

Higher Education Production Analysis

Matthias Klumpp¹, Stephan Zelewski²

¹ Competence Center Logistics, FOM University of Applied Sciences Essen,
Sigsfeldstraße 5, D-45141 Essen, Germany
matthias.klumpp@fom.de

² Institute for Production and Industrial Information Management, University of Duisburg-Essen,
Universitätsstraße 9, D-45141 Essen, Germany
stephan.zelewski@pim.uni-due.de

Abstract

Productivity in service production in general and especially in university teaching and research is an interesting research question with specific difficulties. In Germany since 2006 the new ‘Excellence Initiative Programme’ for universities has inhibited further discussions in the context of university management and the productivity of higher education institutions as DMUs. Therefore an in depth analysis of productivity in universities is of interest for HE managers as well as for HE politicians deciding about public university budgets. This article describes two different ways to measure university productivity (input-output-analysis and data envelopment analysis). Altogether the research results point to the fact that there are in general two ways towards university productivity: (a) Extending budgets (‘clustering/scaling’, which is limited) and (b) excellence in research/university management (‘steering/integration’). Therefore it can be assumed that economies of scale exist in universities but are limited respectively hard to make use of as among the ten most productive universities nine are middle-sized institutions as for example the ‘productivity benchmarks’ Konstanz and Karlsruhe. This could evoke the following thoughts for university managers and education politicians: (i) Use portfolio thinking for budget distribution: A larger number of mid-sized institutions may in total be more productive than a smaller number of large institutions. (ii) Increase steering/control towards larger institutions as productivity is not a ‘given’ (or: inverse budget distribution). (iii) Use productivity as measurement and ranking criteria as otherwise (public) budgets may be ‘wasted’ on less productive institutions – which can be found among large as well as small entities.

Keywords: Higher Education Management, University Productivity, Higher Education Excellence

1. Introduction

Service production in higher education as research and teaching activities is a long standing research objective. Especially an *international perspective* as well as the *self-perspective of research* are interesting in this research field, see [17, 31, 50, 54]. In present day higher education politics this may have an even higher importance as the German Excellence Initiative (GEI) with federal and state level funding is *concentrating resources* in nine universities in Germany - with the objective of making these universities internationally recognised leaders in excellent research and teaching. For the most prominent funding subprogramme within GEI (Area 3 ‘Zukunftskonzept’) the institutions FU Berlin, RWTH Aachen, TH Karlsruhe, TU Munich, Universities of Göttingen, Freiburg, Heidelberg, Konstanz and Munich were selected as ‘elite universities’ [9, 10]. But there are significant hints that general *economies of scale may not exist in higher education production* (research and teaching) and therefore some of this additional public funding may not be invested efficiently [38, 40]. A simple outlined efficiency ranking comparison in research as shown in the following table 1 makes the practical problem and relevance obvious: Though the university with the largest budget among these ten institutions (TU Munich) is able to reach a high research output (269,5 points in a combined ranking result as meta ranking including only the Excellence Initiative Results from 2006) there are *nine middle-sized universities* in Germany led by the University of Konstanz (reaching a third of the research ranking points with less than a sixth of the budget) who have a *higher productivity* in this measurement concept. Therefore public money concentrated in large universities may *not* be invested efficiently as these institutions may not be the most productive ones. This would *contradict* the general trend and requirements in the concepts of *new public management* in public institutions aiming at an efficient use of public funds (as

defined by law in the German ‘Haushaltsgrundsatzgesetz’, § 6, (1) and (2), [57]) by an increasing steering, controlling and measurement of *outputs* and information transparency within public institutions, see e.g. [8, 39]. Especially for universities there is a broad discussion about the necessary steps and models in order to achieve efficient (public) universities, see e.g. [7, 11, 39, 51, 59, 64]. The therefore discussed scientific problem is the *productivity* and the question of economies of scale in universities (research and teaching) as well as the method and correlations regarding the *selection* of universities in the German Excellence Initiative. The scientific method applied is the comparison of the following two different productivity calculation methods: (i) An extended *input-output-analysis* for research and teaching as shown above (chapter 2) and (ii) a *data envelopment analysis* (DEA) modelled on universities with input and output factors (chapter 3). The discussed research question is the existence of economies of scale in university research and teaching production (chapter 4).

University	(a) META Ranking	(b) META Ranking	(c) Budget 2001-2003	(d) Productivity Ratio	(e) Productivity Ranking
	Total Score	Pos	Mio Euro	Mio Euro/Score	Pos
University Konstanz	96,0	29	297,8	3,10	1
University Karlsruhe	214,0	5	708,9	3,31	2
University Stuttgart	152,0	15	904,7	5,95	3
University Bremen	96,5	27	575,7	5,97	4
University Bochum	158,0	12	964,7	6,11	5
University Bielefeld	77,0	33	471,1	6,12	6
TU Darmstadt	103,0	25	633,7	6,15	7
Technical University Berlin	150,0	17	943,5	6,29	8
University Bayreuth	43,0	41	291,8	6,79	9
Technical University Munich	269,5	2	1.917,6	7,12	10

Table 1. Ranking and Size Productivity in selected German Universities. [38], p. 13.

2. Input-Output-Analysis for German Universities

The following table 2 lists the complete set of deployed universities as DMUs in the following input-output-analysis as well as the subsequent DEA calculation. The budget figures (A, sum 2001-2003 in Mio Euro, see [22]) are presented besides the DFG ranking 2006 (B, ranking places DFG funding and EU funding and aggregated as score, see [23]), the SJTU world universities ranking 2005 (C, ranking places world, region, national and aggregated score, see [58]) and the results for the German Excellence Initiative (E, obtained projects in three areas and aggregated score see [9, 10]). The intermediate scores D (adding B and C) and F (adding scores out of B, C and E) are meta score rankings, see [38]. The ranking lists as well as the following productivity ratios envisage *three different trends* (groups) of institutions in the context of the new German Excellence Initiative (GEI) ranking:

- (a) *Cluster Institutions*: There are large institutions with well established positions in terms of budgets and rankings and they were (expectedly) successful in the GEI (TU Munich, U Heidelberg, U Freiburg, U Göttingen, RWTH Aachen, U Munich).
- (b) *Outsider Institutions*: There are large and established institutions who were not successful concerning the GEI (U Tübingen, U Bonn, U Hamburg, U Köln, U Münster, HU Berlin).
- (c) *Benchmark Institutions*: There are small and medium sized universities with younger institutional histories and lower ranking positions (or even without ranking positions before as in the special case of the University of Mannheim) who were successful in the GEI and show a *remarkable productivity* in research rankings as well as in the GEI (U Konstanz, U Karlsruhe, FU Berlin, U Bielefeld, TU Darmstadt, U Bremen, U Stuttgart).

No	University (DMU) Name	A. Budget 2001-03, Mio €	B. DFG Ranking			C. SJTU World Universities Ranking				D. R- Meta B.+C.	E. Excellence Initiative Ranking				F. Meta B.+C.+ E.
			DFG Fund	EU Fund	S	World Rank	Region Rank	National Rank	S		Area 1 GS	Area 2 CL	Area 3 FU	S	
1	Univ Munich	3082,6	1	2	99	51	10	1	100	199,0	1	3	1	100	299,0
2	Tech Univ Munich	1917,6	9	3	90	52	11	2	99,5	189,5	1	2	1	80	269,5
3	Univ Heidelberg	2136,5	3	5	94	71	21	3	94,5	188,5	3	2	1	100	288,5
4	RWTH Aachen	2313,3	2	4	96	203-300	80-123	17-23	65	161,0	1	3	1	100	261,0
5	Univ Karlsruhe	708,9	6	7	89	203-300	80-123	17-23	65	154,0	1	1	1	60	214,0
6	Univ Bonn	2222,1	13	12	77	101-152	36-56	6-11	87	164,0	2	1		40	204,0
7	Univ Goettingen	1996,4	12	9	81	84	26	4	92	173,0	1	1	1	60	233,0
8	Univ Freiburg	1861,7	11	10	81	90	29	5	90,5	171,5	1	1	1	60	231,5
9	Univ Frankfurt	1646,9	20	8	74	101-152	36-56	6-11	87	161,0		2		40	201,0
10	Univ Wuerzburg	1396,7	4	27	71	101-152	36-56	6-11	87	158,0	1			10	168,0
11	Univ Tuebingen	1880,7	8	6	88	101-152	36-56	6-11	87	175,0		1		20	195,0
12	Univ Bochum	964,7	16	13	73	203-300	80-123	17-23	65	138,0	1			10	148,0
13	Univ Erl-Nuernberg	1727,7	7	26	69	203-300	80-123	17-23	65	134,0	1	1		30	164,0
14	Univ Hamburg	1952,9	17	19	66	101-152	36-56	6-11	87	153,0		1		20	173,0
15	Univ Stuttgart	904,7	14	1	87	203-300	80-123	17-23	65	152,0	1	1		30	182,0
16	Tech Univ Dresden	1607,6	21	14	67	301-400	124-168	24-33	43	110,0	1	1		30	140,0
17	Tech Univ Berlin	943,5	22	15	65	203-300	80-123	17-23	65	130,0	1	1		30	160,0
18	Univ Muenster	2159,9	15	25	62	101-152	36-56	6-11	87	149,0		1		20	169,0
19	Univ Mainz	1779,3	19	11	72	153-202	57-79	12-16	76,5	148,5	1			10	158,5
20	Univ Koeln	1871,2	18	20	64	153-202	57-79	12-16	76,5	140,5		1		20	160,5
21	Univ Kiel	1464,9	36	37	29	153-202	57-79	12-16	76,5	105,5	1	2		50	155,5
22	Univ Marburg	1197,1	27	31	44	153-202	57-79	12-16	76,5	120,5				0	120,5
23	Univ Giessen	1408,0	26	24	52	401-500	169-205	34-40	20,5	72,5	1	1		30	102,5
24	Univ Leipzig	1435,8	40	33	29	153-202	57-79	12-16	76,5	105,5	1			10	115,5
25	TU Darmstadt	633,7	25	17	60	301-400	124-168	24-33	43	103,0	1	1		30	133,0
26	HU Berlin	2985,3	5	18	79				0	79,0	3	1		50	129,0
27	Univ Bremen	575,7	23	23	56	401-500	169-205	34-40	20,5	76,5	2	1		40	116,5
28	FU Berlin	1724,7	10	16	76				0	76,0	3	2	1	100	176,0
29	Univ Konstanz	297,8	34	35	33	301-400	124-168	24-33	43	76,0	1	1	1	60	136,0
30	Univ Halle - Wit	1225,3	35	40	27	203-300	80-123	17-23	65	92,0				0	92,0
31	Univ Duesseldorf	1533,6	29	32	41	301-400	124-168	24-33	43	84,0				0	84,0
32	Univ Ulm	1111,4	33	28	41	301-400	124-168	24-33	43	84,0	1			10	94,0
33	Univ Bielefeld	471,1	38	30	34	301-400	124-168	24-33	43	77,0	1	1		30	107,0
34	TU Braunschweig	566,7	31	38	33	301-400	124-168	24-33	43	76,0				0	76,0
35	Univ Regensburg	987,7	37	39	26	301-400	124-168	24-33	43	69,0				0	69,0
36	U Duisburg Essen	1828,3	28	29	45	401-500	169-205	34-40	20,5	65,5				0	65,5
37	Univ Saarlandes	1273,4	39	22	41	401-500	169-205	34-40	20,5	61,5	1	1		30	91,5
38	Hannover Med Sch	1471,1	51	51	0	401-500	169-205	34-40	20,5	20,5	1	1		30	50,5
39	Univ Hannover	765,3	24	21	57				0	57,0		1		20	77,0
40	Univ Jena	1265,0	30	36	36	401-500	169-205	34-40	20,5	56,5	1			10	66,5
41	Univ Bayreuth	291,8	51	51	0	301-400	124-168	24-33	43	43,0	1			10	53,0
42	Univ Greifswald	648,2	51	51	0	301-400	124-168	24-33	43	43,0				0	43,0
43	Univ Dortmund	566,9	32	34	36				0	36,0				0	36,0
44	Univ Rostock	942,0	51	51	0	401-500	169-205	34-40	20,5	20,5				0	20,5
45	Univ Mannheim	220,7	51	51	0				0	0,0	1			10	10,0

Table 2. Input-output data and ranking criteria for German universities.

The subsequent table 3 shows a productivity calculation (G, H, I) for the division of outputs (D, E, F) by the budget input (A) as research productivity (D/A), excellence productivity (E/A) and meta productivity (F/A).

No	University (DMU)	A. Budget	B. DFG Rank*	C. SJTU Rank*	D. Res Rank*	E. Exc Rank*	F. Total Rank	G. Research Productivity**	H. Excellence Productivity**	I. META Productivity**
29	Univ Konstanz	297,8	33,0	43,0	76,0	60,0	136,0	0,255	0,201	0,457
5	Univ Karlsruhe	708,9	89,0	65,0	154,0	60,0	214,0	0,217	0,085	0,302
33	Univ Bielefeld	471,1	34,0	43,0	77,0	30,0	107,0	0,163	0,064	0,227
25	Tech Univ Darmstadt	633,7	60,0	43,0	103,0	30,0	133,0	0,163	0,047	0,210
27	Univ Bremen	575,7	56,0	20,5	76,5	40,0	116,5	0,133	0,069	0,202
15	Univ Stuttgart	904,7	87,0	65,0	152,0	30,0	182,0	0,168	0,033	0,201
41	Univ Bayreuth	291,8	0,0	43,0	43,0	10,0	53,0	0,147	0,034	0,182
17	Tech Univ Berlin	943,5	65,0	65,0	130,0	30,0	160,0	0,138	0,032	0,170
12	Univ Bochum	964,7	73,0	65,0	138,0	10,0	148,0	0,143	0,010	0,153
2	Tech Univ Munich	1917,6	90,0	99,5	189,5	80,0	269,5	0,099	0,042	0,141
3	Univ Heidelberg	2136,5	94,0	94,5	188,5	100,0	288,5	0,088	0,047	0,135
34	Tech Univ Braunschweig	566,7	33,0	43,0	76,0	0,0	76,0	0,134	0,000	0,134
8	Univ Freiburg	1861,7	81,0	90,5	171,5	60,0	231,5	0,092	0,032	0,124
9	Univ Frankfurt	1646,9	74,0	87,0	161,0	40,0	201,0	0,098	0,024	0,122
10	Univ Wuerzburg	1396,7	71,0	87,0	158,0	10,0	168,0	0,113	0,007	0,120
7	Univ Goettingen	1996,4	81,0	92,0	173,0	60,0	233,0	0,087	0,030	0,117
4	RWTH Aachen	2313,3	96,0	65,0	161,0	100,0	261,0	0,070	0,043	0,113
21	Univ Kiel	1464,9	29,0	76,5	105,5	50,0	155,5	0,072	0,034	0,106
11	Univ Tuebingen	1880,7	88,0	87,0	175,0	20,0	195,0	0,093	0,011	0,104
28	FU Berlin	1724,7	76,0	0,0	76,0	100,0	176,0	0,044	0,058	0,102
22	Univ Marburg	1197,1	44,0	76,5	120,5	0,0	120,5	0,101	0,000	0,101
39	Univ Hannover	765,3	57,0	0,0	57,0	20,0	77,0	0,074	0,026	0,101
1	Univ Munich	3082,6	99,0	100,0	199,0	100,0	299,0	0,065	0,032	0,097
13	Univ Erlangen-Nuernberg	1727,7	69,0	65,0	134,0	30,0	164,0	0,078	0,017	0,095
6	Univ Bonn	2222,1	77,0	87,0	164,0	40,0	204,0	0,074	0,018	0,092
19	Univ Mainz	1779,3	72,0	76,5	148,5	10,0	158,5	0,083	0,006	0,089
14	Univ Hamburg	1952,9	66,0	87,0	153,0	20,0	173,0	0,078	0,010	0,089
16	Tech Univ Dresden	1607,6	67,0	43,0	110,0	30,0	140,0	0,068	0,019	0,087
20	Univ Koeln	1871,2	64,0	76,5	140,5	20,0	160,5	0,075	0,011	0,086
32	Univ Ulm	1111,4	41,0	43,0	84,0	10,0	94,0	0,076	0,009	0,085
24	Univ Leipzig	1435,8	29,0	76,5	105,5	10,0	115,5	0,073	0,007	0,080
18	Univ Muenster	2159,9	62,0	87,0	149,0	20,0	169,0	0,069	0,009	0,078
30	Univ Halle - Wittenberg	1225,3	27,0	65,0	92,0	0,0	92,0	0,075	0,000	0,075
23	Univ Giessen	1408,0	52,0	20,5	72,5	30,0	102,5	0,051	0,021	0,073
37	Univ Saarlandes	1273,4	41,0	20,5	61,5	30,0	91,5	0,048	0,024	0,072
35	Univ Regensburg	987,7	26,0	43,0	69,0	0,0	69,0	0,070	0,000	0,070
42	Univ Greifswald	648,2	0,0	43,0	43,0	0,0	43,0	0,066	0,000	0,066
43	Univ Dortmund	566,9	36,0	0,0	36,0	0,0	36,0	0,064	0,000	0,064
31	Univ Duesseldorf	1533,6	41,0	43,0	84,0	0,0	84,0	0,055	0,000	0,055
40	Univ Jena	1265,0	36,0	20,5	56,5	10,0	66,5	0,045	0,008	0,053
45	Univ Mannheim	220,7	0,0	0,0	0,0	10,0	10,0	0,000	0,045	0,045
26	HU Berlin	2985,3	79,0	0,0	79,0	50,0	129,0	0,026	0,017	0,043
36	Univ Duisburg Essen	1828,3	45,0	20,5	65,5	0,0	65,5	0,036	0,000	0,036
38	Hannover Med Sch	1471,1	0,0	20,5	20,5	30,0	50,5	0,014	0,020	0,034
44	Univ Rostock	942,0	0,0	20,5	20,5	0,0	20,5	0,022	0,000	0,022

* Values of "0" are replaced with a small non-zero number ("0,0001") for the following data envelopment analysis.

** In Ranking Score per Million Euro (Budget).

Table 3. Input-output productivity results for German universities.

These results can be compared to the following DEA results to describe HE productivity.

3. Data Envelopment Analysis for German Universities

3.1. DEA Methodology and Literature

A data envelopment analysis (DEA) is an important and widely used tool to calculate the efficiency by individual input-output-comparisons of decision making units (DMU, numbered universities for this research study as shown in table 2). This efficiency can be assumed as economic productivity. A knowledge of specific production functions as input-output-transformation laws is not necessary ('black box') as they are in general not known for universities. Moreover there is no fixed weighting distribution as input necessary but the DEA algorithm is calculating these weighting factors individually and internally for each DMU in order to allow different and individual tracks to efficiency – therefore there is little room for an external bearing on weighting criteria in order to influence productivity results. DEA is seen as an objective method; for general method amendments see [13, 14, 15, 16, 18, 19, 20, 24, 25, 31, 36, 37, 44, 49, 52, 53, 55, 56, 61, 63]. As a DEA calculation does not require external weighting factors it is often used in areas with assumed and necessary but unidentified weighting factors as well as 'non-monetary indicators', see [45, 48]. This holds true especially for universities as there is *no common sense* in university input as well as output measurement or evaluation, see [39, 54]. Therefore areas with *social output* dimensions ('non-monetary') are typically a striving environment for DEA calculations as e.g. health care and education; see for the *health care* sector e.g. [12, 21, 27, 29, 35, 41, 62] and for the education and especially *university* sector e.g. [1, 2, 3, 4, 26, 28, 31, 32, 34, 40, 43, 46, 47, 60]

3.2. DEA Modelling

Different modelling decisions and parameters regarding the DEA calculation model are necessary – the most important ones are discussed in detail, for general criteria compare [33]: (A) DEA can be basically used as input-oriented or output-oriented model (not-oriented models can be neglected). Both models provide interesting research questions and outputs in an university analysis: In an *input-orientation* the assumption has to hold true that universities are faced with *fixed* outputs and try to *minimize* their input resources – this is obviously the 'budgeting' perspective of higher education politicians and politics (ministry of education or ministry of finance). They are not able to steer or act *within* the higher education institutions due to their professional service character and complexity and are therefore forced to steer via *input* scaling. As *output-oriented* model it has to be assumed that input parameters are inflexible and can not be influenced – this is naturally the perspective of institutional management within the universities who has only a very small definition clout to change resource inflow. Proximate university management will try to *maximise output* indicators by steering mechanisms in order to increase university productivity. This can be compared to the management concept of a *resource-based view* emphasising the intangible nature especially of e.g. human capital as most important production factor in universities. It can be safely assumed that this output-oriented model largely reflects the *interior perspective* of universities and universities management respectively (depending on individual organisational 'culture'). Altogether for the following analysis it may be noted that both models or perspectives of HE politics and HE management may contain interesting research questions and findings in the use of the attached DEA models in terms of input- or output-oriented calculations used in this study.

(B) A modus for assumed *returns to scale* has to be identified depicting the actual production context: Based on practical management experience and heuristic assumptions generally a model with *constant* returns to scale is used as CCR-Model [15, 56]. The specific situation of universities with unknown production technologies and functions requires this modus and therefore it will be used here. Additionally the prerequisite of a university's ability to *scale its size* according to external requirements (calculated by amounts of total inputs and total outputs) can be assumed to hold true and in this way a comparison to other research findings

(most of them using this modus) is possible. An alternative could be the so-called BCC-Model with *variable* returns to scale, see [5, 6]. This is not needed in the provided case.

(C) The number of required DMU data sets (for n_{in} inputs und n_{out} outputs, here: number of universities) has to be checked against the general fuzzy requirement as n_{ob} with: $n_{ob} \geq \max \{ n_{in} \cdot n_{out}, 3 \cdot (n_{in} + n_{out}) \}$; see [19, 33]. With 45 DMUs in this DEA calculation there is no significant restriction to model combinations as there are only three possible factors present altogether (inputs or outputs). This would denote that $n_{in} + n_{out} = 3$ holds true for all cases and therefore $n_{ob} \geq \max \{ 2, 9 \}$, implying $n_{ob} \geq 9$ for all possible cases.

3.3. DEA Results

The presented results were calculated and printed with the software ‚Frontier Analyst®‘, version 4.0.10, of Banxia Holdings Ltd. Three cases (a to c) can be expedient for the data set:

(a) Input A (Budget); Output D (Research Ranking) and E (Excellence Initiative Ranking)

Within this input-oriented combination the DEA analysis refers to the DMU Nr 29 (University of Konstanz) as the *sole* efficient institution, being referred to 45 times for efficiency improvements of other DMUs (which stands for a very high ‘benchmarking power’ of this university). Combined with the institutional history as a very young institution founded less than 50 years ago this productivity result is astonishing and can be related to a very special history (‘reform university’) as well as professional concept development and tender management in the process of the Excellence Initiative Programme during 2006 and 2007. The next second efficient DMU in this calculation is the University of Karlsruhe (Nr 5) with 85,1% efficiency – and subsequently all other universities are positioned below 70% efficiency compared to Nr 29. The following figure 1 shows the specific efficiency frontier with the exceptional position of Nr 29 (University of Konstanz).

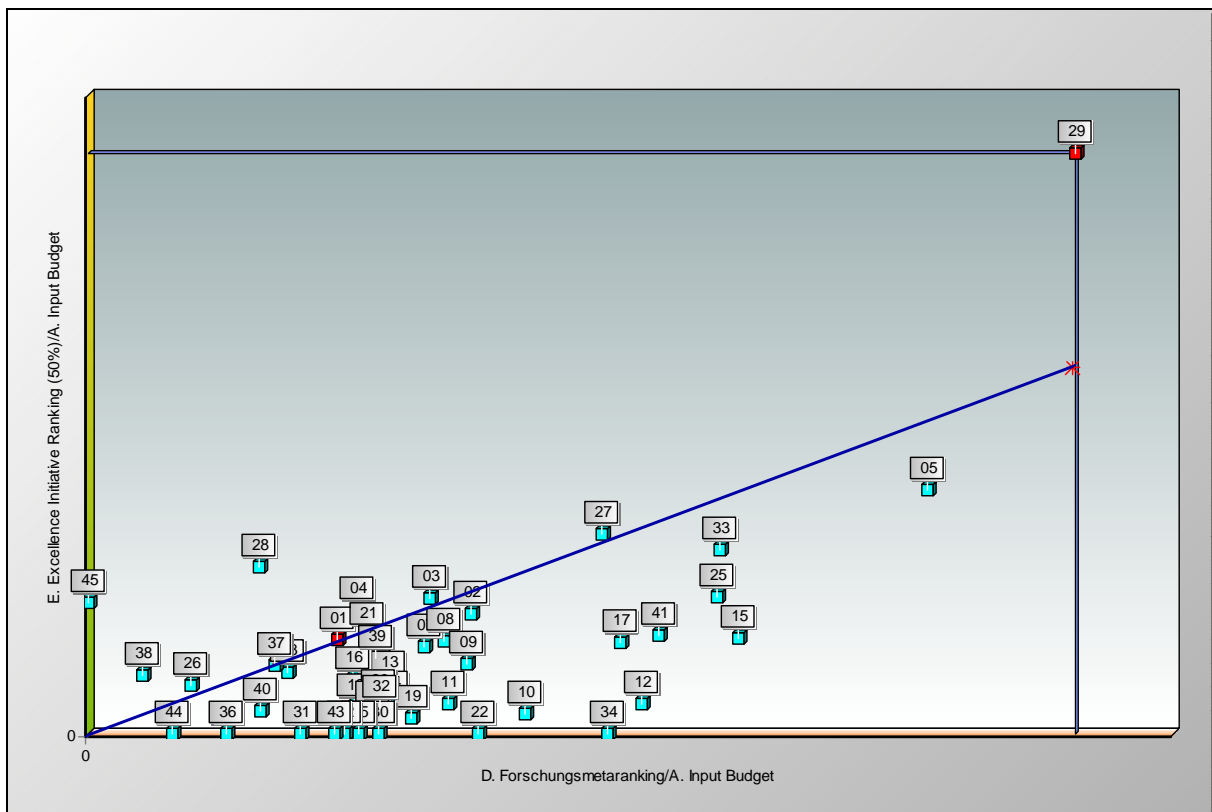


Figure 1. DEA efficiency frontier for input A (Budget) and outputs D (Research Meta Ranking) and E (Excellence Initiative Ranking).

For the explained *political* interpretation (input-oriented model) this would translate into the thesis, that public funding ‘invested’ in the most efficient universities in Konstanz and Karlsruhe relatively yield the *highest* ‘returns’ in terms of research output, ranking positions and the ‘excellence position’ in the GEI Programme.

An additional interesting result can be shown in this calculation regarding the combination of efficiency score (‘institutional efficiency’) and budget size: As plotted in figure 2 there is a *slightly inverted correlation* in this indicator set announcing a slightly higher efficiency for smaller institutions (measured in budget size). Therefore traditional economies of scale can be negated for universities (at least for larger institutions *above* an annual budget of 500 Mio €).

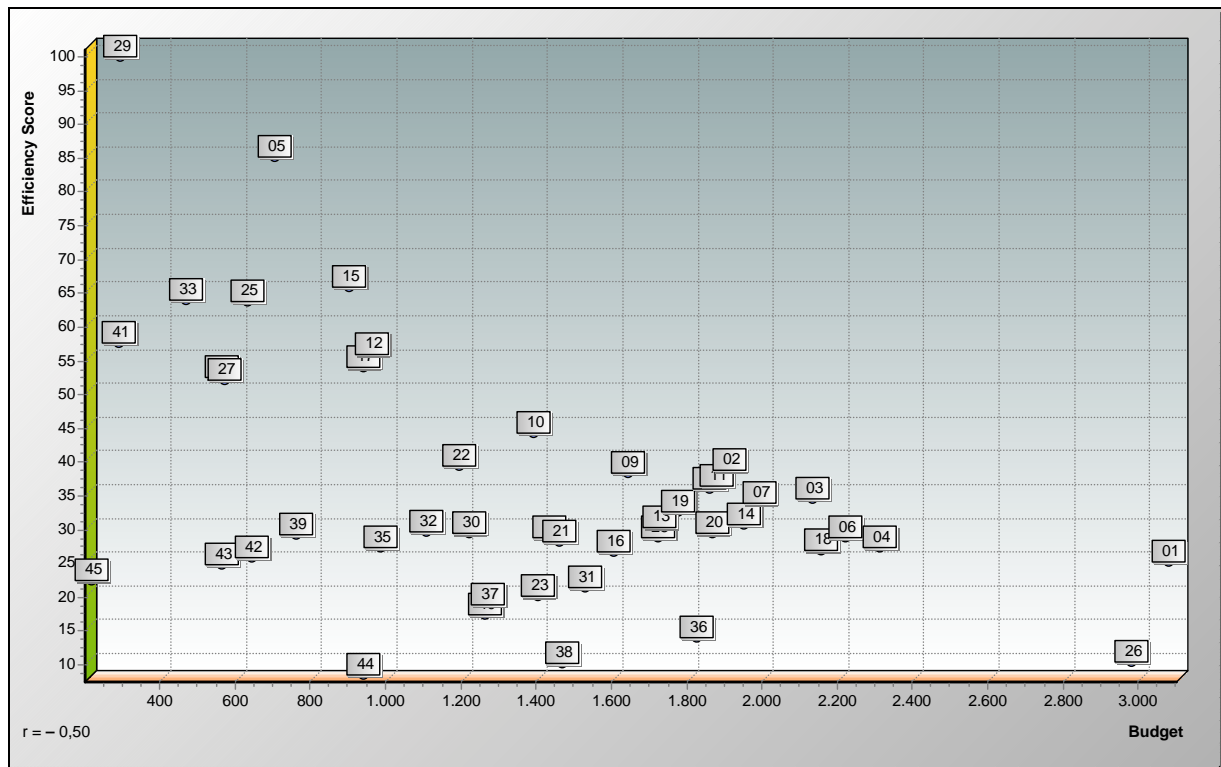


Figure 2. DEA efficiency plot for input A (Budget, three year sum 2001-2003).

(b) Input A (Budget) and (B) DFG Ranking; Output E (Excellence Initiative Ranking)

The second *output-oriented* calculation with the indicators budget, DFG ranking (inputs) and excellence initiative ranking (output) can be translated into the question of *university management* ‘how to efficiently enter the excellence initiative?’. It presents the DMUs Nr 29 (U Konstanz), Nr 38 (Hannover Med School) and Nr 45 (U Mannheim) as most efficient units. These universities were able to be successful in GEI selection in contradiction to severe disadvantages as e.g. small institutional sizes and budgets as well as missing establishment in existing rankings as e.g. the DFG research ranking. These ‘start-up’ universities are exercising a widely discussed professional ‘profiling’ focussing a university to a small number of excellent focal points of teaching and research. This concentration strategy was obviously *one successful way* in GEI participation – especially for small and less established institutions.

In this setting Figure 3 explains that the *single most important precondition advantage* for a successful participation in GEI was a high DFG research ranking – contradicting the public announcement that GEI was established to foster excellence in teaching. On the other hand subsequent Figure 4 depicts the DEA efficiency across the excellence initiative ranking – proposing that effective (Nr 29) as well as quite ineffective universities (Nr 1, Nr 28) were able to enter the excellence university group. In other terms besides the DFG ranking position

there were quite *fair equal chances for all universities* in the GEI competition situation as no single factor as e.g. budget or ranking was dominating the GEI positioning too much.

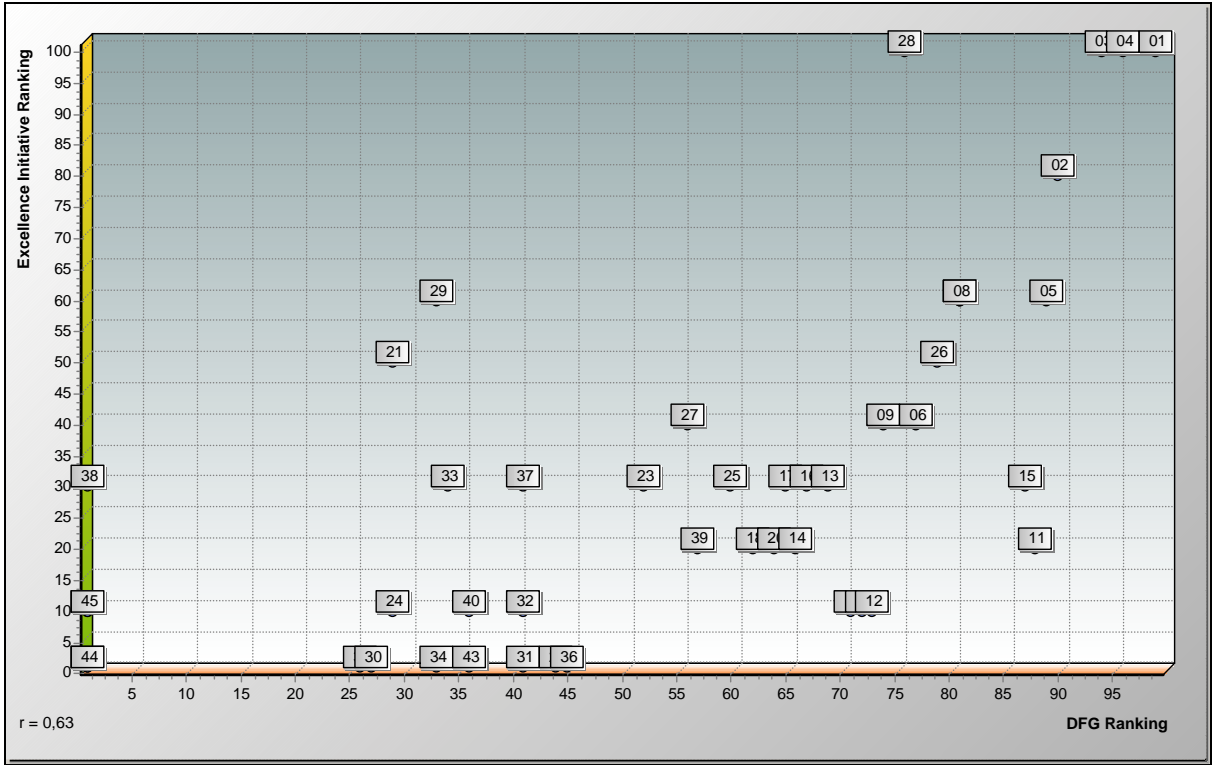


Figure 3. DEA correlation plot between input A (DFG Ranking) and output E (Excellence Initiative Ranking).

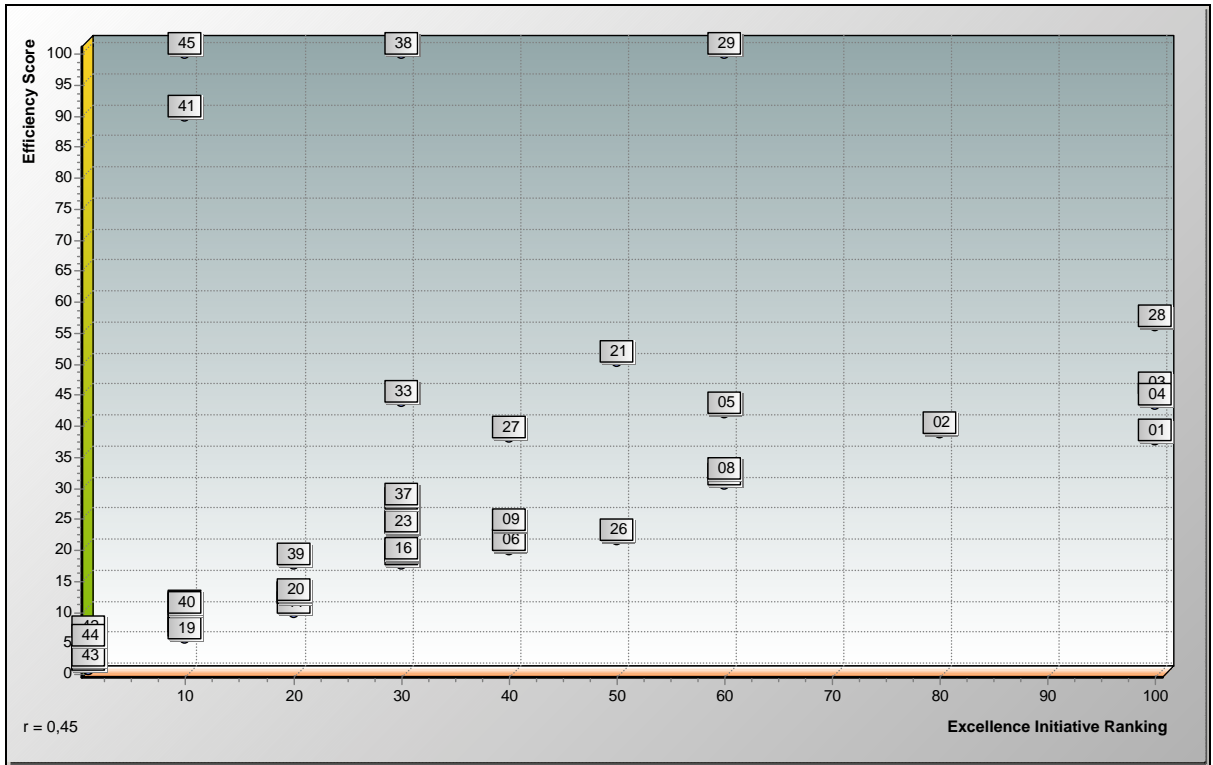


Figure 4. DEA efficiency plot for output E (Excellence Initiative Ranking).

(c) Input A (Budget) and (C) SJTU Ranking; Output E (Excellence Initiative Ranking)

In a final DEA calculation setting the output-oriented combination of budget and SJTU world ranking as inputs and GEI ranking as output were described. In this indicator set the DMUs Nr 28 (FU Berlin) and Nr 29 (U Konstanz) are presented as most efficient as they were able to enter the top 9 in the excellence group (area 3, ‘elite universities’) starting from a very low (Nr 29, only among the top 30 in Germany) or even missing SJTU ranking position (Nr 28, not among the top 40 in Germany according to SJTU). This could imply that obviously national and international ranking and reputation systems are only loosely coupled for the case of Germany meaning that (i) the international ranking position (SJTU) has *no significant influence* on national funding decisions and (ii) national changes in university excellence are transferred to international rankings and reputation with a *significant time lag*. Also this can be understood as verification of the second DEA case stating the DFG research ranking as single most important factor for GEI selection decisions. This is verified as the alternative SJTU world ranking doesn’t correlate with GEI ranking very strongly as shown in figure 5.

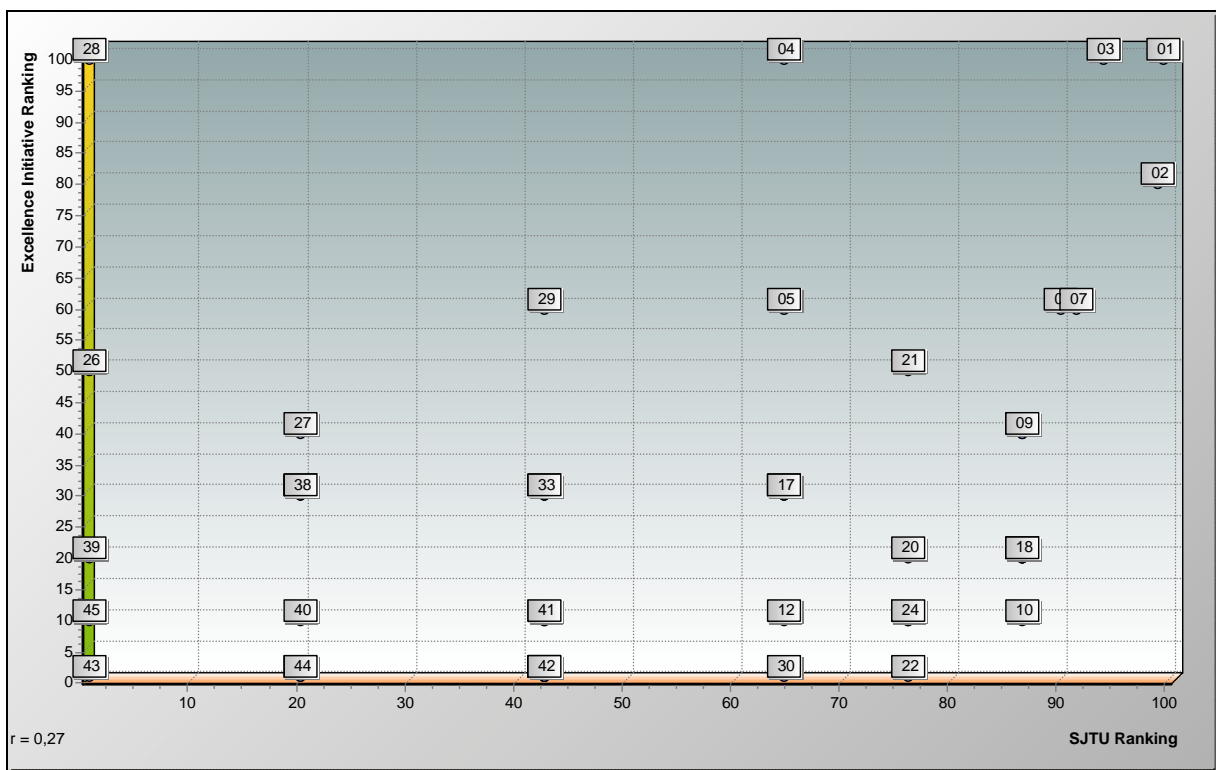


Figure 5. DEA correlation plot between input C (SJTU Ranking) and output E (Excellence Initiative Ranking).

3.4. Model Discussion

The presented DEA model has the precondition of *constant* returns to scale. This concept is widely used and acknowledged but should also be reviewed critically regarding the specific situation of university production environments – especially as the underlying assumption of a freely scalable university size could be *seriously doubted* in the light of the DEA results presented here (and additionally assuming traditional *decreasing* marginal productivity rates respectively utilities). It could easily be assumed on the contrary that for universities as well as for other economic entities there may exist an *optimal institutional size* (which can even be ‘quantified’ with the example of the presented excellence initiative data between annual budget sizes of 100 to 500 Mio Euro). Larger universities may well be confronted with *disproportionate higher* input requirements in order to increase their output further and therefore

experience *decreasing* productivity ratios. Whereas in the area below optimal institutional size increasing productivity ratios for smaller institutions can be assumed. Therefore a BCC model for a further DEA analysis should be tested for universities in order to allow for variable returns to scale, see [5]. In a later research study then a *comparison* between the DEA results in the CCR model and the BCC model may establish further insights into the specific production situation and efficiency in universities.

4. Conclusions

The described input-output-analysis and DEA modelling lead to the following general research results:

- University productivity is only weakly linked to (budget) *size* of universities. It can be assumed that an optimal size of universities can be defined in a middle range institutional size.
- University productivity is also *not* strongly correlated to ranking positions (regardless whether as input or as output indicators). Very productive and also less productive universities can be found among high ranked institutions as well as lower ranked ones. This can be added to the existing criticism towards ranking systems as further weakness.
- For the *selection process* in the German Excellence Initiative the following statements may hold true: Research rankings play a role in selection but not as strongly as could have been assumed. Productivity did *not* play a hand in awarding budgets as the top four universities RWTH Aachen, U Heidelberg, U Munich and FU Berlin depict only an *average* productivity (table 2). DEA calculation showed that there was a quite fair chance for all universities to be successful in the GEI funding allocation.
- This could lead to the thought that productivity should be a *new parameter in rankings* ('on its own right') in order to increase incentives for universities to foster productivity.
- A new innovative distribution model could be deduced: Programmes could distribute budget *inversely proportional* to the budget size of institutions as large institutions mainly may profit from the reputation factor and have a large enough existing 'resource base' to exploit this (new) reputation whereas smaller institutions may be able to improve their output and efficiency mainly through a budget increase (*inverse budget distribution model*). This might define 'smart investments' from the general public (tax payers) point of view.
- Even better would be an *integration of efficiency indicators* in the distribution of public budgets for universities as otherwise in a solely output oriented distribution there may be a risk of misallocation of public funds (*a less than pareto efficient* distribution).

References

1. Abbott, M., Doucouliagos, C., 2003. The efficiency of Australian universities: A data envelopment analysis. *Economics of Education review*, 22 (1), 89-97.
2. Ahn, T., Charnes, A., Cooper, W.W., 1998. Some statistical and DEA evaluations of relative efficiencies of public and private institutions of higher learning. *Socio-Economic Planning Sciences*, 22 (6), 259-269.
3. Ahn, H., Dyckhoff, H., Gilles, R., 2007. Datenaggregation zur Leistungsbeurteilung durch Ranking: Vergleich der CHE- und DEA-Methodik sowie Ableitung eines Kompromissansatzes. *Zeitschrift für Betriebswirtschaft*, 77 (6), 615-643.
4. Avkiran, N.K., 2001 Investigating technical and scale efficiencies of Australian universities through data envelopment analysis. *Socio-Economic Planning Sciences*, 35 (1), 57-80.
5. Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30 (9), 1078-1092.
6. Banker, R.D., Conrad, R.F., Strauss, R.P., 1986. A Comparative Application of Data Envelopment Analysis and Translog Methods: An Illustrative Study of Hospital Production. *Management Science*, 32 (1), 30-44.
7. Brinckmann, H., 1998. *Die neue Freiheit der Universität: Operative Autonomie für Lehre und Forschung an Hochschulen*. Berlin: Sigma.
8. Budäus, D., 1994. *Public Management, Konzepte und Verfahren zur Modernisierung öffentlicher Verwaltungen*. Berlin: Sigma.

9. Bundesministerium für Bildung und Forschung (BMBF), 2006. *Press Release No 181/2006* as of 18th of October 2006. Berlin: Eigenverlag.
10. Bundesministerium für Bildung und Forschung (BMBF), 2007. *Press Release No 213/2007* as of 19th of October 2007. Berlin: Eigenverlag.
11. Buschor, E., 2005. Potenziale von New Public Management (NPM) für Bildung und Wissenschaft. In: Fisch, R., Koch, S. (Eds), 2005. *Neue Steuerung von Bildung und Wissenschaft*. Bonn: Lemmens, 25-36.
12. Butler, T.W., Li, L., 2005. The utility of returns to scale in DEA programming: An analysis of Michigan rural hospitals. *European Journal of Operations Research*, 161 (2), 469-477.
13. Cantner, U., Krüger, J.J., Hanusch, H., 2007. *Produktivitäts- und Effizienzanalyse: Der Nichtparametrische Ansatz*. Berlin et al.: Springer.
14. Cebi, F., Coban, B., Gozlu, S., 2006. Strategic supplier evaluation and selection based on DEA: A case study in a home textile company. *Fourteenth International Working Seminar on Production Economics*, 20.-24.02.2006 in Innsbruck, Pre-Prints, Vol. 3. Innsbruck: Eigenverlag, 37-45.
15. Charnes, A., Cooper, W., Rhodes, E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2 (6), 429-444.
16. Charnes, A., Cooper, W. W., Thrall, R. M., 1991. A Structure for Classifying and Characterizing Efficiency and Inefficiency in Data Envelopment Analysis. *Journal of Productivity Analysis*, 2 (3), 197-237.
17. Connell, H., 2004. *University Research Management, Meeting the Institutional Challenge*. Paris: OECD Eigenverlag.
18. Cook, W.D., Kress, M., Seiford, L.M., 1996. Data Envelopment Analysis in the Presence of Both Quantitative and Qualitative Factors. *Journal of the Operational Research Society*, 47, 945-953.
19. Cooper, A., Seiford, L.M., Tone, K., 2006. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. 2. Ed. New York et al.: Springer US.
20. Cooper, W.W., Seiford, L.M., Zhu, J. (Eds), 2004. *Handbook on Data Envelopment Analysis*. Boston, Dordrecht, London: Springer US/Kluwer Academic Publishers.
21. Dervaux, B., Leleu, H., Nogues, H., Valdmanis, V., 2006. Assessing French nursing home efficiency: An indirect approach via budget-constrained DEA models. *Socio-Economic Planning Sciences*, 40, 70-91.
22. Deutsche Forschungsgemeinschaft (DFG), 2004. *Förder-Ranking 2003, Institutionen – Regionen – Netzwerke, DFG-Bewilligungen und weitere Basisdaten öffentlich geförderter Forschung*. Bonn: Eigenverlag.
23. Deutsche Forschungsgemeinschaft (DFG), 2007. *Förder-Ranking 2006, Institutionen – Regionen – Netzwerke, DFG-Bewilligungen und weitere Basisdaten öffentlich geförderter Forschung*. Bonn: Eigenverlag.
24. Dyckhoff, H., Allen, K., 1999. Theoretische Begründung einer Effizienzanalyse mittels Data Envelopment Analysis (DEA). *Zeitschrift für betriebswirtschaftliche Forschung*, 51 (5), 411-436.
25. Dyckhoff, H., Gilles, R., 2004. Messung der Effektivität und Effizienz produktiver Einheiten. *Zeitschrift für Betriebswirtschaft*, 74 (8), 765-784.
26. Fandel, G., 2003. Zur Leistung nordrhein-westfälischer Universitäten – Gegenüberstellung einer Verteilungslösung und der Effizienzmaße einer Data Envelopment Analysis. In: Backes-Gellner, U., Schmidtke, C. (Eds), 2003. *Hochschulökonomie – Analysen interner Steuerungsprobleme und gesamtwirtschaftlicher Effekte*. Berlin: Duncker & Humblodt, 33-50.
27. Felder, S., Schmitt, H., 2004. Data envelopment analysis based bonus payments – Theory and application to inpatient care in the German state of Saxony-Anhalt. *The European Journal of Health Economics*, 5 (4), 357-364.
28. Feng, Y.J., Lu, H., Bi, K., 2004. An AHP/DEA method for measurement of the efficiency of R&D management activities in universities. *International Transactions in Operational Research*. 2004 (11), 181-191.
29. Ferrier, G.D., Rosko, M.D., Valdmanis, V.G., 2006. Analysis of uncompensated hospital care using a DEA model of output congestion. *Health Care Management Science*, 9, 181-188.
30. Forker, L.B., Mendez, D., 2001. An Analytical Method for Benchmarking Best Peer Suppliers. *International Journal of Operations and Production Management*, 21 (1-2), 195-209.
31. Gilles, R., 2005. *Performance Measurement mittels Data Envelopment Analysis: Theoretisches Grundkonzept und universitäre Forschungsperformance als Anwendungsfall*. Dissertation, RWTH Aachen. Lohmar-Köln: EUL Verlag.
32. Gutierrez, M., 2005. *Effizienzmessung in Hochschulen – Evaluation von Forschungs- und Lehrinhalten mit der Data Envelopment Analysis*. Wiesbaden: Deutscher Universitäts-Verlag.
33. Hülsmann, S., Peters, M.L., 2007. *Data Envelopment Analysis im Bankgewerbe – Theorie und praktische Anwendung*. Saarbrücken: VDM Verlag Dr. Müller.
34. Johnes, J., 2006. Measuring Efficiency: A Comparison of Multilevel Modelling and Data Envelopment Analysis in the Context of Higher Education. *Bulletin of Economic Research*, 58 (2), 75-104.
35. Katharaki, M., 2008. Approaching the management of hospital units with an operation research technique: The case of 32 Greek obstetric and gynaecology public units. *Health Policy*, 85, 19-31.
36. Kleine, A., 2004. A general model framework for DEA. *Omega*, 32, 17-23.

37. Kleinsorge, I.K., Schary, P.B., Tanner, R.D., 1992. Data Envelopment Analysis for Monitoring Customer-Supplier Relationships. *Journal of Accounting and Public Policy*, 11 (4), 357-372.
38. Klumpp, M., 2007. *Research Rankings for German Universities*. Campus Sapiens Paper, No 7, Essen: Eigenverlag.
39. Klumpp, M., 2008. *Modern Public Budgeting, Analysis and Evaluation of Information Management and Risk Management Systems in Public Institutions with the Example of a Risk-Return-Concept for Universities*. Dissertation University of Leipzig. Frankfurt a.M. et al.: Lang (in print).
40. Klumpp, M., Krol, B., Zelewski, S., 2006. Knowledge Intensive Services Production Analysis. *Fourteenth International Working Seminar on Production Economics, 20.-24.02.2006 in Innsbruck*, Pre-Prints, Vol. 1. Innsbruck: Eigenverlag, 193-206.
41. Kontodimopoulos, N., Nanos, P., Niakas, D., 2006. Balancing efficiency of health services and equity of access in remote areas in Greece. *Health Policy*, 76 (1), 49-57.
42. Kruszynski, J., 2007. *Bewertung von Führungseffizienz – Möglichkeiten und Grenzen der Data-Envelopment-Analysis*. Saarbrücken: VDM Verlag Dr. Müller.
43. Kuosmanen, T., Cherchye, L., Sipiläinen, T., 2006. The law of one price in data envelopment analysis: Restricting weight flexibility across firms. *European Journal of Operational Research*. 170 (3), 735-757.
44. Liu, J., Ding, F.-Y., Lall, V., 2000. Using Data Envelopment Analysis to Compare Suppliers for Supplier Selection and Performance Improvement. *Supply Chain Management: An International Journal*, 5 (3), 143-150.
45. Lucht, T., 2007. *Strategisches Human-Resource-Management – ein Beitrag zur Revision des Michigan-Ansatzes unter besonderer Berücksichtigung der Leistungsbeurteilung*. Dissertation, Fernuniversität Hagen.
46. Luptáčík, M., 2003. Data Envelopment Analysis als Entscheidungshilfe für die Evaluierung von Forschungseinheiten in der Universität. *Ergänzungsheft 3/2003 der Zeitschrift für Betriebswirtschaft*, 59-74.
47. McMillan, M.L., Datta, D., 1998. The relative Efficiencies of Canadian Universities: A DEA Perspective. In: *Canadian Public Policy*. 24 (4), 485-511.
48. Murias, P., Martinez, F., de Miguel, C., 2007. An Economic Wellbeing Index for the Spanish Provinces: A Data Envelopment Analysis Approach. *Social Indicators Research*, 77 (3), 395-417.
49. Narasimhan, R., Talluri, S., Mendez, D., 2001. Supplier Evaluation and Rationalization via Data Envelopment Analysis: An Empirical Examination. *Journal of Supply Chain Management*, 37 (3), 28-37.
50. Organisation for Economic Cooperation and Development (OECD), 2002. *Steering and Funding of Research Institutions, Country Report: Germany*. Paris: Eigenverlag.
51. Pasternack, P. 2005. Wechselwirkungen von Politik und Neuen Steuerungsmodellen im Hochschulreformprozess. In: Fisch, R., Koch, S. (Eds), 2005. *Neue Steuerung von Bildung und Wissenschaft*. Bonn: Lemmens, 131-144.
52. Peters, M.L., 2008. *Vertrauen in Wertschöpfungspartnerschaften zum Transfer von retentivem Wissen – Eine Analyse auf Basis realwissenschaftlicher Theorien und Operationalisierung mithilfe des Fuzzy Analytic Network Process und der Data Envelopment Analysis*. Wiesbaden: Deutscher Universitäts-Verlag (in print).
53. Ramanathan, R., 2003. *An Introduction to Data Envelopment Analysis – A Tool for Performance Measurement*. New Delhi, Thousand Oaks, London: SAGE Publications Inc.
54. Rassenhövel, S., Dyckhoff, H., 2006. Die Relevanz von Drittmittelindikatoren bei der Beurteilung der Forschungsleistung im Hochschulbereich. In: Zelewski, S., Akca, N. (Eds), 2006. *Fortschritt in den Wirtschaftswissenschaften*. Wiesbaden: Deutscher Universitäts-Verlag, 85-112.
55. Reiner, G., Hofmann, P., 2004. Performance evaluation of supply chain processes – an integrated benchmarking approach using dependency analysis and data envelopment analysis. *Thirteenth International Working Seminar on Production Economics, 16.-20.02.2004 in Igls*, Pre-Prints, Vol. 2. Igls: Eigenverlag, 495-511.
56. Schefczyk, M., Gerpott, T.J., 1995. Ein produktionswirtschaftlicher Benchmarking-Ansatz: Data Envelopment Analysis. *Journal für Betriebswirtschaft*, 45 (5-6), 335-346.
57. Schuy, J., 2001. *Haushaltsrecht*, Vollschriftensammlung. Heidelberg: C.F. Müller.
58. Shanghai Jiao Tong University (SJTU), 2007. *World University Ranking 2005*. Download at: <http://www.sjtu.edu.cn> and <http://ed.sjtu.edu.cn/rank/2005/ARWU2005Main.htm> on 12.06.2007.
59. Seidler, H.H., 2005. Implementationserfahrungen mit Instrumenten der Neuen Steuerung. In: Fisch, R., Koch, S. (Eds), 2005. *Neue Steuerung von Bildung und Wissenschaft*. Bonn: Lemmens, 123-130.
60. Taylor, B., Harris, G., 2004. Relative efficiency among South African universities: A Data Envelopment Analysis. *Higher Education*, 47 (1), 73-89.
61. Weber, C.A., 1996. A Data Envelopment Analysis Approach to Measuring Vendor Performance. *Supply Chain Management: An International Journal*, 1 (1), 28-39.
62. Zanakis, S.H., Alvarez, C., Li, V., 2007. Socio-economic determinants of HIV/AIDS pandemic and nations efficiencies. *European Journal of Operational Research*, 176, 1811-1838.
63. Zhu, J., Cook, W.D. (Eds), 2007. *Modeling Data Irregularities and Structural Complexities in Data Envelopment Analysis – A Problem-Solving Handbook*. New York: Springer US.
64. Ziegele, F., 2005. Die Umsetzung von Neuen Steuerungsmodellen (NSM) im Hochschulrecht. In: Fisch, R., Koch, S. (Eds), 2005. *Neue Steuerung von Bildung und Wissenschaft*. Bonn: Lemmens, 107-122.