\ N(0, \sigma_v^2)$$
$$\rho_i \sim iid\ N(0, \sigma_\rho^2)$$
$$\mu_i \sim N^+(0, \sigma_\mu^2)$$
$$\tau_{it} \sim N^+(0, \sigma_\tau^2)$$

Again, the term v_{it} denotes the normally distributed noise term, ρ_i represents heterogeneity and μ_i the persistent and τ_{it} the residual efficiency. Following Kumbhakar et al. (2015) the specification is estimated in the following three steps:

Step 1: Standard random effect panel data estimator on:

$$c_{it} = \alpha_0^* + f(x_{it}, \beta) + \alpha_i + \varepsilon_{it} \quad \text{with} \quad (3)$$

$$\alpha_0^* = \alpha_o - E(\mu_i) - E(\tau_{it})$$

This provides estimates on $\hat{\beta}$ as well as predictions for $\widehat{\alpha_i}$ and $\widehat{\varepsilon_{it}}$, which will be used in the following steps.

Step 2: Stochastic frontier model for panel data on:

$$\varepsilon_{it} = v_{it} - \tau_{it} + E(\tau_{it}) \quad (4)$$

using the estimated values of $\widehat{\varepsilon_{it}}$.

Applying the Battese and Coelli (1988) procedure we obtain predictions of the time-varying residual technical efficiency component τ_{it}.

Step 3: Stochastic frontier model for cross-section data on:

$$\alpha_i = \mu - \mu_i + E(\mu_i) \quad (5)$$

using the estimated values of $\widehat{\alpha_i}$.

Applying the Battese and Coelli (1988) procedure we obtain predictions of the persistent technical efficiency component μ_i.

The overall technical efficiency is then obtained from the product of τ_{it} and μ_i.

T.2 Kumbhakar and Heshmati (1995)

In the specification by Kumbhakar and Heshmati (1995) the efficiency term is divided and persists of a residual (short-term) and a persistent (long-term) part. Hence the estimation contains only one time-invariant parameter, namely persistent efficiency. Structural differences between institutions are compound in the efficiency term, assumable leading to an overall relatively low estimated efficiency value. The model is specified as:

$$ln\, C_{it} = \alpha + f(Q_{it}, w_{it}) + v_{it} + u_{it} \qquad \text{with} \qquad u_{it} = \mu_i + \tau_{it} \tag{6}$$

As before the term v_{it} denotes the normally distributed noise term and u_i captures efficiency differences across observations. Overall efficiency (u_{it}) is composed of two distinct components, μ_i the persistent and τ_{it} the residual efficiency

A multistep procedure is implemented for the estimation (see Kumbhakar et al. (2015) for a detailed review). While the inclusion of persistent effects is insightful, the clear drawback of the model is that, firm specific effects (heterogeneity) are entirely treated as (persistent) inefficiency.