

AN EVALUATION AND EXPLANATION OF (IN)EFFICIENCY IN HIGHER EDUCATION INSTITUTIONS IN EUROPE AND THE U.S. WITH THE APPLICATION OF TWO-STAGE SEMI-PARAMETRIC DEA

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MOTIVATION

- Academic research - a key factor of human capital creation
- Lisbon Strategy/Europe 2020
- The debate about universities: their role (teaching versus research), funding, governance and efficiency
- Europe versus U.S.

"In the global knowledge economy, people's skills, learning, talents, and attributes - their human capital - have become key to both their ability to earn a living and to wider economic growth. Education system can do much to help people to realise their potential, but when they fail it can lead to lifelong social and economic problems"(OECD, 2007 p.21)

"...Europe simply must have a first-class university system - with universities recognized internationally as the best in the various field involved" (European Commission, 2003 p.22)

LITERATURE REVIEW

- Survey of DEA applications (Liu et al. , 2013), education is among the top-five sectors addressed
- Cross-country studies: Agasisti and Johnes (2009): Italy/UK; Agasisti and Perez-Esparrells (2010): Italy/Spain, Agasisti and Pohl (2012): Italy/Germany; Bonaccorsi et al.(2007a): Italy/Spain/Portugal/Switzerland; Bonaccorsi et al.(2007b): Finland/Italy/Norway/Switzerland; Bonaccorsi et al. (2014): 16 European countries; Wolszczak-Derlacz and Parteka (2011): 7 European countries
- No intercontinental studies (exceptions: Reichmann and Sommersguter-Reichmann (2006) - 118 university libraries in Australia, Austria, Canada, Germany, Switzerland and the United States; Colbert et al. (2000) - 10 MBA programs)

DATA ENVELOPMENT ANALYSIS (DEA)

- no functional form
- multiply inputs and multiply outputs
- relative efficiency of each HEI (vis-a-vis the best performance)
- output orientated model: maximising output while using no more than observed amount of inputs
- 3 inputs: academic staff, total revenue in euro, number of students; 2 outputs: graduates and scientific publications listed in ISI Web of Knowledge
- MODEL:
 - ▶ MODEL 1 - Global frontier
 - ▶ MODEL 2 - European vs American frontier



TWO-STAGE BOOTSTRAP DEA ANALYSIS

based on Simar and Wilson (2007) procedure

1st step: DEA scores:

$$\hat{\lambda}_{VRS}(x, y) = \sup \left\{ \lambda \mid x, \lambda y \leq \sum_{i=1}^n \gamma_i y_i; x \geq \sum_{i=1}^n \gamma_i x_i, \text{ for } (\gamma_1 \dots \gamma_n) \right. \\ \left. \text{such that } \sum_{i=1}^n \gamma_i = 1 \text{ and } \gamma_i \geq 0; i = 1, \dots, n \right\}$$

2nd step: determinants of efficiency

$$\hat{\lambda}_i = a + z_i \beta + \varepsilon_i$$

where:

$\hat{\lambda}_i$ - DEA scores

z_i - environmental variables

ε_i - noise, $\varepsilon_i \geq 1 - a - z_i \beta$



BOOTSAPPED TRUNCATED REGRESSION

- 1 Use maximum likelihood to estimates of $\hat{\lambda}_i$ to obtain , in a truncated regression, estimates of $(\hat{\beta}, \hat{\sigma})$
- 2 Repeat L times over steps 2.1-2.3 to obtain b numbers of the bootstrap estimates of $\left\{ (\hat{\beta}^*, \hat{\sigma}^*)_b \right\}_{b=1}^L$
 - 2.1 For each, draw ε_i from the left-truncated $(1 - z_i\beta)$ normal distribution
 - 2.2. Use ε_i for each DMU to calculated fitted DEA scores: $\hat{\lambda}_i^* = z_i\hat{\beta} + \varepsilon_i$
 - 2.3 Use maximum likelihood to estimates of $\hat{\lambda}_i^*$ to obtain, in a truncated regression, estimates of $(\hat{\beta}^*, \hat{\sigma}^*)$
- 3 Compute bias-corrected estimates of $\hat{\beta}$ as well as percentile bootstrap confidence intervals at a given level of significance, using the bootstrap estimates obtained in the previous step $\left\{ (\hat{\beta}^*, \hat{\sigma}^*)_b \right\}_{b=1}^L$ and the original parameters $(\hat{\beta}, \hat{\sigma})$.

DATA AND PANEL COMPOSITION

Micro database on 500 European and American HEIs, 2000-2010

country	number of HEIs	source of data
Austria	11	Austrian Federal Ministry of Science and Research
Finland	13	Finnish Ministry of Education
Germany	65	Federal Statistical Office
Italy	54	National Agency for the Evaluation of Universities (ANVUR)
Netherlands	10	Association of Universities Netherlands (VSNU)
Poland	30	Ministry of Science and Higher Education
Spain	47	Spanish Rectors Conference (CRUE)
Sweden	24	Swedish Higher Education Authority
Switzerland	9	Swiss Federal Statistic Office
UK	85	Higher Education Statistics Agency
US*	152	National Center for Education Statistics,
Total	500	

*limit to the HEIs classified as public 4-year or above and public research according to Carnegie Commission

TABLE: Key statistics on HEIs – mean values by country, time period 2000–2010

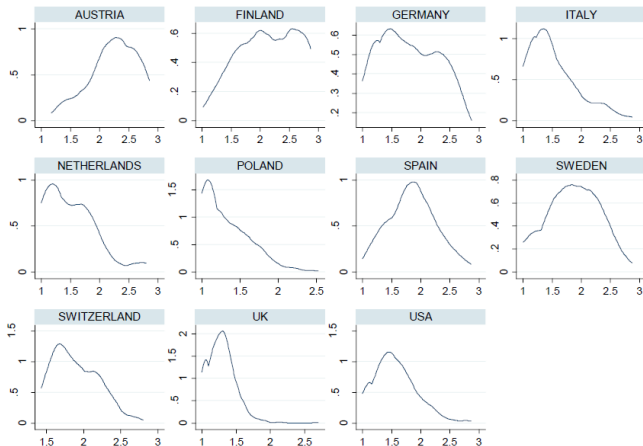
country	Publications per academic staff member	Publications per 1 m revenue (in real euros)	Graduates per academic staff member	Total number of students	Revenue per student per year in real euros	Revenue from government funding in % of total revenue	Revenue from tuition fees in % of total revenue
AUSTRIA N=11	0.61 (0.28)	4.21 (1.79)	1.70 (0.75)	19576 (18655)	9606 (4972)	79 (9)	n.a
FINLAND N=13	0.63 (0.33)	4.77 (2.27)	1.56 (0.72)	12176 (8570)	10836 (2808)	65 (7)	n.a
GERMANY N=65	0.55 (0.29)	6.94 (4.75)	1.37 (0.71)	17781 (10689)	9645 (3880)	63 (12)	n.a
ITALY N=54	0.86 (0.40)	5.23 (2.37)	4.51 (1.54)	30143 (25038)	5706 (2356)	81 (7)	14 (6)
NETHERLANDS N=10	1.42 (0.89)	6.62 (2.06)	1.95 (1.20)	17983 (6109)	24517 (5594)	61 (8)	7 (2)
POLAND N=30	0.21 (0.13)	5.41 (2.50)	3.02 (1.06)	21262 (9974)	2346 (797)	65 (7)	19 (8)
SPAIN N=47	0.32 (0.16)	4.90 (2.20)	1.79 (0.42)	28493 (19616)	4239 (1072)	n.a.	n.a
SWEDEN N=24	0.66 (0.68)	3.08 (2.58)	2.69 (1.11)	11099 (7627)	16062 (16264)	72 (11)	n.a
SWITZERLAND N=9	0.91 (0.32)	5.48 (1.53)	0.79 (0.39)	11526 (5444)	31443 (13250)	87 (5)	n.a
UK N=85	0.76 (0.55)	3.84 (2.73)	5.16 (2.03)	18136 (7193)	12436 (7395)	41 (9)	22 (8)
European N=348	0.64 (0.49)	4.98 (3.27)	3.16 (2.10)	20658 (15732)	10445 (9013)	62 (18)	18 (8)
USA N=152	1.04 (0.76)	2.53 (1.77)	3.90 (1.50)	21885 (15755)	26101 (16321)	64 / 30* (12)/(10)	30 (12)

SUMMARY STATISTICS FOR EFFICIENCY MEASURES USING A COMMON AND EUROPEAN-US FRONTIER

Country	Global frontier			European - US frontier		
	Mean DEA scores	Std. dev.	Total number of efficient units	Mean DEA scores	Std. dev.	Total number of efficient units
AUSTRIA	2.25	0.41	0	1.93	0.41	6
FINLAND	2.15	0.51	0	1.89	0.39	0
GERMANY	1.82	0.54	52	1.71	0.46	61
ITALY	1.52	0.43	57	1.38	0.32	72
NETHERLANDS	1.51	0.44	9	1.39	0.31	11
POLAND	1.31	0.31	74	1.29	0.29	78
SPAIN	1.85	0.41	9	1.78	0.35	8
SWEDEN	1.85	0.46	22	1.77	0.42	22
SWITZERLAND	1.9	0.31	0	1.81	0.26	0
UK	1.29	0.2	84	1.24	0.17	104
Europe	1.61	0.36	307	1.51	0.26	362
US	1.56	0.36	98	1.33	0.26	180

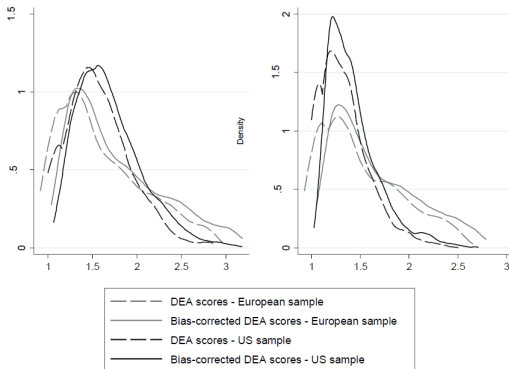
THE DISTRIBUTION OF EFFICIENCY SCORES

FIGURE: The distribution of efficiency scores by country (all year pooled)



BIAS-CORRECTED DEA SCORES

FIGURE: The distribution of DEA and bias-corrected DEA efficiency scores: global versus European-US frontier



PRODUCTIVITY CHANGES

TABLE: Annual changes in productivity (MI), efficiency (TE) and technology (TT) – mean value of statistically significant* indices by country for the period 2000-2010

	Common frontier			European-US frontier		
	MI	TE	TT	MI	TE	TT
AUSTRIA	1	1.029	0.972	0.982	0.986	0.995
FINLAND	1.042	1.118	0.979	1.031	1.062	0.996
GERMANY	1.041	1.081	1.012	1.036	1.048	1.018
ITALY	1.061	1.134	0.962	1.042	1.08	0.984
NETHERLANDS	1.059	1.092	1.021	1.056	1.067	1.026
POLAND	1.021	1.043	1.003	1.013	1.032	1.002
SPAIN	0.983	0.983	1.01	0.99	0.98	1.015
SWEDEN	1.039	1.065	1.008	1.023	1.046	0.998
SWITZERLAND	1.025	1.054	1	1.015	1.091	0.988
UK	1.011	1.051	0.984	0.992	1.029	0.979
Europe	1.026	1.064	0.993	1.015	1.037	0.997
US	0.99	1.039	0.965	1.002	1.015	0.996

STEP 2: PARAMETRIC APPROACH: ESTIMATED MODEL

$$\lambda_{i,t} = \alpha + \beta_1 GDP_{n,t} + \beta_2 NOFAC_i + \beta_3 MED_i + \beta_4 TECH_i + \beta_5 FOUND_i + \beta_6 REVgov_{i,t} / REVfee_{i,t} + \chi_j + v_t + \varepsilon_{i,t}$$

where:

i refers to institution, t - time and j - country

$\lambda_{i,t}$ - DEA scores

$GDP_{n,t}$ - real GDP per capita in euro PPS of the region n (NUTS2/state) where the university is located

$NOFAC_i$ - number of different faculties/departments

MED_i - dummy variable, equals 1 if university has medical or pharmacy faculty, 0 otherwise

$TECH_i$ - dummy variable, equals 1 if technical university, 0 otherwise

$FOUND_i$ - year of foundation

$REVgov_{i,t}$ - the share of government funding revenues in total revenues

$REVfee_{i,t}$ - the share of tuition fees in total revenues

χ_j - country effect

RESULTS

TABLE: The determinants of inefficiency scores for the European sample – DEA 3-input/2-output model with common frontier

	(1) Bias- adjusted coefficients	95% bootstrap confidence intervals		(2) Bias- adjusted coefficients	95% bootstrap confidence intervals		(3) Bias- adjusted coefficients	95% bootstrap confidence intervals	
		low	high		high	low		high	low
GDP	-0.330***	-0.449	-0.191	-0.357***	-0.491	-0.221	-0.230***	-0.338	-0.129
NOFAC	-0.029***	-0.037	-0.021	-0.025***	-0.033	-0.015	-0.006*	-0.014	0.003
MED	-0.301***	-0.369	-0.230	-0.360***	-0.426	-0.287	-0.028	-0.097	0.044
FOUND	0.083***	0.066	0.100	0.088***	0.067	0.107	0.029***	0.015	0.043
TECH	0.469***	0.383	0.547	0.486***	0.403	0.568	0.248***	0.133	0.346
REV_GOV				0.348**	0.014	0.683			
REV_FEE							-1.321***	-1.77	-0.856

RESULTS

TABLE: The determinants of inefficiency scores for the U.S. sample – DEA 3-input/2-output model with common frontier

	(1) Bias- adjusted coefficients	95% bootstrap confidence intervals		(2) Bias- adjusted coefficients	95% bootstrap confidence intervals		(3) Bias- adjusted coefficients	95% bootstrap confidence intervals	
		low	high		high	low		high	low
GDP	-0.848***	-1.039	-0.677	-0.854***	-1.037	-0.685	-0.840***	-1.026	-0.671
NOFAC	-0.035***	-0.042	-0.027	-0.036***	-0.043	-0.028	-0.033***	-0.04	-0.025
MED	0.072*	-0.008	0.146	0.073*	-0.008	0.146	0.068*	-0.015	0.141
FOUND	-0.01	-0.059	0.043	-0.019	-0.071	0.036	-0.007	-0.058	0.045
TECH	0.126*	-0.005	0.247	0.123*	-0.008	0.243	0.130*	-0.001	0.25
REV_GOV				0.148	-0.08	0.377			
REV_FEE							0.288*	-0.005	0.551
	1672			1672			1672		

Notes: * indicates that the value zero does not fall within the 90% confidence interval, ** indicates that the value zero does not fall within the 95% confidence interval, *** indicates that the value zero does not fall within the 99% confidence interval. Confidence intervals obtained from 1000 bootstrapping interactions.

Constants are not reported. Year included in all models.

Source: own calculations

ROBUSTNESS CHECK

- Common frontier versus European/US frontier
- 2 inputs 2 outputs DEA model
- 4 inputs 3 outputs DEA model
- Single bootstrap procedure
- Alternative truncation points
- U.S: state dummies
- Lagged values of the funding structure

EUROPEA-US FRONTIER, EUROPEAN SAMPLE

FIGURE: The determinants of inefficiency scores for European sample – DEA 3-input/2-output model with regional (European-US) frontier

	Bias-adjusted coefficients	confidence intervals		Bias-adjusted coefficients	confidence intervals		Bias-adjusted coefficients	confidence intervals	
		low	high		high	low		high	low
GDP	-0.295***	-0.39	-0.185	-0.289***	-0.399	-0.17	-0.247***	-0.32	-0.173
NOFAC	-0.018***	-0.024	-0.011	-0.015***	-0.022	-0.007	0.002	-0.004	0.006
MED	-0.296***	-0.35	-0.242	-0.341***	-0.395	-0.278	-0.075***	-0.121	-0.023
FOUND	0.056***	0.043	0.07	0.067***	0.049	0.083	0.007	-0.003	0.016
TECH	0.383***	0.314	0.445	0.406***	0.337	0.474	0.227***	0.147	0.295
REV_GOV				0.405***	0.124	0.684			
REV_FEE							-0.691***	-1.002	-0.39
	3826			3088			1576		

EUROPEA-US FRONTIER, U.S. SAMPLE

FIGURE: The determinants of inefficiency scores for the U.S. sample - DEA 3-input/2-output model with regional (European-US) frontier

	(1)	95% bootstrap confidence intervals		(2)	95% bootstrap confidence intervals		(3)	95% bootstrap confidence intervals	
	Bias-adjusted coefficients			Bias-adjusted coefficients			Bias-adjusted coefficients		
		low	high		high	low		high	low
GDP	-0.69***	-0.874	-0.518	-0.7***	-0.879	-0.529	-0.689***	-0.871	-0.516
NOFAC	-0.023***	-0.03	-0.016	-0.025***	-0.031	-0.017	-0.023***	-0.03	-0.015
MED	0.074*	-0.002	0.15	0.075*	-0.001	0.149	0.073*	-0.007	0.148
FOUND	-0.001	-0.05	0.052	-0.015	-0.068	0.039	0.000	-0.05	0.052
TECH	0.147*	0.014	0.261	0.141*	0.009	0.254	0.148*	0.016	0.263
REV_GOV				0.29	-0.065	0.508			
REV_FEE							0.063*	-0.025	0.316
	1672			1672			1672		

CONCLUSION

- High level of technical inefficiency of HEIs and a substantial variability in the efficiency scores both between and within countries
- Inefficiency is lower in U.S. compared to the mean value for the whole Europe, although higher in relation to some countries
- On average, inefficiency decreases over time for the European sample and is stable for the U.S.
- Inefficiency is determined by:
 - ▶ size (number of students and number of different faculties)
 - ▶ specialisation (number and composition of faculties)
 - ▶ location
 - ▶ funding structure
 - ★ Government funding - increases inefficiency in European HEIs, U.S. - not statistically significant
 - ★ Tuition fee - decreases the efficiency of American public institutions but relates to efficiency improvements in European universities.
- Policy implications

Thank you for your attention

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