

# Assessing Health Efficiency across Countries with a Two-step and Bootstrap Analysis

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## Introduction

In this paper we:

- i) **estimate output efficiency scores** for OECD countries, taking into account the resources employed;
- ii) **explain efficiency scores**, controlling for environment factors (non-discretionary inputs).
  
- Methodology:
  - “raw” efficiency scores: **DEA** (data envelopment analysis);
  - explaining inefficiency: **tobit regression, bootstrap technique.**

## Motivation (1)

- Importance of health spending
  - Germany, France 2003 – 10-11% of GDP, of which 76-78% is public spending.
  - OECD countries, 2003 – 8.7 % of GDP, of which 72.5 percent is public spending.
- European Union, 25 countries
  - Total government spending, 2003 – 47.7 % of GDP
  - Health government spending, 2003 – 6.4 % of GDP
  - Health spending is 13.4 % of government spending
- There is an increased concern about health spending and with cross-country comparison, namely from the EC and OECD:



## Motivation (2)

### – Main questions

- Are “health results” satisfactory considering the amount of resources allocated to this activity?
- Could we have better results using the same resources?
- Could we have the same results with lower expenses?
- Can we measure inefficiency across countries?
- Can we explain measured inefficiency?
  - a systemic component,
  - and an environmental or non-discretionary component.

## Some literature on public sector efficiency

Previous research suggests the existence of inefficiencies:

- Afonso, Schuknecht and Tanzi (2005), public sector efficiency in the OECD;
- Afonso, Schuknecht and Tanzi (2006), public sector efficiency in emerging markets;
- Evans, Tandon, Murray and Lauer (2000), comparative efficiency of national health systems in 191 countries;
- Afonso and St. Aubyn (2005), health and education efficiency in OECD;
- Afonso and St. Aubyn (2006), education efficiency in OECD.

## Methodology (1) - efficiency frontier analysis

- The more common “production function” relates several inputs to the output:

$$y = F(x_1, x_2)$$

- New interpretation:

$F(x_1, x_2)$  is a production possibilities frontier

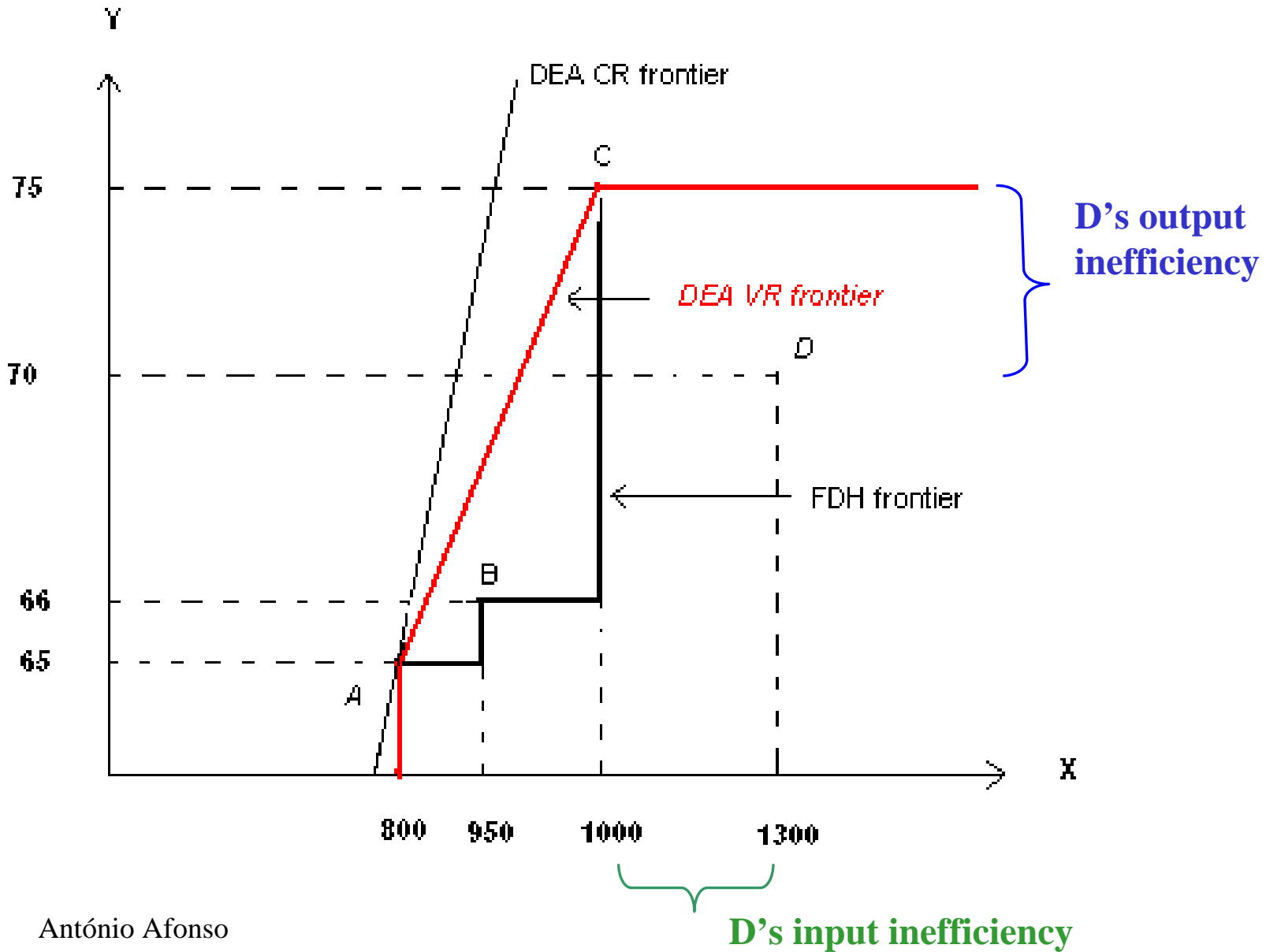
- Note that:

- usually there are several outputs.
- their joint production depends on several inputs.
- and on other variables (“environment variables”).

Methodologies used in the literature

- FDH or DEA, or both;
- Non-discretionary inputs are seldom considered;
- Some examples of two-step analysis.

# Methodology (2) - efficiency frontier illustrations



## Methodology (3) - non-discretionary inputs and two-step procedure

### Non-discretionary inputs:

Socio-economic differences may play a relevant role in determining heterogeneity across DMUs – either secondary schools, universities or countries' achievements in an international comparison – and influence educational outcomes.

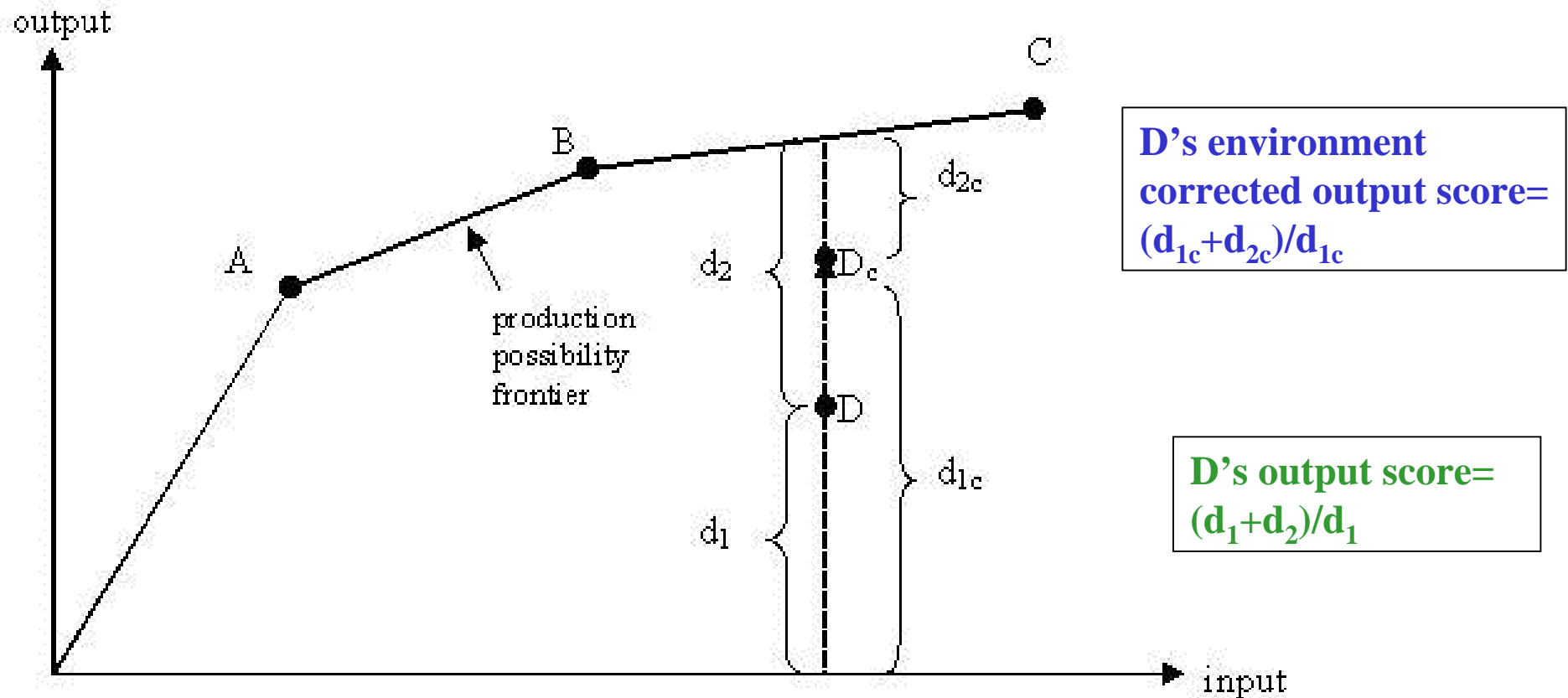
### Typical two stage approach:

The output efficiency score is regressed on non-discretionary outputs ( $z$ ):

$$\hat{\delta}_i = z_i \beta + \varepsilon_i$$

The output score is not smaller than 1. This has led researchers to use a tobit regression approach.

## Methodology (4) - non-discretionary inputs and two-step procedure



$1 < (d_{1c} + d_{2c}) / d_{1c} < (d_1 + d_2) / d_1$ , the environment corrected score is closer to the frontier.

## Inputs

- practising nurses;
- number of practising physicians;
- acute care beds per thousand habitants;
- high-tech diagnostic medical equipment [magnetic resonance imagers (MRI)].

Source: OECD Health Data 2005.

## Outputs

- Life expectancy;
- Infant survival rate (ISR);
  - [children that survived]/[children that died before 1 year]
  - $ISR = [1000\text{-infant mortality rate}] / [\text{infant mortality rate}]$
- Potential Years of Life Not Lost, PYLNL;
  - [number of potential years of life till 70] – [number of life years lost due to all causes before the age of 70 and that could be prevented].

Source: OECD Health Data 2005.

# Data summary

Table 2 – Summary statistics of the input and output data

	Mean	Standard deviation	Minimum	Maximum	
Life expectancy (in years) 1/	77.5	2.8	68.4 (TUR)	81.5 (JAP)	} Outputs
Infant mortality rate (deaths per 1000 live births) 2/	4.5	6.5	2.4 (ICE)	36.3 (TUR)	
Potential years of life lost (All causes - <70 year./100 000) 2/	4083	981.2	2917 (JAP)	7056 (HU)	
Practising physicians, density per 1000 population 2/	2.8	0.8	1.4 (TUR)	4.4 (GRC)	} Inputs
Practising nurses, density per 1000 population 2/	8.0	3.4	1.6 (KOR)	14.7 (IRE)	
Acute care beds, density per 1000 population 2/	4.2	1.8	1.0 (MEX)	9.1 (JAP)	
MRI units, per million population 2/	6.8	6.4	0.2 (MEX)	32.3 (JAP)	

Notes: 1/ Average for 2000 and 2003. 2/ Average for 2000-2003.

TUR – Turkey; JAP – Japan; ICE – Iceland; HU – Hungary; GCR – Greece; KOR – Korea; IRE – Ireland; MEX – Mexico.

# Empirical analysis (1) – principal component analysis (PCA)

- PCA reduces the dimensionality of multivariate data;
- We applied PCA to the 4 input variables
  - and used the first 3 principal components as the 3 input measures (they explain around 88 per cent of the variation)
- We also applied PCA to the three output variables
  - we selected the first principal component (it accounts for around 84 per cent of the variation)
- This reduces the problem to **one output – three input**.

## Empirical analysis (2)

- First step:
  - Data envelopment analysis (inputs, outputs)
  - Inefficient scores are computed for each country
- Second step:
  - Regression analysis
  - Inefficient scores are explained by environment variables
  - Two regression methods – Tobit and bootstrap

# Empirical analysis (3) – 1<sup>st</sup> step DEA results

Table 5 – DEA output efficiency results for health efficiency in OECD countries, 3 inputs (PCA on doctors, nurses, beds and MRI) and 1 output (PCA on life expectancy, infant survival rate, and potential number of years of life not lost)

Country	VRS TE	Rank	Peers	Rank 2
Australia	1.101	10	Canada, Sweden, Korea, Finland	10
Austria	1.304	15	Sweden, Japan	15
Canada	1.000	1	Canada	6
Czech Republic	1.592	18	Japan, Sweden	18
Denmark	1.368	16	Korea, Japan, Sweden, Finland	16
Finland	1.000	1	Finland	4
France	1.106	11	Sweden, Spain	11
Germany	1.282	14	Sweden, Japan	14
Hungary	4.386	21	Sweden, Japan, Korea	21
Italy	1.143	12	Sweden, Japan	12
Japan	1.000	1	Japan	2
Korea	1.000	1	Korea	3
Luxembourg	1.372	17	Korea, Japan, Sweden	17
Poland	1.876	19	Spain, Korea	19
Portugal	1.083	9	Korea, Spain	9
Slovak Republic	2.667	20	Korea, Sweden, Japan	20
Spain	1.000	1	Spain	4
Sweden	1.000	1	Sweden	1
Switzerland	1.166	13	Sweden, Japan	13
United Kingdom	1.070	8	Canada, Sweden, Korea, Finland	8
United States	1.000	1	United States	7
Average	1.406			

With the same inputs, on average, output could increase by 40%.

Note: VRS TE - variable returns to scale technical efficiency. Rank 2 – ranking taking into account the number of times the efficient countries are peers of inefficient countries.

## Empirical analysis (4) – 2<sup>nd</sup> step

$$\hat{\delta}_i = \beta_0 + \beta_1 Y_i + \beta_2 E_i + \beta_3 O_i + \beta_4 T_i + \varepsilon_i$$

- Regression of efficiency scores on GDP per capita ( $Y$ ), educational level ( $E$ ), obesity ( $O$ ), and tobacco consumption ( $T$ ).
  - Tobit regression
  - Bootstrap, Simar and Wilson (2007) algorithm 1 and 2
  - Results are similar

# Empirical analysis (5) – 2<sup>nd</sup> step (Tobit)

Table 6 – Censored normal Tobit results (19 countries)

	Model 1	Model 2	Model 3	Model 4
Constant	-3.2574 (0.000)	9.0162 (0.029)	-1.1185 (0.092)	9.9146 (0.009)
<i>Y</i>	-4.38E-05 (0.000)		-4.44E-05 (0.000)	
<i>Log(Y)</i>		-1.2476 (0.000)		-1.1546 (0.000)
<i>E</i>			-0.1060 (0.010)	-0.0891 (0.034)
<i>O</i>	0.0895 (0.000)	0.0783 (0.001)	0.0946 (0.000)	0.0841 (0.000)
<i>T</i>	0.1708 (0.000)	0.1453 (0.000)	0.1463 (0.000)	0.122 (0.001)
$\hat{\sigma}_\varepsilon$	0.5677 (0.000)	0.5600 (0.000)	0.4759 (0.000)	0.5088 (0.000)

Notes: *Y* – GDP per capita; *E* – Educational level; *O* – Obesity; *T* – Tobacco consumption.  $\hat{\sigma}_\varepsilon$  – Estimated standard deviation of  $\varepsilon$ . P- values in brackets.

$$\Delta Y, \Delta E \Rightarrow \nabla \delta \Rightarrow \Delta \text{efficiency}$$

$$\Delta O, \Delta T \Rightarrow \Delta \delta \Rightarrow \nabla \text{efficiency}$$

## Empirical analysis (6) – 2<sup>nd</sup> step (bootstrap)

	Algorithm 2			
Constant	-7.3757 (0.00)	15.5263 (0.00)	-6.4315 (0.043)	20.4362 (0.000)
<i>Y</i>	-0.9365E-04 (0.00)		-0.8663E-04 (0.000)	
<i>Log(Y)</i>		-2.42259 (0.00)		-2.7953 (0.000)
<i>E</i>			-0.1133 (0.135)	-0.2223 (0.012)
<i>O</i>	0.1545 (0.00)	0.1441 (0.00)	0.2399 (0.000)	0.1872 (0.000)
<i>T</i>	0.3071 (0.00)	0.2795 (0.00)	0.2630 (0.000)	0.2978 (0.000)
$\hat{\sigma}_\varepsilon$	0.5849 (0.00)	0.5338 (0.00)	0.7734 (0.000)	0.7728 (0.000)

Notes: *Y* – GDP per capita; *E* – Educational level; *O* – Obesity; *T* – Tobacco consumption.  $\hat{\sigma}_\varepsilon$  – Estimated standard deviation of  $\varepsilon$ . P- values in brackets.

# Empirical analysis (7) – corrections

Table 9 – Corrected output efficiency scores (for Model 4)

	Bias corrected scores (1)	GDP correction (2)	Education correction (3)	Obesity correction (4)	Tobacco correction (5)	Fully corrected scores (6)=(1)+(2)+ (3)+(4)+(5)	Rank
Australia	1.141	0.440	0.840	-1.447	1.657	2.630	15
Canada	1.489	0.564	1.129	-0.062	2.491	5.611	19
Czech Republic	1.637	-1.159	-0.960	-0.156	0.376	1.000	1
Denmark	1.416	0.669	-0.827	0.836	-0.785	1.309	9
Finland	1.066	0.252	-0.071	0.219	0.942	2.407	13
France	1.158	0.260	-0.716	0.855	-0.487	1.069	8
Germany	1.318	0.289	-0.471	0.200	0.317	1.652	12
Hungary	4.564	-1.497	-0.294	-0.904	-2.513	1.000	1
Italy	1.175	0.232	-1.272	1.023	0.346	1.505	11
Japan	1.063	0.344	0.973	2.015	-1.470	2.926	16
Korea	1.129	-0.921	0.707	2.015	-1.500	1.430	10
Luxembourg	1.427	2.588	-1.227	-0.829	-2.274	1.000	1
Poland	2.049	-2.130	-0.716	0.481	-0.666	1.000	1
Slovak Republic	2.757	-1.718	-1.183	-1.578	0.317	1.000	1
Spain	1.057	-0.313	0.306	0.163	-0.815	1.000	1
Sweden	1.043	0.191	0.240	0.799	2.342	4.614	18
Switzerland	1.205	0.538	0.084	1.173	-0.428	2.572	14
United Kingdom	1.188	0.237	0.573	-1.690	-0.190	1.000	1
United States	1.055	1.134	2.885	-3.113	2.342	4.302	17
Average	1.523	0.000	0.000	0.000	0.000	2.054	

lower level  
of adult  
education,  
better  
habits

richer  
countries,  
lower level  
of adult  
education

rich, and  
good adult  
education,  
poorer  
habits

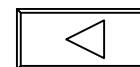
Note: the fully corrected scores do not always add up to the indicated sum since for the cases where the result was below one we truncated it to the unity.

## Conclusions

- Inefficiencies may be quite high.
- On average, and as a conservative estimate, countries could have increased their results by 40 per cent using the same resources.
- GDP per head, educational attainment, tobacco consumption, and obesity are highly and significantly correlated to output scores.
- Country rankings and output scores derived from this correction can be substantially different from standard DEA results.
- Non-discretionary outputs cannot be changed in the short run (education, smoking habits, obesity).
- Results were strikingly similar with three different estimation processes, which bring increased confidence to the results.

## Background material (1)

Expenditure on health	Total expenditure, % of GDP		Public expenditure, % of total expenditure		Total health expenditure per capita US\$ PPP	
	1995	2003	1995	2003	1995	2003
Australia	8.3	9.3	66.7	67.5	1745	2699
Austria	8.5	7.5	69.7	67.6	1973	2302
Belgium	8.4	9.6	..	..	1820	2827
Canada	9.2	9.9	71.4	69.9	2051	3001
Czech Republic	6.9	7.5	<b>92.7</b>	<b>90.1</b>	873	1298
Denmark	8.2	9.0	82.5	83.0	1848	2763
Finland	7.5	7.4	75.6	76.5	1433	2118
France	9.5	10.1	76.3	76.3	2033	2903
Germany	10.6	11.1	80.5	78.2	2276	2996
Greece	9.6	9.9	52.0	51.3	1253	2011
Hungary	7.5	8.4	84.0	72.4	676	1269
Iceland	8.4	10.5	83.9	83.5	1858	3115
Ireland	6.8	7.4	71.6	78.0	1216	2451
Italy	7.3	8.4	71.9	75.1	1535	2258
Japan	6.8	7.9	83.0	81.5	1538	2139
Korea	4.2	<b>5.6</b>	<b>35.3</b>	49.4	538	1074
Luxembourg	6.4	6.9	92.4	89.9	2059	3705
Mexico	5.6	6.2	42.1	46.4	382	583
Netherlands	8.4	9.8	71.0	62.4	1826	2976
New Zealand	7.2	8.1	77.2	78.7	1247	1886
Norway	7.9	10.3	84.2	83.7	1897	3807
Poland	5.6	6.5	72.9	69.9	417	744
Portugal	8.2	9.6	62.6	69.7	1079	1797
Slovak Republic	5.8	5.9	91.7	88.3	543	777
Spain	7.6	7.7	72.2	71.2	1198	1835
Sweden	8.1	9.4	86.6	85.2	1738	2703
Switzerland	9.7	11.5	53.8	58.5	2579	3781
Turkey	<b>3.4</b>	7.4	70.3	70.9	<b>185</b>	<b>513</b>
United Kingdom	7.0	7.7	83.9	83.4	1374	2231
United States	<b>13.3</b>	<b>15.0</b>	45.3	<b>44.4</b>	<b>3654</b>	<b>5635</b>
Mean	7.7	8.7	72.5	72.5	1494.8	2340
EU 15 average	8.1	8.8	69.9	69.9	1644.1	2525



## Background material (2): non-discretionary inputs and two-step procedure

Problems with **tobit traditional procedure**:  $\hat{\delta}_i = z_i \beta + \varepsilon_i$

- Each efficiency score estimate depends on all observed inputs and outputs:  $\varepsilon_i$  is serially correlated.
- The environmental variables are correlated with both inputs and outputs:  $\varepsilon_i$  is not independent from  $z_i$ .

Simar and Wilson (2007) propose alternative estimation and inference procedures based on **bootstrap methods**. They assume:

$$\delta_i = \psi(z_i, \beta) + \varepsilon_i \geq 1,$$

where  $\varepsilon_i$  is a left truncated normal random variable.

## Background material (3): some references

- Evans, D.; Tandon, A.; Murray, C. and Lauer, J. (2000). “The Comparative Efficiency of National Health Systems in Producing Health: an Analysis of 191 Countries”, GPE Discussion Paper Series 29, Geneva, World Health Organisation.
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