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Efficiency and Productivity in Higher Education: An Assessment of Universities in The United Kingdom

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The Size of UK Higher Education

In 2011/12 there were:

2.5m	Students of whom 2m UG, 0.5m PG
120	Institutions (approx)
378,000	staff were employed (181,000 academic, and 197,000 non academic)
$44.5bl	Income

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INVESTIGATING THE COST STRUCTURE OF ENGLISH UNIVERSITIES

- This study covers English Higher Education.
- It uses panel data for 3 years: 2001/2 – 2003/4, at 2002 prices.
- There are a total of 121 institutions analysed.
- For more information see

Thanassoulis, E. Kortelainen M. Geraint Johnes, Jill Johnes (2011) An Analysis of Costs in Institutions of Higher Education In England: DEA approach Journal of the Operational Research Society Vol. 62, pp 1282–1297

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Questions Addressed

- What would expansion of Higher Education cost?
- What is the cost per student?
- Are there economies of scale?
- How far can student numbers expand through efficiency savings?
- Has productivity in the sector changed over time?

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The key outputs from universities

- Universities are multi-product ‘firms’
  Key outputs are:
  - Teaching (dissemination of knowledge);
  - Research (generation of knowledge);
  - *Third leg* (the provision of advice and other services to business, the storage and preservation of knowledge and the provision of a source of independent comment on public issues).

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Methodology

The study used two main methods to assess efficiency and productivity:

- Econometric methods, consisting of ‘ordinary’ panel methods and Stochastic Frontier Analysis (SFA).
- Data Envelopment Analysis (DEA).
- Here of the econometric results only those from SFA are reported.

Econometric Approach: Choosing a Suitable Functional Form

The function should be capable of:

- explaining how economies of scale or scope can occur for some output profiles, yet diseconomies of scale can occur for other output profiles;
- ensuring that estimates of costs are sensible under conditions where an institution produces positive quantities of some output types, but zero amounts of other outputs.

The Quadratic Functional Form

For the econometric estimations we used a quadratic function of the form:

$$C_k = a_0 + \sum_i a_i F_{ik} + \sum_i b_i y_{ik} + (1/2)\sum_i \sum_j c_{ij} y_{ik} y_{jk} + v_k$$

where y_{ik} is output i at institution k , a_0, a_i, b_i and c_{ij} are coefficients to be estimated, and F_{ik} is a dummy variable such that $F_{ik} = 1$ if output *i* in institution *k* is positive, and zero otherwise.

The function was estimated under Random Effects using GLS and SFA. Only the SFA results are reported here to match the frontier nature of DEA.

Dependent variable in SFA/Input variable for DEA	
COSTDEF	Total operating costs in £000 in constant prices. This figure is inclusive of depreciation.
Independent variables in SFA/ Outputs in DEA	
UGMED	Undergraduates in medicine or dentistry (000).
UGSCI	Undergraduate in science (000). Summation of subjects allied to medicine, veterinary, biological, agriculture, physical sciences, maths, computing, engineering and architecture.
UGNONSCI	Undergraduate in non-science subjects (000). Summation of social economics, law, business, librarianship, languages, humanities, creative arts and education.
RESEARCH	Quality related funding and research grants, in £000000, constant prices.
PG	Postgraduate student numbers in 000s (sum of PGR, PGT and PGOTHER).
3RD MISSION	Income from other services rendered in £000000s at constant prices.

Average Incremental Costs

- The average incremental cost of product *i* is defined in the general case as:

$$AIC(y_i) = \left[C(y_n) - C(y_{n-i})\right] / y_i = IC(y_i) / y_i$$

- where $C(y_n)$ is the total cost of producing all the outputs at the levels in y_n, while $C(y_{n-i})$ is the total cost of producing all the outputs at the levels in y_n *except output i* which is zero.

For SFA we set $C(y_n)$ at average output levels so that AICs reflect the cost on average for a unit of output were a HEI to go from zero to an average level of that output while keeping the rest of the outputs at average levels.

Estimates of economies of scale

Product-specific returns to scale for product *i* are $S_i(y)$ where

$$S_i(y) = AIC(y_i)/C_i(y)$$

and $C_i(y)$ is the marginal cost of producing the *i*th output.

If $S_i(y) > 1$ then there are product-specific economies of scale for product *i*.

Ray economies of scale (S_R) is calculated in the general case as: $S_R = \frac{C(y)}{\sum_i y_i C_i(y)}$

If $S_R > 1$ then there are ray economies of scale and if $S_R < 1$ then we have ray diseconomies of scale.

Findings on Economies of Scale

There are slight ray diseconomies of scale.

There are diseconomies of scale for PG students and economies of scale for research.

Based on the SFA model

	Evaluated at: Mean	80% of mean	120% of mean
Ray economies	0.96	0.96	0.97
Product-specific economies			
Medicine Ug	0.98	0.99	0.98
Science Ug	1.01	1.00	1.01
Non-science Ug	1.02	1.02	1.02
Postgraduate	0.87	0.89	0.86
Research	1.07	1.05	1.08

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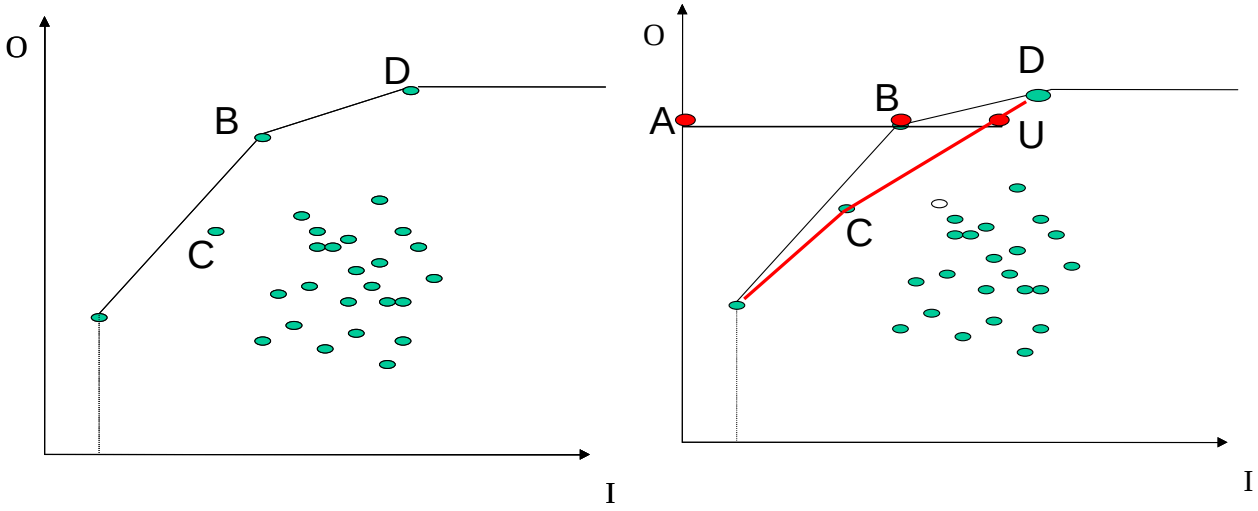
ASSESSMENT USING DEA

We used a Variable Returns to Scale, input oriented model.

The Total Cost was the input.

The outputs were the 6 explanatory variables used in the SFA model.

Using 120% as cut off we identified 5 outliers and did not permit them to influence the location of the efficient boundary



Super-efficiency of B=AU/AB>1

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Comparing DEA and SFA efficiency findings – pooled categories of HEIs

	N	Min	Q1	Mean	Median	Q3	Max	St Dv
DEA	358	27.5	79.3	86.3	91.2	99	100	15.8
DEA year 3 only	118	27.6	78.9	85.4	90.5	98.7	100	16.7
SFA year 3 only	121	6.0	67.0	74.7	83.7	89.7	98.7	22.9

The DEA efficiencies exhibit a higher mean and narrower range than the SFA efficiencies. Spearman's rank correlation coefficient between DEA and SFA is 0.60 which is significant at the 1% significance level.

The sector as a whole has weighted efficiency of about 92.35% which is high.

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DEA efficiencies by university grouping

Group	N	Min	Q1	Median	Q3	St. Dev.
Pre-92 HEIs without medical schools (minus 3 outliers)	96	39.65	91.06	98.91	100	13.63
Post-92 universities (no outliers)	99	73.65	88.79	96.5	100	7.352
SCOP colleges (minus 2 outliers)	114	27.55	78.88	90.5	100	16.85
Pre-92 HEIs with medical schools (no outliers)	54	87.97	97.16	100	100	3.16

Arriving at marginal output costs through DEA

In DEA, we have a different set of marginal costs per unit output at each efficient segment (or facet). For an efficient unit we get:

Cost= DEA weight 1 x output 1 + DEA weight 2 x output 2….
The DEA weights can be seen as marginal output costs

In order to get unique marginal costs we can attempt a parametric description of the DEA boundary.

It involves projecting the units on the efficient boundary so that in effect inefficiencies have been eliminated.

We can then use OLS regression on the 'efficient' input output profile of each HEI to derive an equation for the boundary.[1]

[1] For further details of this and related approaches see E. Thanassoulis, (1996) "A data envelopment analysis approach to clustering operating units for resource allocation purposes, ***Omega: the international journal of management science, Vol. 24, No. 4, pp. 463 - 476***)".

DEA marginal output costs v SFA AICs

Note that AIC shown here under SFA are not defined in the same way as the DEA margi-nal costs

Subgroup	Method	UGSCI	UGNONSCI	PG	UGMED	DEA-Eff'cy
Pre-1992 HEIs without medical students	DEA	4655	3047	12369		
	SFA	4935	3981	8133		94%
Post-1992 HEIs	DEA	6006	2714	7504		
	SFA	4465	2725	7680		93.5%
SCOP colleges	DEA	7046	3070	6273		
	SFA	5604	4808	2030		90%
Pre-1992 HEIs with medical students	DEA	3992	3992	7572	10631	98.4%
	SFA	2805	4778	4607	17079	

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Observations on unit costs

Looking across student categories

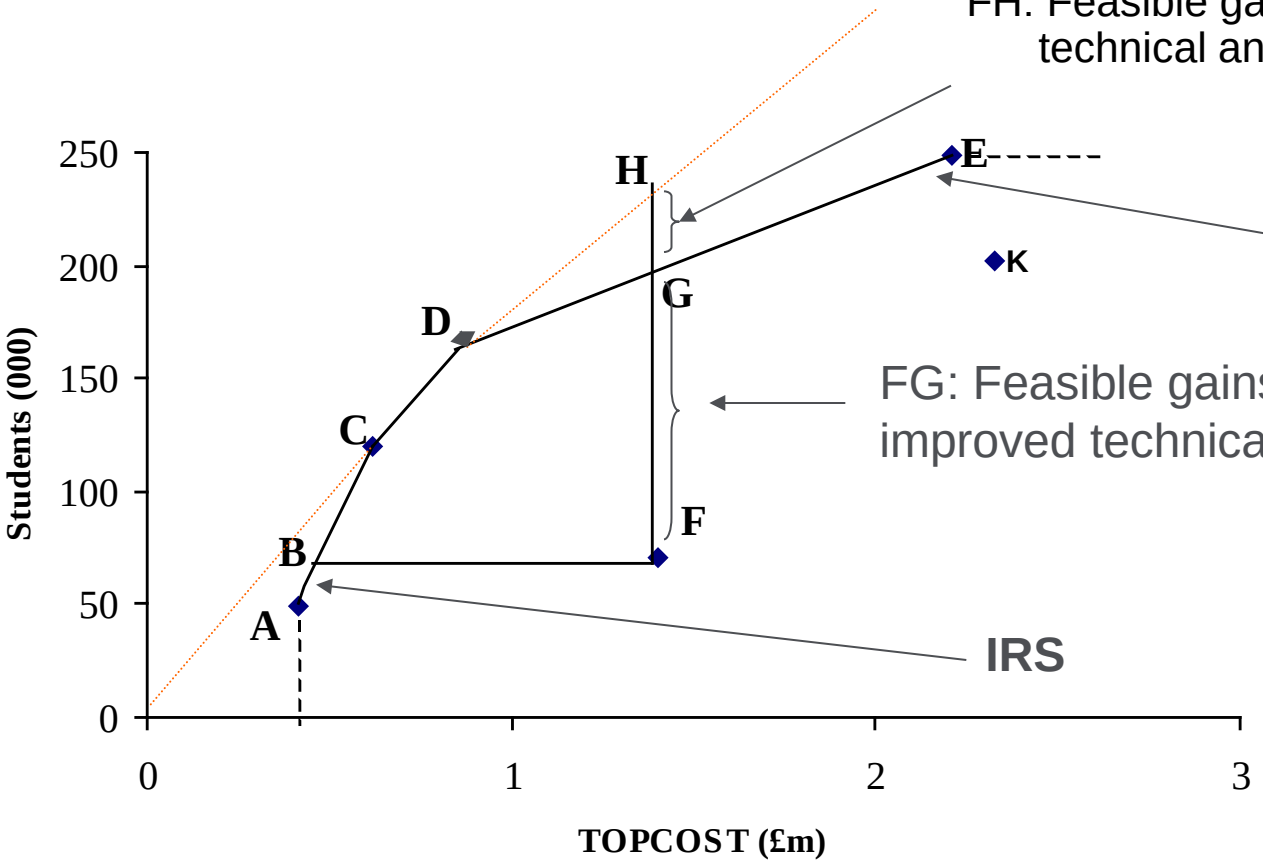
- Pre-92: It is more than two times costlier to educate a PG than a science UG student;
- Pre-92: Non-science UG students have the lowest unit costs.
- Post-92: The same applies as for Pre-92 universities but the difference is less between PG and science UG;

Comparing DEA and SFA derived unit costs

- DEA tends to yield higher cost per PG student than does SFA;
- This is usually but not always at the expense of DEA estimating lower cost per UG student;
- The higher DEA costs are closer to what universities charge for PG degrees than are the SFA PG unit costs.
- SFA units costs are based on AICs based in turn on average output levels. Some universities have a limited portfolio of PG courses so AICs likely to be less accurate.

Returns to Scale and Potential Output Gains

FH: Feasible gains for F through improved technical and scale efficiency



FG: Feasible gains for F through improved technical efficiency

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Returns to Scale on the Efficient Frontier

	IRS	CRS	DRS
Pre 92 no medical schools	3	20	21
Pre 92 with medical schools	1	18	17
Post 92 Universities	10	21	3
SCOP colleges	1	24	12

Expenditure Savings Recoverable Through Improved Technical and Scale Efficiency.

	Percent of expenditure attributable to Technical inefficiency	Percent of expenditure attributable to scale inefficiencies	Percent of expenditure recoverable through operating and scale efficiency gains
Pre-92 no medical schools (N = 96)	6.02	6.49	12.51
Pre-92 with medical schools (N = 54)	1.65	2.65	4.30
Post-92 Universities (N = 99)	6.51	2.28	8.80
SCOP colleges (N = 114)	10.66	4.94	15.60

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Potential Output Augmentation Maintaining Current Levels of Expenditure and Output mix – by DEA

	Percent rise through eliminating technical inefficiency			Percent rise through eliminating technical and scale inefficiency.		
	UG S	**UG N S**	**PG**	**UG S**	**UG N S**	**PG**
Pre92- no med, N=96	7.71	13.32	8.78	12.67	26.02	21.62
Pre92- with med (N=54)	2.09	2.33	2.34	8.4	5.6	9.35
Post-92 (N=99)	10.05	11.34	13.27	11.22	13.5	18.48
SCOP colleges (N=114)	13.64	13.21	24.5	20.62	22	36.73
Total	**7.63**	**10.15**	**9.32**	**11.33**	**15.26**	**17.52**

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Gains of the order of 8%-10% in student numbers are possible by eliminating technical inefficiency and a further 3%-8% by adopting most-productive scale size.

Potential Output Augmentation Prioritising Student Numbers over Research and Third Mission – by DEA

	Percent rise through eliminating technical inefficiency			Percent rise through eliminating technical and scale inefficiency.		
	UG S	**UG N S**	**PG**	**UG S**	**UG N S**	**PG**
Pre92- no med, N=96	33.33	24.85	9.84	64.74	57.53	20.30
Pre92- with med (N=54)	2.83	1.59	4.44	11.23	0.69	15.72
Post-92 (N=99)	8.38	13.45	22.85	10.25	17.92	27.11
SCOP colleges (N=114)	19.16	6.67	55.33	30.84	11.63	98.36
Total	**12.17**	**11.83**	**15.97**	**22.00**	**19.81**	**27.16**

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The large gains now estimated are because we have dropped the need to maintain student mix, focusing on where largest student increases are feasible.

Productivity Change between 2001 and 2003 – by DEA

	Geometric Mean			Malmquist index		
	Ef Ch	B shift	Malm	Q1	Med	Q3
Pre92- no med, N=32	1	0.98	0.99	0.91	0.98	1.04
Pre92- with med (N=18)	1	0.94	0.95	0.90	0.94	1.01
Post-92 (N=33)	0.96	1.04	1	0.95	0.98	1.07
SCOP colleges (N=38)	0.94	0.95	0.89	0.88	0.94	1.06

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On average productivity between 2001 and 2003 is constant for all universities except those with medical schools. The latter and the SCOP colleges lose considerable productivity over time.

Figure 12: Total Factor Productivity Change by Type of HEI: Values over 1 mean gain and under 1 loss.

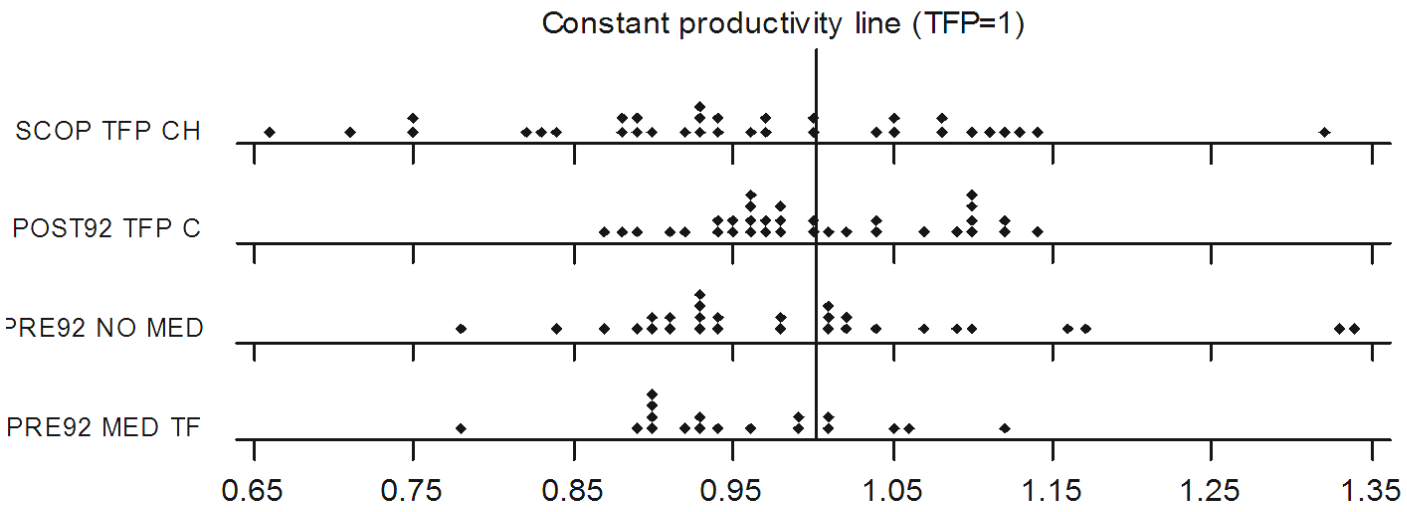

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Figure 13: Efficiency change by Type of HEI: Values over 1 mean gain and under 1 loss.

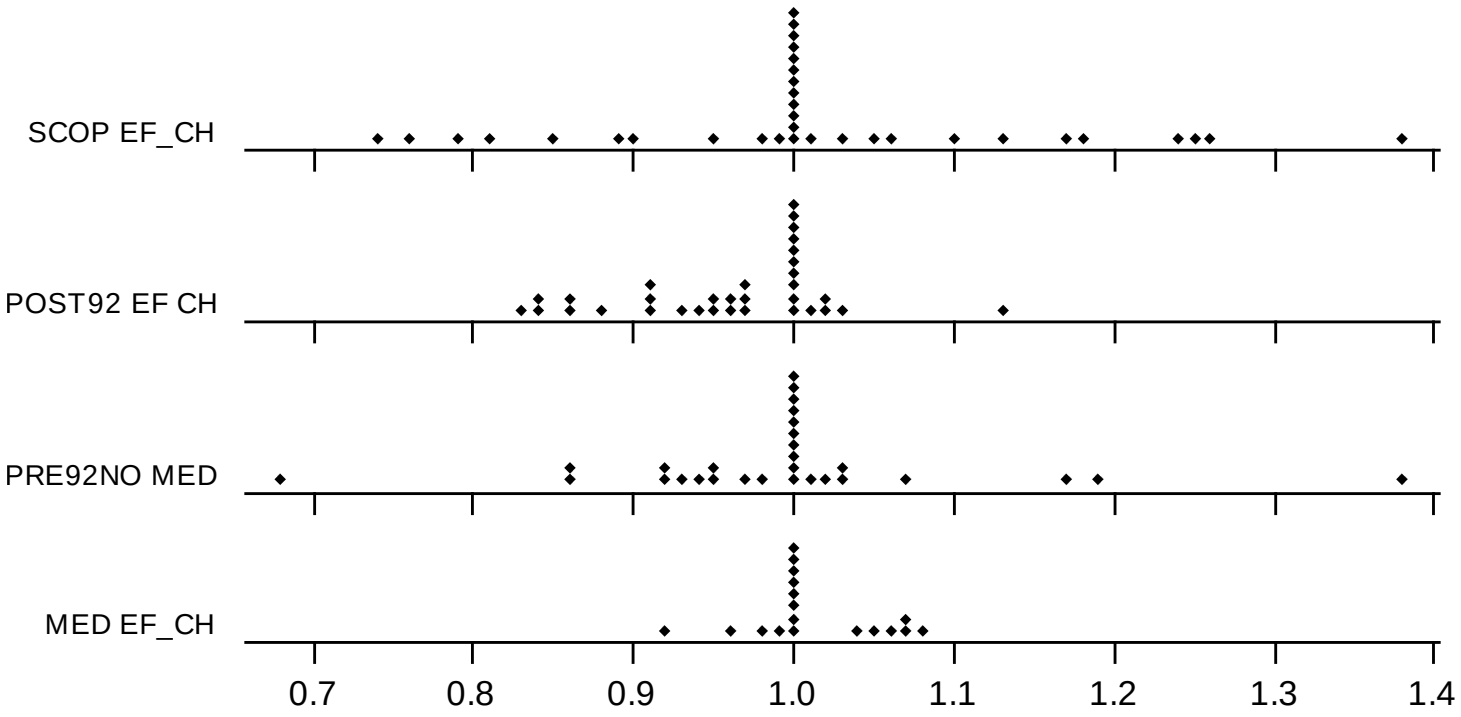

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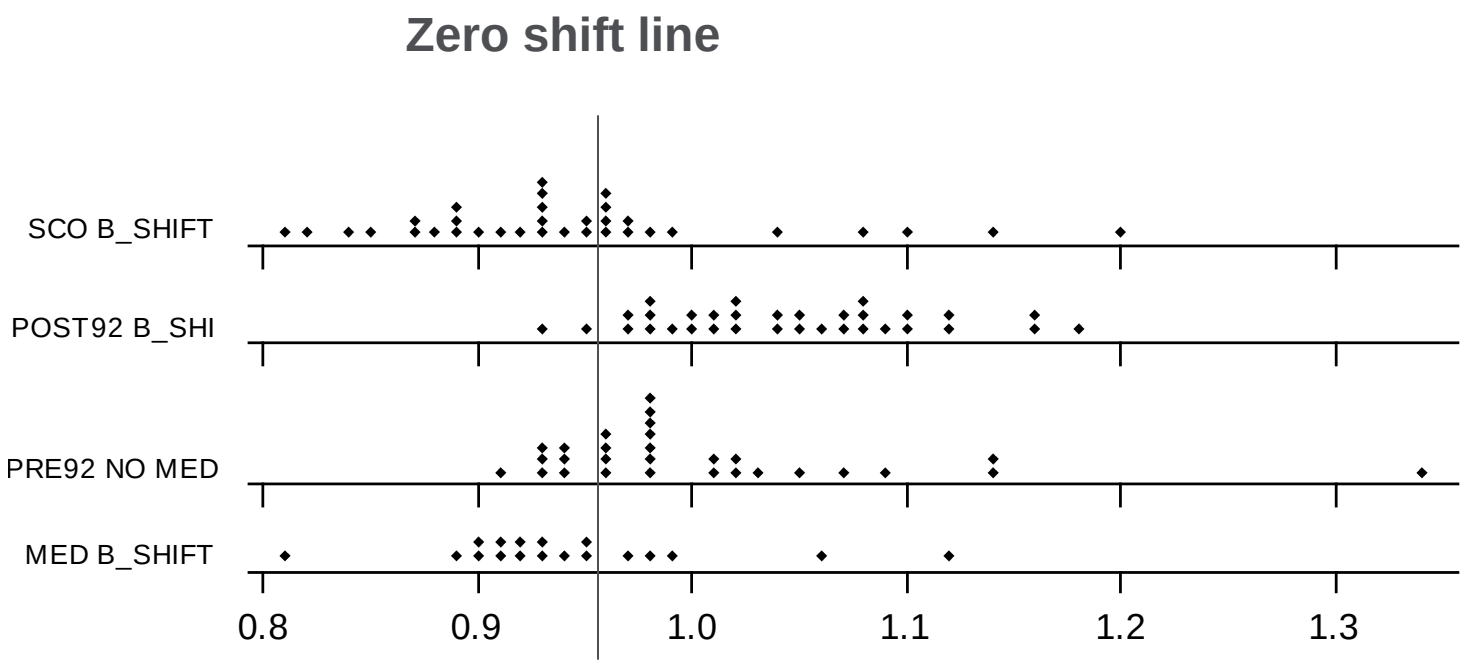
Figure 14: Boundary shift by Type of HEI: Values over 1 mean productivity gain and under 1 loss.



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CONCLUSIONS

- It is important to use BOUNDARY methods (e.g. DEA, SFA) to study the cost structure of universities. This will have two major benefits:
  - It will identify efficient benchmarks and therefore targets and good practices to disseminate;
  - It will avoid the problem of reproducing the funding formula used by government;

- Studies can be at a variety of levels. E.g:
  - At overall university level;
  - At academic department level;
  - By function such as administration, library, IT services etc (but care is needed the units should be self-contained).

- In the UK there is considerable scope for savings in administration but not so much at overall university level (in percentage terms);

- There is great variability among institutions on cost-efficiency and on productivity gains over time.

- There are groups of institutions which have consistently good and others consistently poor performance;

- Better data is needed (in the UK) to arrive at more robust efficiency and productivity results.

Conclusions -2

- The DEA analysis suggests that there is substantial scope for gains in student numbers at no additional costs, especially if all efficiency gains are directed to raising student numbers, permitting each HEI to raise numbers in areas where it has itself the largest scope for gains.
- Potential student number gains peak at about 20% -25% through a combination of exploiting efficiency gains, economies of scale and student mix adjustments.
- In the shorter term and before any scale size adjustments are made the gains reduce to between 12%-15%, and reduce still further to between 7-10% if both scale size and output mix are maintained.
- It must be recalled that the efficiency gains estimated here are relative to the best observed performance among the HEIs in the comparative set used. Further gains may be possible in absolute terms but these can only be identified by going beyond observed practice reflected in the comparative data used.

THANK YOU

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