

Efficiency of Hospitals in the Czech Republic Conditional Efficiency Approach

Paper by Jana Votápková & Lenka Št'astná

Jana Votápková

ICDEAEF, Ostrava, CZ
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Motivation

Research Questions:

1. How efficient are Czech hospitals?
2. Which variables characterizing the operating environment of hospitals influence efficiency scores and what effect they have?

Outline

1. Motivation and Background
2. Theoretical Model
 - conditional order-m
 - non-parametric significance test
 - partial regression plots
3. Data
 - input & output variables
 - environmental characteristics
4. Empirical Results
5. Conclusions and Motivation for Further Research

Conditional order-m I.

Consider $i \in (1 \dots n)$ decision-making units and a production technology with a set of all feasible input-output combinations

$\Psi = (x, y) \in \mathbb{R}_+^{p+q} | \mathbf{x}$ can produce \mathbf{y} , where $\mathbf{x} \in \mathbb{R}_+^p$ and $\mathbf{y} \in \mathbb{R}_+^q$

- Joint probability function, given $Z = z$, is defined as:

$$H_{XY|Z}(x, y|z) = Pr(X \leq x, Y \geq y|Z = z) \quad (1)$$

$$H_{XY|Z}(x, y|z) = Pr(X \leq x|Y \geq y, Z = z)Pr(Y \geq y|Z = z) \quad (2)$$

$$= F_{X|Y,Z}(x|y, z)S_{Y|Z}(y|z) \quad (3)$$

where $F_{X|Y,Z}$ denotes a cumulative distribution function of X and $S_{Y|Z}$ is the conditional survivor function of Y

- Efficiency frontier:

$$\theta(x, y|z) = \inf \{ \theta | F_{X|Y,Z}(\theta x|y, z) > 0 \} \quad (4)$$

Conditional order-m II.

- Smoothing in z due to $Z = z$

$$\hat{F}_{X|Y,Z} = \frac{\sum_{i=1}^n I(X_i \leq x, Y_i \geq y) K((z - z_i)/h)}{\sum_{i=1}^n I(Y_i \geq y) K((z - z_i)/h)} \quad (5)$$

where $I(\cdot)$ denotes the indicator function, $K(\cdot)$ is the kernel and h is the bandwidth parameter

$$K(z, z_i, h) = \prod_{s=1}^r \frac{1}{h_s^c} I^c\left(\frac{z_s^c - z_{is}^c}{h_s^c}\right) \prod_{s=r+1}^{r+v} I^o(z_s^o, z_{is}^o, h_s^o) \prod_{s=r+v+1}^{r+v+w} I^u(z_s^u, z_{is}^u, h_s^u) \quad (6)$$

where $I^c(\cdot)$, $I^o(\cdot)$ and $I^u(\cdot)$ are univariate kernel functions and h_s^c , h_s^o and h_s^u are bandwidths for continuous, ordered and unordered environmental variables, respectively.

- Conditional order-m frontier

$$\hat{\theta}_m(x, y|z) = \hat{E}_{X|Y,Z}(\theta_m(x, y), |Y \geq y, Z = z) \quad (7)$$

$$= \int_0^\infty [1 - \hat{F}_X(ux|y, z)]^m du \quad (8)$$

Non-parametric significance test & partial regression plots

Non-parametric significance test

- Non-parametric model:

$$\hat{Q}_i^z = \tilde{f}(z_i) + \epsilon_i, i = 1 \dots n \quad (9)$$

where $\hat{Q}_i^z = \frac{\hat{\theta}_{mn}(x,y|z)}{\hat{\theta}_{mn}(x,y)}$, ϵ_i is the error term uncorrelated with environmental variables [$E(\epsilon_i|z_i) = 0$] and $\tilde{f} = \tilde{\alpha} - (z_i^c - z^c)\tilde{\beta}$ represents the conditional mean function of the estimated ratio \hat{Q}_i^z .

- Solve local linear least squares minimization problem

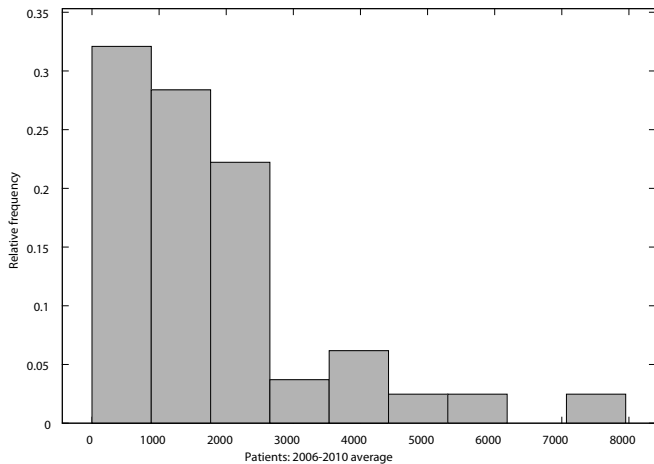
Partial regression plot

- Q_i^z is plotted against one variable fixing all other variables (at the median)

Data - overview

- 81 General Hospitals: 2006–2010
- unbalanced panel: 395 observations
- data sources:
 - Institute of Health Information and Statistics of the Czech Republic
 - Narodni referencni centrum
 - Web of Science
 - Ministry of Health
 - Czech Statistical Office
 - Registry of Companies of the Czech Republic
- adjustment for inflation using 2006 as a base
- estimation software:
 - R 2.14.0 (R Development Core Team, 2006)

Size Distribution of Hospitals



Data

Input & Output Variables

- Input Variable: total operating costs
- Output Variables:
 - number of acute care patients adjusted for the DRG case-mix index
 - number of nursing patients
 - number of publications

Environmental characteristics

- not-for-profit ownership status
- dummy for a specialized center
- year dummy
 - (i) joint dummy for 2009 and 2010
 - (ii) dummy for 2009 & dummy for 2010
- salary

Conditional efficiency scores

Table: Summary of efficiency scores

	Whole sample		Small		Medium		Big	
	$\theta(x, y)$	$\theta(x, y z)$	$\theta(x, y)$	$\theta(x, y z)$	$\theta(x, y)$	$\theta(x, y z)$	$\theta(x, y)$	$\theta(x, y z)$
Min	0.358	0.416	0.358	0.457	0.426	0.416	0.547	0.648
Max	1.418	1.023	1.237	1.023	1.418	1.009	1.238	1.008
Mean	0.901	0.953	0.868	0.927	0.904	0.957	0.933	0.976
Median	0.949	1	0.943	1	0.919	1	1	1
St. dev.	0.169	0.114	0.202	0.144	0.167	0.110	0.117	0.065
Efficiency ≥ 1	155	294	51	96	39	100	65	98
Efficiency ≥ 1.1	18	0	5	0	9	0	1	0
Efficiency ≥ 1.2	10	0	3	0	6	0	1	0
Efficiency ≥ 1.4	1	0	0	0	1	0	0	0
No. obs.	395	395	136	136	134	134	125	125

Note: No separate benchmark was created for size groups.

Non-parametric significance test I.

Table: Effects of environmental variables: whole sample

	P-value	Model 1 Banwth	Effect		P-value	Model 2 Banwth	Effect
not_profit	0.126 †	0.1003	favorable		0.126 †	0.3063	favorable
specialization	0.008 ***	0.2050	favorable	<	2e-16 ***	0.0830	favorable
2009					0.048 **	0.1247	unfavorable
2010					0.010 **	0.2068	unfavorable
2009_2010	< 2e-16 ***	0.2068	unfavorable				
salary	0.192 †	652.17	mixed		0.714	646.25	mixed

Notes: signif. codes – 0.01 '****' 0.05 '***' 0.1 '**', one-tail '†'; 'Banwth' denotes bandwidths.

Non-parametric significance test II.

Table: Effects of environmental variables: big, small and medium hospitals

Big hospitals						
	P-value	Model 1 Banwth	Effect	P-value	Model 2 Banwth	Effect
not_profit	0.042 **	0.0028	favorable	0.056 *	0.0000	favorable
specialization	0.116 †	0.2083	favorable	0.002 ***	0.2909	unfavorable
2009				0.002 ***	0.1769	unfavorable
2010				0.008 ***	0.1677	favorable
2009_2010	0.038 **	0.0139	unfavorable			
salary	0.990	489.42	mixed	0.208	4579.06	mixed

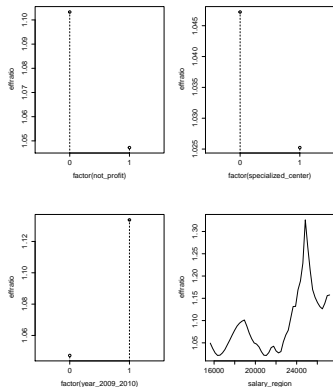
Small and medium hospitals						
	P-value	Model 1 Banwth	Effect	P-value	Model 2 Banwth	Effect
not_profit	< 2e-16 ***	0.4093	unfavorable	0.062 *	0.3745	unfavorable
specialization	0.010 ***	0.0161	unfavorable	0.042 **	0.1468	unfavorable
2009				0.098 *	0.2032	unfavorable
2010				0.406	0.2438	unfavorable
2009_2010	0.012 **	0.1878	unfavorable			
salary	0.778	321.01	mixed	0.544	293.38	mixed

Notes: signif. codes – 0.01 '***' 0.05 '**', 0.1 '*', one-tail '†'; 'Banwth' denotes bandwidths.

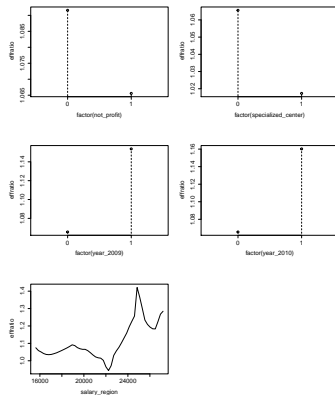
Partial regression plots I.

Figure: Partial regression plots: whole sample

Model 1

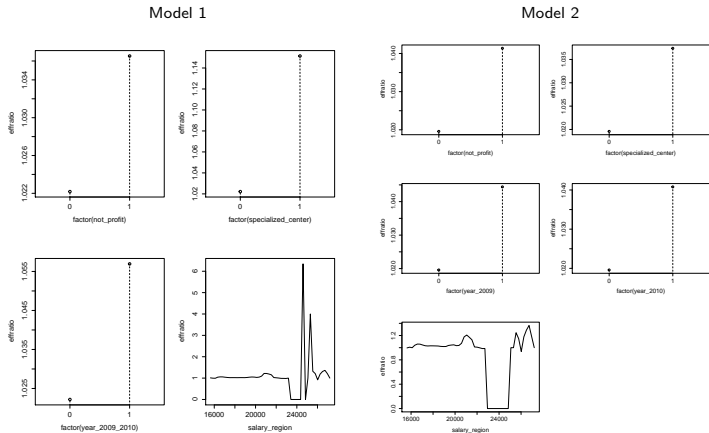


Model 2



Partial regression plots II.

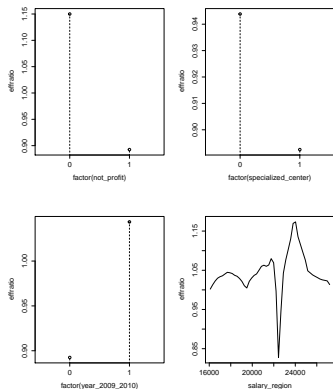
Figure: Partial regression plots: small and medium hospitals



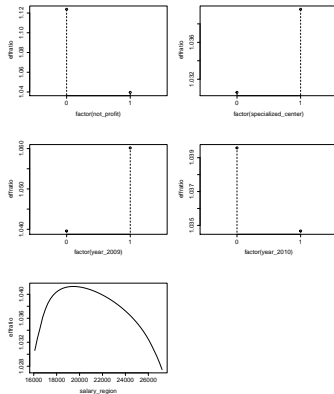
Partial regression plots III.

Figure: Partial regression plots: big hospitals

Model 1



Model 2



Conclusions

- Robust conditional efficiency of 81 general hospitals in 2006–2010 estimated
- Not-for-profit ownerships status exert a non-linear pressures on efficiency
 - favorable to performance of big hospitals
 - unfavorable to performance of small and medium hospitals
- big hospitals took some cost-saving measures in 2010

Next steps

- generalized non-parametric smoothing to determine bandwidths with mixed discrete and continuous data
 - allow different bandwidth parameters for continuous variables in different categories of discrete variables

THANK YOU FOR YOUR ATTENTION!

jana.votapkova@fsv.cuni.cz