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Economies of scale and scope of universities – towards bigger size and specialization?

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Abstract

This paper provides an estimation of the specific cost structure of the Italian public universities, considering their complex function of producing teaching and research. The analysis employs a quadratic cost function and an innovative dataset for the year 2016. When modelling the cost structure, we explicitly take the potential inefficiency into account, using a Stochastic Frontier Analysis. Current levels of marginal and average costs suggest that economies of scale can be still exploited. Strong diseconomies of scope between teaching and research also exist. Policies dealing with mergers and specialization are justified from the cost-efficiency point of view.

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1. Introduction

The estimation of universities' cost functions provides an essential analytical basis for discussing crucial economic issues about the higher education (HE) system, and particularly its financing mechanism. There is a growing demand for reliable information reporting the efficiency of institutions in several countries that are reforming their HE sector (Wolszczak-Derlacz 2017).

The Italian HE system has gone through several institutional changes in the last ten years, some of which related to its financing mechanism. Exploiting the introduction (2015) of a mandatory adoption of the accrual accounting system for all Italian universities, we use the new accounting data (year 2016) for the estimation of a multi-product cost function, considering different outputs: undergraduate and graduate students, doctoral students and research. Since we employ a multi-product cost function, we estimate product-specific and Ray economies of scale for the whole Italian HE sector. The former represents crucial information for the implementation of the main pillar of the new financing system of Italian universities, namely the "standard cost per student", which is currently based on a substantially uniform cost per student. Furthermore, we analyze the potential economies of scope between research and teaching activities. This information contributes to the ongoing political and institutional debate about the desirability of a policy aimed at inducing a specialization of higher education institutions (this debate is particularly fierce internationally, see Zhang and Worthington 2018).

Even if there have been previous attempts to estimate a cost function for the Italian universities (Agasisti and Salerno 2007, Agasisti and Johnes 2010, Agasisti 2016), our contribution is substantially different for the innovative nature of the data we use. The existing works are based on financial accounting data, while we use accrual accounting data comparable and homogenous with the ones used in most international literature. Second, we are able to use the number of publications, classified according to different categories, to represent the research output of universities, instead of the financial value of research grants.

In section 2 we briefly describe the background and framework for the empirical analysis, while section 3 illustrates the empirical model and data. Section 4 reports and discusses the results; section 5 concludes.

2. Background and framework

Italy, like several other countries, has experienced a severe decline in the amount of financial resources accruing to HE institutions in the last ten years. The most recent international data (OECD 2019) reveal that the OECD average total expenditure on tertiary educational institutions as a percentage of GDP, in 2016, was about 5% less than in 2010. In this context, there is a general quest for efficiency for maintaining an adequate level of teaching and research production. The objective of improving the efficiency of higher education institutions is also relevant for governance purposes, especially when we consider the allocation mechanisms of public funding to every single institution. Italy's current funding scheme is based partly on historical trends and partly on performance indicators. The most innovative component is related to the computation of a "standard cost" (SC) per student for each institution; in the government's plans, SC-based allocation will cover 70% of the allocation of the entire budget. The nature of this allocation mechanism is of the fixed-price type, since universities are (partially) reimbursed on the basis of a predetermined amount and not on their actual costs. The computation of the standard cost per student, however, does not ensure that its outcome reflects appropriate conditions of efficient production of the teaching activity. Indeed, the parameter is based on the aggregation of different cost items (teaching and administrative staff, operating costs, etc.) whose computation reflects a predetermined standard for each item.

The estimation of a cost function (as conducted in this paper) is useful to understand whether the current values of standard costs are different from the efficient ones. Moreover, it provides essential information on the structure of costs and, in particular, on the potential economies of scale. Finally, it allows exploring the cost-efficiency impact of HE institutions' specialization, with one of the potential lines of differentiation being between research and teaching.

3. Model and data

In this paper we use a quadratic specification for the cost function, coherently with some of the best practices in this literature (Cohn and Cooper 2004):

$$TC = \beta_1 Students + \beta_2 PhD + \beta_3 Research + \beta_4 Students^2 + \beta_5 PhD^2 + \beta_6 Research^2 + \beta_7 Students * Phd + \beta_8 Students * Research + \beta_9 Research * Phd + \beta_{10} Geo \quad (1)$$

Total costs (TC) include all the operating expenses, net of financial interests and unusual expenses. We identify three different outputs: students (undergraduate and graduate), PhDs and research. As for the variable STUDENTS, we consider, for each institution, the total number of bachelor and master students in the academic year 2015-2016. We weight the number of students enrolled in each degree programme, by the ratio of the standard number of teaching staff and the standard number of students (as determined by the national regulations for each programme). PHD is the number of PhD students in the academic year 2015-2016. As for RESEARCH, we use a measure of the number of total works published by the faculty members of each institution. Our data differentiate documents according to a national categorization of the disciplinary areas – i.e. bibliometric vs non-bibliometric. For each area, documents are weighted by publication type (articles in Scopus, books, chapters, etc.), according to weights, whose details are reported in Section A1 of the Annex.

The variable GEO is a categorical variable representing the geographical area where an institution is located: Northern, Central and Southern Italy, aiming at capturing potential contextual effects (this is common for most studies of the efficiency of Italian public services, given the wide regional differences). We do not include a variable reflecting prices of inputs, as salary standards are uniform across the country and they represent the main input factor. Table I provides a summary of the definition of the variables.

The empirical analysis considers a sample of 59 Italian State universities (out of 61 operating in the country): for one there was no financial data, and we excluded Sapienza University of Rome because of its out-of-scale size. We did not include non-State (private) universities in our analysis.

The data come from several official sources, all aggregated by the Ministry of Education and the National Agency for the Evaluation of Research (ANVUR).

Table I. Description of the variables included in the empirical model

Variable name	Definition	Description
TC	Operating Expenses	Operating Expenses of universities in 2016, expressed in thousand euros
Geo	Geographic Area	Categorical variable for university location. Three categories are considered: North, Centre and South (including islands) of Italy.
Students	Students	Number of students in the master's and the bachelor's degree programmes, in the academic year 2015/2016. The number of bachelor students and master students (including Laurea Magistrale, Laurea a Ciclo Unico, Laurea del Vecchio Ordinamento) are calculated as the sum of the number of students, weighted by the ratio of the standard number of teaching staff to the standard number of students, per degree programme type. The standard number of teaching staff and of students per degree programme type is provided by the Italian Ministry of Education. The weights are normalized, taking as reference the value for the scientific and technological courses in bachelor programmes (0.03 teaching staff/student, weight=1).
PhD	PhD Students	Number of PhD students in the academic year 2015/2016.
Research	Research	The overall research is defined as the sum of Bibliometric Research and Non-Bibliometric Research. The bibliometric research is calculated as a weighted sum of the number of bibliometric documents in 2016 and considers the number of articles in Scopus (weight: 1), the number of articles not in Scopus (weight: 0.5), other bibliometric documents, such as book chapters, conference papers, conference reviews, editorial, articles in press (weight: 0.3). The non-bibliometric research is defined as a weighted sum of the number of non-bibliometric documents in 2016 and considers the number of articles and monographs (weight: 1), the number of book chapters (weight: 0.7) and other non-bibliometric documents, such as abstracts, bibliography, datasets, posters, prefaces (weight: 0.3).

Note: Authors’ elaboration.

4. Results

4.1. Estimates

The results about the estimation of the cost function are presented in Table II. We report six alternative specifications, i.e. by including/excluding quadratic and interaction terms, as well as the constant. The model well approximates the cost function of universities (R^2 is >0.9) notwithstanding the lack of statistical significance of many independent variables, especially quadratic and interaction terms, that can be attributed to the small number of observations.

Table II. Regression results – cost function of Italian universities

VARIABLES	(R1) TC	(R2) TC	(R3) TC	(R4) TC	(R5) TC	(R6) TC
Research	26.7624***	26.1219***	27.0113***	26.5265***	27.4430**	25.9407**
	(4.4971)	(4.4373)	(9.4005)	(9.2737)	(12.3950)	(12.1202)
Students	2.8637***	2.9635***	2.5926*	2.7182**	3.2064	3.5140*
	(0.6598)	(0.6500)	(1.3839)	(1.3480)	(1.9686)	(1.9032)
PhD	51.6888***	55.0028***	73.4746	81.0571*	34.5559	45.9719
	(12.8284)	(12.3000)	(45.7739)	(42.5705)	(50.0815)	(46.8212)
Research2			-0.0000	0.0001	-0.0067	-0.0069
			(0.0007)	(0.0007)	(0.0080)	(0.0079)
students2			0.0000	-0.0000	-0.0001	-0.0001
			(0.0000)	(0.0000)	(0.0002)	(0.0002)
phd2			-0.0115	-0.0152	-0.0431	-0.0451
			(0.0226)	(0.0210)	(0.0345)	(0.0342)
Students* PhD					0.0004	0.0005
					(0.0035)	(0.0035)
Research*Students					0.0015	0.0017
					(0.0021)	(0.0021)
Research* PhD					0.0181	0.0164
					(0.0311)	(0.0308)
South	-1,476.7345	2,905.0457	-889.8070	938.6580	-205.0567	2,331.1592
	(7,388.0482)	(5,657.2067)	(7,703.6133)	(6,621.0441)	(7,726.0268)	(6,695.8549)
North	7,831.9154	11,431.8566*	6,935.6840	7,840.0538	5,298.7273	6,643.9737
	(7,148.3326)	(5,984.9399)	(7,684.9517)	(7,388.3927)	(7,715.8019)	(7,406.9446)
Constant	5,726.9789		3,865.0705		5,588.3536	
	(6,198.5734)		(8,140.6897)		(8,342.8196)	
Observations	59	59	59	59	59	59
R-squared	0.9800	0.9920	0.9802	0.9921	0.9816	0.9927

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. Authors' elaboration using Stata 14.

To control for the potential impact of technical inefficiency of universities on our estimates, the data have been analyzed using a stochastic frontier model (SFM, see Aigner and Chu 1968). SFM estimates a frontier around the data and interprets the deviation between the observation and the frontier as inefficiency. The error term of SFM is indeed composed of two components: the usual statistical noise and an asymmetric residual that captures the technical inefficiency. The results of SFM analyses are reported in Table III, where four different model specifications have been considered (i.e. including/excluding interaction and constant terms). The coefficients in Table III are similar to the ones estimated through regression analysis and reported in the previous Table II, however, taking into account the efficiency of the universities allows improving the statistical significance of the independent variables, especially concerning the geographical controls.

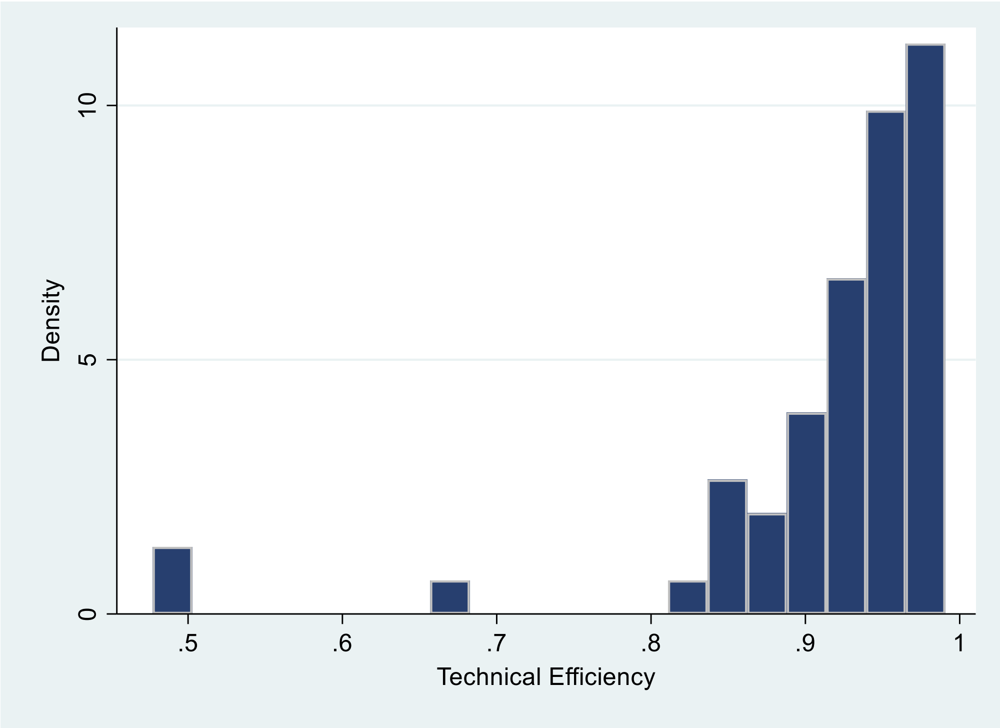
The results of the four models are similar to each other, and we focus on the SF4 model (with all the regressors but without the constant term) for estimating the economies of scale and scope. For the same model (i.e. SF4), we report the efficiency scores, which are represented by the histogram in Figure 1. The results show that higher education institutions are generally efficient, with only three universities having efficiency scores under 0.8. These values correspond with small universities, having the lowest number of PhD students (i.e. under 35 students), and suggest a presence of high inefficiency for this typology of higher education institutions.

Table III. Estimates – Stochastic frontier models

	(SF1) TC	(SF2) TC	(SF3) TC	(SF4) TC
Research	29.859***	27.471***	28.264***	28.056**
	(3.930)	(4.2580)	(10.790)	(10.904)
Students	2.5365***	2.7605***	3.1023*	3.0952*
	(0.5133)	(0.597)	(1.646)	(1.684)
PhD	42.512***	49.166***	31.77	30.983
	(10.151)	(11.552)	(41.158)	(41.281)
Research2			-0.006	-0.006
			(0.007)	(0.007)
students2			-0.0001	-0.000
			(0.0001)	(0.0001)
phd2			-0.039	-0.041
			(0.029)	(0.029)
Research*Students			0.0013	0.0014
			(0.002)	(0.002)
Research* PhD			0.0180	0.0184
			(0.027)	(0.027)
Students* PhD			0.0002	0.0004
			(0.003)	(0.003)
South	-1411.0**	-3176***	-205.01***	-745.6***
	(447.720)	(1.000)	(1.294)	(1.031)
North	7796.0***	6435.9***	5298.7***	5012***
	(244.730)	(1.002)	(1.253)	(1.093)
Constant	-11494.0***		-5558.2***	
	(487.230)		(1.3482)	
Ln(sigSq)	20.338***	19.927***	19.980***	19.809***
	(0.000)	(0.000)	(0.000)	(0.000)
Gamma	0.7686***	0.2572	0.4418**	0.19659
	(0.1025)	(0.2218)	(0.1951)	(0.2323)
Observations	59	59	59	59

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. Authors' elaboration using R package 'frontier'.

Figure 1. Efficiency scores – SF4



Note: The efficiency scores represented are the inverse of the estimated technical efficiency – the latter is originally always higher or equal to 1 for a cost function. Authors' elaboration using R package 'frontier' and Stata 14.

Focusing on model SF4, we calculated the marginal (MC) and the average incremental (AIC) costs, as reported in equations (2) and (3).

For the estimation of economies of scale and scope, we use the methodology suggested by Baumol *et al.* (1982) for multiproduct organizations. For the economies of scale, we first computed marginal (MC) and average incremental (AIC) costs:

$$MC_i = \frac{\partial TC}{\partial Q_i} \qquad (2)$$

$$AIC_S = \frac{TC\{Q_S, Q_R, Q_P\} - TC\{0, Q_R, Q_P\}}{Q_S} \qquad (3)$$

with Q_i representing the outputs, $i = S$ (Students), R (Research), P (PhD).

The product specific economies of scale (E_S) are computed as:

$$E_S = \frac{AIC_S}{MC_S}, \quad E_R = \frac{AIC_R}{MC_R}, \quad E_P = \frac{AIC_P}{MC_P} \qquad (4)$$

while the Ray economies of scale (RE) are defined as:

$$RE = \frac{TC\{Q_S, Q_R, Q_P\}}{Q_S MC_S + Q_R MC_R + Q_P MC_P} \qquad (5)$$

Product and Ray economies of scale exist if the coefficients E_i and RE are greater than one. Marginal/average incremental costs and economies of scale have been computed for different potential sizes of the institutions (around output means), as is standard in this type of analysis. The results are reported in Tables IV, V and VI.

We first look at the values of the AICs for students. Since the Italian standard cost focuses on the costs of "serving" students, the AIC considers the specific (average) incremental cost due to serving students, when this function is "added" to a given size of the other outputs. As shown in Table V, AICs for students depend on the number of students being served. The national standard cost per student in 2018 was estimated at 6,700€ (net of the equalization component), and the values computed for the single institutions range between 5,000€ and 8,000€. The variability of the Italian standard cost per student is related to the composition of students by disciplinary groups, and it does not take into account the size of the institution. Our findings reveal that the current way of determining the component of the Italian budget (FFO) is penalizing the institutions with high enrolments.

An apparently contrasting result is in Table VI, which indicated that economies of scale are never exhausted for the students' output. We find that economies of scale are also realized when the composition of students by disciplinary groups is shifted towards those with a higher weight (i.e. the groups like STEM or medicine). This result may be due to the relevance of some general costs (administrative staff, buildings, etc.), as well as to a more than proportional increase in the teaching staff with respect to the number of students.

Also, the findings reveal that size helps the cost efficiency of the teaching activity also at postgraduate level. The result for PhDs' economies of scale is not so surprising, given the limited numbers of doctoral students per institution (the highest number of PhD students enrolled was about 1,750). The economies of scale for postgraduate students are indeed even higher than for master and bachelors ones.

As for research, instead, economies of scale seem to exist only up to a scale comparable to 125% of the output mean. The realization of high volumes of academic publications seems to require large investments that rapidly exhaust economies of scale.

Finally, economies of scale are confirmed when we consider a change in the scale of all outputs: Ray economies of scale are never exhausted. Altogether, therefore, our results prove that a bigger scale helps the cost efficiency of universities.

Table IV. Marginal costs estimate

% of output mean	MC(Students)	MC(PhD)	MC(Research)
25%	3.132*** (0.213)	59.88*** (4.962)	30.45*** (1.327)
50%	3.104*** (0.183)	61.47*** (4.368)	29.25*** (1.163)
75%	3.075*** (0.162)	63.05*** (3.969)	28.05*** (1.053)
100%	3.047*** (0.155)	64.64*** (3.826)	26.85*** (1.014)
125%	3.019*** (0.162)	66.23*** (3.969)	25.65*** (1.053)
150%	2.990*** (0.183)	67.81*** (4.368)	24.45*** (1.163)
175%	2.962*** (0.213)	69.40*** (4.962)	23.25*** (1.327)
200%	2.933*** (0.249)	70.99*** (5.690)	22.05*** (1.526)
225%	2.905*** (0.249)	72.58*** (5.690)	20.86*** (1.526)
250%	2.877*** (0.330)	74.16*** (7.386)	19.66*** (1.989)
275%	2.848*** (0.374)	75.75*** (8.305)	18.46*** (2.239)
300%	2.820*** (0.419)	77.34*** (9.252)	17.26*** (2.497)

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. Values in ,000€. Authors' elaboration using Stata 14.

Table V. Average incremental costs estimate

% of output mean	AIC(students)	AIC(PhD)	AIC(Research)
25%	3.219*** (0.213)	197.6*** (46.94)	30.66*** (1.377)
50%	3.948*** (0.184)	244.1*** (41.32)	35.09*** (1.208)
75%	4.677*** (0.163)	290.6*** (37.54)	39.52*** (1.094)
100%	5.407*** (0.156)	337.0*** (36.20)	43.94*** (1.053)
125%	6.136*** (0.163)	383.5*** (37.54)	48.37*** (1.094)
150%	6.865*** (0.184)	430.0*** (41.31)	52.80*** (1.208)
175%	7.594*** (0.213)	476.5*** (46.94)	57.23*** (1.377)
200%	8.323*** (0.249)	523.0*** (53.83)	61.65*** (1.584)
225%	9.052*** (0.249)	569.5*** (53.83)	66.08*** (1.584)
250%	9.781*** (0.331)	615.9*** (69.87)	70.51*** (2.065)
275%	10.51*** (0.375)	662.4*** (78.56)	74.94*** (2.324)
300%	11.23*** (0.420)	708.9*** (87.52)	79.36*** (2.592)

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. Values in ,000€. Authors' elaboration using Stata 14.

Table VI. Product specific and Ray economies of scale

% of output mean	E (students)	E (PhD)	E (Research)	E (Ray)
25%	0.876* (0.482)	3.313*** (0.499)	2.474*** (0.645)	0.970*** (0.007)
50%	1.387*** (0.414)	3.633*** (0.439)	1.937*** (0.566)	0.978*** (0.006)
75%	1.898*** (0.368)	3.954*** (0.399)	1.400*** (0.512)	0.986*** (0.005)
100%	2.410*** (0.351)	4.275*** (0.384)	0.862* (0.493)	0.993*** (0.005)
125%	2.921*** (0.368)	4.595*** (0.399)	0.325 (0.512)	1.001*** (0.005)
150%	3.433*** (0.414)	4.916*** (0.439)	-0.21 (0.566)	1.009*** (0.006)
175%	3.944*** (0.481)	5.237*** (0.499)	-0.74 (0.645)	1.016*** (0.007)
200%	4.455*** (0.562)	5.558*** (0.572)	-1.28* (0.742)	1.024*** (0.008)
225%	4.967*** (0.562)	5.878*** (0.572)	-1.82** (0.742)	1.032*** (0.008)
250%	5.478*** (0.747)	6.199*** (0.742)	-2.35** (0.968)	1.039*** (0.011)
275%	5.989*** (0.845)	6.520*** (0.835)	-2.89** (1.089)	1.047*** (0.012)
300%	6.501*** (0.947)	6.840*** (0.930)	-3.43*** (1.215)	1.055*** (0.014)

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. *E(Students), E(PhD) and E(Research)* are the product specific economies of scale, while E Ray represents the Ray economies of scale. Authors' elaboration using Stata 14.

Discussing the contrast between AIC increasing with the size and the existence of product-specific economies of scale, a potential explanation may reside in economies of scope. Following Dundar and Lewis (1995) and Hashimoto and Cohn (1997), we estimate product-specific economies of scope according to the following definition (provided for the students' output; the others are analogous):

$$PSE_S = \frac{TC\{Q_S,0,0\}+TC\{0,Q_R,Q_P\}- TC\{Q_S,Q_R,Q_P\}}{TC\{Q_S,Q_R,Q_P\}} \quad (6)$$

We also estimate global economies of scope, defined as:

$$ESG = \frac{TC\{Q_S,0,0\}+TC\{0,Q_R,0\}+ TC\{0,0,Q_P\}- TC\{Q_S,Q_R,Q_P\}}{TC\{Q_S,Q_R,Q_P\}} \quad (7)$$

Economies of scope, at both levels, exist if the values of *PSE* or *ESG* are greater than zero. Therefore, the results of our estimation (see Table VII) show the existence of diseconomies of scope. This result might explain why, despite the existence of product-specific economies of scale for students and PhDs, their average incremental costs increase with the size of the institution. AICs are computed for different universities' size taking into account a proportional increase of all the outputs: if the negative complementarities between the different outputs are strong enough (as is apparent from the estimates), they more than compensate the potential economies of scale on a single product. In such conditions, a higher degree of specialization (in teaching or research) would reduce average costs, improving efficiency.

Table VII. Product specific and global economies of scope

% of output mean	PES(students)	PES(PhD)	PES(Research)	ESG
25%	-0.015	-0.222***	-0.106***	-0.005
	(0.015)	(0.067)	(0.018)	(0.020)
50%	-0.200***	-0.381***	-0.295***	-0.214***
	(0.013)	(0.059)	(0.016)	(0.018)
75%	-0.385***	-0.540***	-0.484***	-0.423***
	(0.012)	(0.054)	(0.014)	(0.016)
100%	-0.569***	-0.698***	-0.673***	-0.632***
	(0.011)	(0.052)	(0.013)	(0.015)
125%	-0.754***	-0.857***	-0.862***	-0.842***
	(0.012)	(0.054)	(0.014)	(0.015)
150%	-0.939***	-1.016***	-1.051***	-1.051***
	(0.013)	(0.059)	(0.016)	(0.017)
175%	-1.124***	-1.175***	-1.240***	-1.260***
	(0.015)	(0.067)	(0.018)	(0.019)
200%	-1.309***	-1.334***	-1.429***	-1.469***
	(0.018)	(0.077)	(0.021)	(0.022)
225%	-1.494***	-1.492***	-1.618***	-1.679***
	(0.018)	(0.077)	(0.021)	(0.022)
250%	-1.679***	-1.651***	-1.808***	-1.888***
	(0.024)	(0.100)	(0.027)	(0.030)
275%	-1.864***	-1.810***	-1.997***	-2.097***
	(0.027)	(0.113)	(0.030)	(0.034)
300%	-2.049***	-1.969***	-2.186***	-2.307***
	(0.030)	(0.126)	(0.034)	(0.038)

Note: *** indicates significance at the 1% level, ** at the 5% level and * at the 10% level. Standard errors are reported in parentheses. *PES(students), PES(PhD)* and *PES(Research)* are the product specific economies of scope, while *ESG* represents the global economies of scope. Authors' elaboration using Stata 14.

5. Concluding remarks

The findings presented in this paper provide an estimation of the specific cost structure of the Italian public universities, considering their complex function of producing teaching and research. When modelling the cost structure, we explicitly take the potential inefficiency into account, using a Stochastic Frontier Analysis (SFA). Current levels of marginal and average costs suggest that economies of scale can be exploited. We also find that diseconomies of scope between teaching and research exist. In terms of cost-efficiency, therefore, there could be a gain in considering policies for (i) increasing the average size of smaller universities (for example, through mergers), in the medium-long run while (ii) adjusting the funding formulas to take into account differences in size. Policies favoring more specialization between institutions (for example, through excellence initiatives for concentrating research activities in some universities) may be helpful, even if their results, in terms of cost-efficiency, should not be as strong as the ones aiming at increasing their size. Of course, the impact of these policies under other relevant criteria may offset their cost-efficiency gains, but the information provided by our results may help in clarifying the trade-off at play in these decisions.

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