“ASSESSING RESEARCH PRODUCTIVITY IN TERMS OF ENDOGENEITY OR EXOGENEITY OF ACADEMIC SALARIES”

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MOTIVATION

A major component of University expenditure is salaries for academic staff.

We present here two DEA methods which can be used to compare individual academics and academic departments on their cost effectiveness.

One of the methods focuses on savings in salary costs for given academic outcomes, taking account of the fact that institutions have a degree of flexibility on salary levels.

The second method takes the salary levels paid as given, and focuses on comparing Groups of academics on some classification variable of choice (e.g. home grown v externally recruited staff) on performance in cost terms.

ASSESSING COST EFFECTIVENESS WHEN INPUT PRICES ARE ENDOGENOUS

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We can use the model developed in Portela and Thanassoulis (2014) Omega, The International Journal of Management Science Vol 47 pp 36–44 DOI http://authors.elsevier.com/sd/article/S0305048314000267

The model allows for determining minimum aggregate cost of securing a given output bundle (e.g. in-career research) through the SIMULTANEOUS optimisation of inputs levels (e.g. prior qualifications, time in post) and input prices (e.g. salaries)

PORTELA AND THANASSOULIS PRICE EFFICIENCY MODEL

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$$\min_{\gamma_i,\theta_i,\lambda_j,z_{ij}} \{C = \sum_{i=1}^{m} \gamma_i p_{io}\, \theta_i x_{io} \mid \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_i x_{io},\ i = 1, ..., m,\ \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}, r = 1, ..., s,$$

$$\sum_{j=1}^{n} z_{ij}\ p_{ij} \leq \gamma_i p_{io}, i = 1, ..., m \sum_{j=1}^{n} z_{ij} = 1,\ i = 1, ..., m,\ \beta_i \leq \gamma_i \leq \alpha_i,\ z_{ij}, \lambda_j, \theta_i \geq 0\} \sum_{j}^{n} \lambda_j = 1$$

Model 1

The θ_i reflect potential proportional changes in observed levels of inputs;

The γ_i reflect potential proportional changes in observed input prices between user-specified upper bounds α_i and lower bounds β_i.

$\sum_{j}^{n} \lambda_j = 1$ defines the traditional VRS PPS using observed input-output levels;

$\sum_{j}^{n} z_{ij} = 1$ i=1...m defines a convex Price Possibility Set using observed input prices.

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POTENTIAL SAVINGS AND THEIR DECOMPOSITION

The cost efficiency yielded by model (1) is the ratio of the minimum estimated to the observed aggregate cost of inputs,

$$CE = \frac{C^*}{C_o} = \frac{\sum_{i=1}^{m} \theta_i^* \gamma_i^* x_{io} p_{io}}{\sum_{i=1}^{m} x_{io} p_{io}}$$

The total potential savings can be decomposed

$$\frac{\sum_{i=1}^{m} x_{io} p_{io} - \sum_{i=1}^{m} x_i^* p_{io}^*}{\sum_{i=1}^{m} x_{io} p_{io}} = \frac{\sum_{i=1}^{m} (x_{io} - x_{io}^*)(\frac{p_{io} + p_{io}^*}{2})}{\sum_{i=1}^{m} x_{io} p_{io}} + \frac{\sum_{i=1}^{m} (p_{io} - p_{io}^*)(\frac{x_{io} + x_i^*}{2})}{\sum_{i=1}^{m} x_{io} p_{io}}$$

Component attributable to input level optimisation

Component attributable to input price optimisation

AN ILLUSTRATIVE APPLICATION

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- DMUs: 100 Academics at a Greek University
- SALARIES (input prices) assumed endogenous to capture potential savings through both reduced time for research and/or slower promotions.

INPUTS	OUTPUTS
Publications up to joining Dept+2 years[1] (reduced to A+ rated equivalent)	Publications from joining Dept+2 years (Rated A+ plus rated A/1.2)
Number of years in post-2 years[2]	Publications from joining Dept+2 years (rated B + rated C/1.5)

INPUT	PRICE
Publications up to joining Dept+2 years	Starting salary/publications at recruitment (P1- euro'000)
Number of years in post-2	Mean annual salary (P2-euro'000)

1. Assuming first 2 years in post are set aside to develop research agenda.

COST EFFICIENCIES – SIX DEPARTMENTS (100 STAFF)

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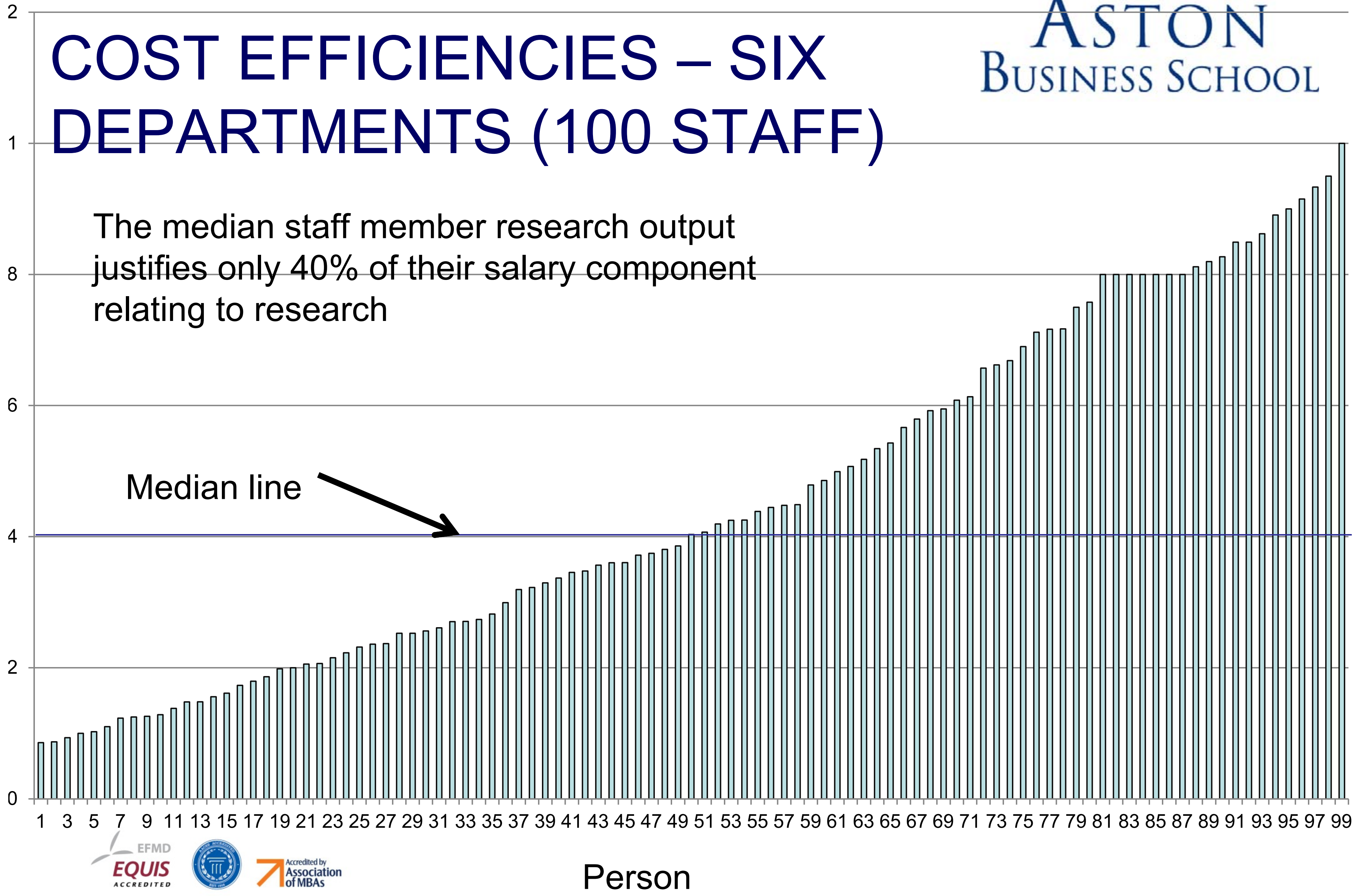
The median staff member research output justifies only 40% of their salary component relating to research



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Summary results – Institution level

Mean drop in A+ publications at appointment[1]: Down to:	**0.85 (median 1)**
Mean potential reduction in years taken to deliver the in post research: Down to:	**0.51 (median 1)**
Mean potential reduction in cost per initial A+[1] publication down to:	**0.81 (median 0.8)**
Mean potential reduction in annual salary down to:	**0.86 (median 0.8)**
Proportion of total salary costs savable by accepting lower publications on appointment and/or delivering research in fewer years	**53.53%**
Proportion of total salary costs savable through lower mean annual salaries	**12.47%**
Grand total proportion of salary costs that can be saved	**66%**
Proportion of salary costs that can be saved ignoring the first 2 years in post	**68%**

1: Excludes those offering no A+ equivalent publications

Example - Academic with scope to achieve savings through input level reductions

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Potential Savings mainly via input levels 66%-time and initial A+ 2% -Salary	Inputs A+ at Appnt	Years in Post	Outputs A+ in post	B in post	Input prices Euro'000 per publication at recruitment	Mean annual salary
Actual	20.37	4	0	1.67	1.05	22.185
Target	7.10	1.29			1.05	21.408

Efficient peers	A+ at Appnt	Years in Post	A+ in post	B in post	Euro'000 per publication at recruitment	Mean annual salary
Peer 1 (λ=0.3)	6.02	2	0	5.667	3.557022	22.962
Peer 2 (λ=0.7)	7.55	1	0	0	2.833412	21.408

Contrasting Senior with Junior Academics

	Professors and Associate Professors	Assistant Professors and Lecturers
Staff Numbers (Normalised Junior=100)	186	100
Expenditure on salaries (Normalised Junior=100)	621	100
Mean drop in A+ publications at appointment (excluding those with 0 A+ at appoint) (θ1)	0.86 (st dev 0.2)	0.835 (st dev 0.2)
Mean potential reduction in years taken to deliver the in post research: (θ2)	0.44 (st dev 0.3)	0.62 (St Dev 0.26)
Proportion of salary costs that can be saved: (Ignoring the first 2 years in post)	69.5%	57%

Notes of Caution

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This work is to be seen as 'illustrative'

There are a number of assumptions which would need to be debated and modified if need be.

They include:

- The use of research output only when it appears in ranked journals;
- The use of a subjective trade off between papers published in journals of different ranks;
- The assumption that the same proportion of an academic's salary is dedicated to research across all staff;
- The potential trade off between research and other outputs (eg teaching)
- The potential recruitment of 'names' for external visibility rather than research output.

COMPARING GROUPS OF UNITS ON COST EFFECTIVENSS

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Assuming exogenously fixed salaries, we can use the traditional DEA cost efficiency model to determine the minimum cost for an academic person's research output.

We can compare academics and their departments using the method in Thanassoulis et al. *A Cost Malmquist Productivity Index Capturing Group Performance*, forthcoming, European Journal of Operational Research.

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A COST INDEX FOR COMPARING GROUPS OF DMUS

Denote the cost efficiency for DMU j (academic person) of Group (Department) A as

$$CE^{A}\left(X_{j}^{A}, Y_{j}^{A}, W_{j}^{A}\right)=\frac{C^{A}\left(Y_{j}^{A}, W_{j}^{A}\right)}{W_{j}^{A} X_{j}^{A}}$$

DMU j operating in Group A is represented by its input-output vector $\left(X_{j}^{A}, Y_{j}^{A}\right)$ and input prices $\boldsymbol{W_j^A}$.

$C^{A}\left(Y_{j}^{A}, W_{j}^{A}\right)$ represents the minimum cost at which DMU j of Group A can secure its outputs;

$\boldsymbol{W_j^A X_j^A}$ represents the observed cost at which DMU j of Group A secures its outputs .

Define CROSS-GROUP cost-efficiency of DMU j in Group B with reference to the Group A boundary as

$$\boldsymbol{CE_j^{A,B}} = {C^A(Y_j^B, W_j^B)} \Big/ {W_j^B X_j^B}$$

$$C^A\left(y_j^B, w_j^B\right) = \min_{x_i, \lambda_j} \sum_{i=1}^{m} w_{j_0}^B x_i$$

Subject to

$$\sum_{j=1}^{n} \lambda_j x^A_{ij} \le x_i \quad , i = 1, \dots, m,$$

$$\sum_{j=1}^{n} \lambda_j y^A_{rj} \ge y^B_{rj_0}, r = 1, \dots, s,$$

$$\lambda_j \ge 0, x_i \ge 0, \quad j = 1, \dots, n; i = 1, \dots, m$$

AN INDEX FOR COMPARING GROUPS A AND B ON COSTS

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$$CI^{BA} = \left(CI^{A} \times CI^{B}\right)^{0.5} = \left[\frac{\left(\prod_{j=1}^{\delta_B} CE_j^{B}\right)^{\frac{1}{\delta_B}}}{\left(\prod_{j=1}^{\delta_A} CE_j^{B,A}\right)^{\frac{1}{\delta_A}}} \times \frac{\left(\prod_{j=1}^{\delta_B} CE_j^{A,B}\right)^{\frac{1}{\delta_B}}}{\left(\prod_{j=1}^{\delta_A} CE_j^{A}\right)^{\frac{1}{\delta_A}}} \right]^{0.5}$$

A value greater than 1 for CI^{BA} would indicate that the DMUs in Group *B* are more productive in cost terms than those in Group *A;*

A value below 1 would indicate the converse; and

A value equal to 1 would suggest equal cost productivity of the DMUs in the two groups.

DECOMPOSING THE INDEX OF COST PRODUCTIVITY

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$$CI^{BA} = OECG^{BA} \times CTCG^{AB}$$

$$OECG^{BA} = \frac{\left(\prod_{j=1}^{\delta_B} CE_j^B\right)^{1/\delta_B}}{\left(\prod_{j=1}^{\delta_A} CE_j^A\right)^{1/\delta_A}}$$

$$CTCG^{AB} = \left[\frac{\left(\prod_{j=1}^{\delta_A} CE_j^A\right)^{1/\delta_A}}{\left(\prod_{j=1}^{\delta_A} CE_j^{B,A}\right)^{1/\delta_A}} \times \frac{\left(\prod_{j=1}^{\delta_B} CE_j^{A,B}\right)^{1/\delta_B}}{\left(\prod_{j=1}^{\delta_B} CE_j^B\right)^{1/\delta_B}}\right]^{1/2}$$

$OECG^{BA}$ Reflects the relative spread of DMUs from the home Group frontier. The larger its value the closer the DMUs in Group *B* to their own cost frontier compared to the DMUs in Group *A*.

$CTCG^{AB}$ captures the distance between the cost frontier of the DMUs in A from that of the DMUs in B. This is akin to **boundary shift** in the traditional Malmquist index but it relates to cost frontiers of Groups of DMUs. The larger the value of **$CTCG^{AB}$** the more demanding the target in cost terms for a DMU when based on Group B rather than Group A.

GRAPHICAL ILLUSTRATION OF THE **CTCG^{AB}** COMPONNET

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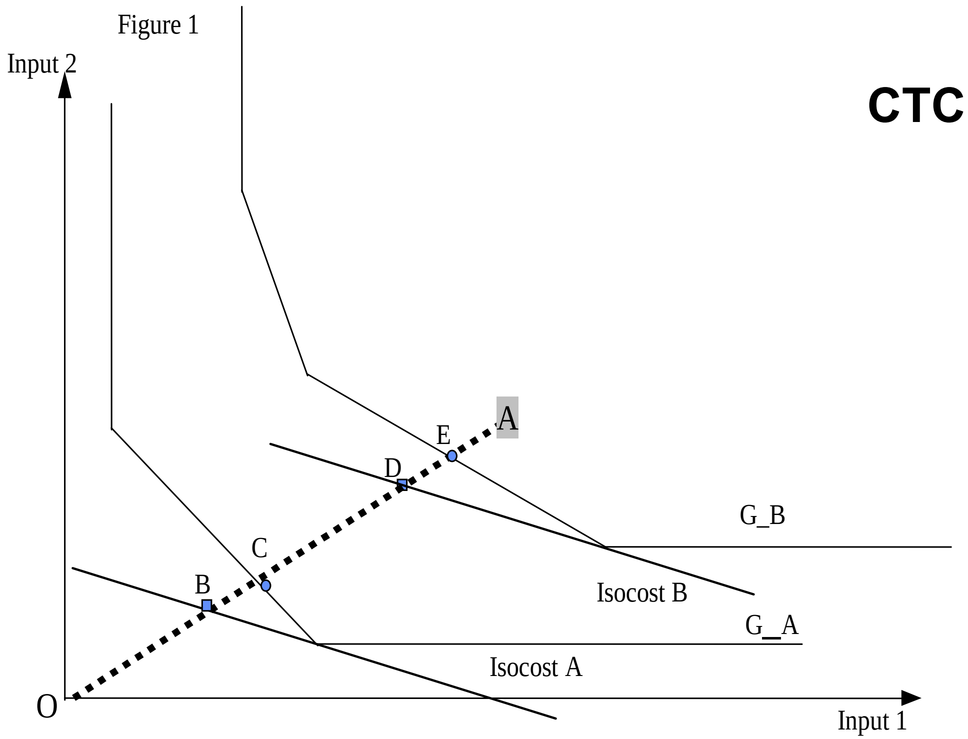

CTCG^{AB} with ref to DMU A => OB/OD

OB/OD reflects the distance between the cost frontiers Isocost B:IsocostA

The distance between the cost frontiers reflects

a) Technical shift, between G_A and G_B and

b) The difference in allocative efficiency of DMU A in relation to the two Groups of DMUs, depicted by the difference between BC and DE.

POTENTIAL USE OF THE COST MALMQUIST INDEX IN HIGHER EDUCATION

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- It enables comparison of Groups of academics on chosen input – output variables based on any classification parameter of interest: (e.g. academic discipline, gender, level of seniority, recruitment period, etc.)
- It enables a decomposition of performance both in technical and cost terms.
- Two-levels of decomposition are available.

DECOMPOSITION LEVEL 1

$CI^{BA} = OECG^{BA} \times CTCG^{AB}$

- $OECG^{BA}$ reflects how far or close to their own efficient (in cost terms) boundary are the academics of each Group.

- $CTCG^{AB}$ reflects a combination of technical boundary shift and allocative efficiency change between Groups.

PART a OF DECOMPOSITION LEVEL 2

$OECG^{BA} = TECG^{AB} \times AECG^{BA}$

- $TECG^{AB}$ reflects how far or close to their own efficient (in technical terms) boundary are the academics of each Group.
- $AECG^{BA}$ mean allocative efficiency of the academics of one group against that of another.

PART b OF DECOMPOSITION LEVEL 2

$CTCG^{AB} = TCG^{BA} \times PEG^{AB}$

- TCG^{BA} reflects the relative productivity in technical (non cost) terms of the ‘boundary academics’ of one Group relative to that of a second Group.

- PEG^{AB} reflects the comparative distance between the cost and technical efficient frontiers in each Group.

Conclusion

We have looked at two DEA methods of analysis which are general purpose, but lend themselves for use in assessing at person and Group level academics in Universities.

The method assuming endogenous prices can be used when the aim is to assess potential salary savings that might have been made through reducing input levels (e.g. time taken to deliver research outcomes) and through lower input prices (e.g. offering lower starting salaries or matching more gradually promotions to outcomes.)

The potential savings can be decomposed in terms of origin through changes in
- input levels and
- input prices (salaries)

The second method has focused on comparing **Groups** of academics, classified by some variable of interest such as discipline, gender, internal v external recruitment etc.

The approach computes an index of relative productivity of the academics in each Group.

The index can be decomposed in two ways:
a) in technical efficiency terms and

b) In cost efficiency terms.

The Groups can be compared on 4 different components,
- relative spread from technical or cost efficient boundary;

- Boundary shift of cost frontiers which can be decomposed into technical boundary shift and allocative efficiency differences between the Groups.

Thank you!

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