# Cost and Technical Efficiency of German Hospitals

## Does Ownership Matter?

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This is a presentation of an article published in Health Economics 17(9): 1057-1071, 2008.

Infraday 2008

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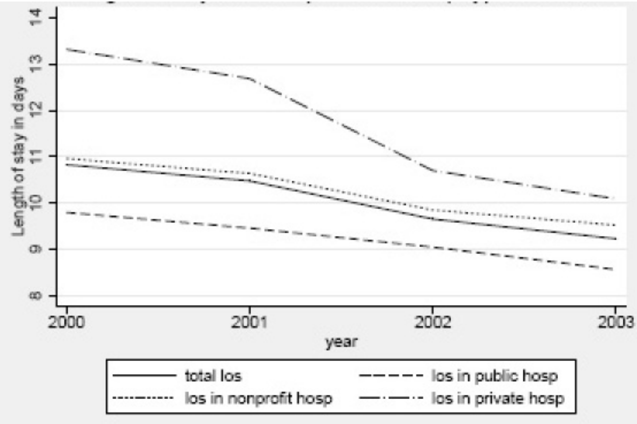
- 50% increase in per capita costs since 1993
- €235 billion spent on health care in 2003 (11.1% of German GDP)
- 30% spent on hospitals

# Unweighted average length of stay by ownership type and year




own calculations, final sample

# Outline

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# Literature overview: Hospital efficiency studies

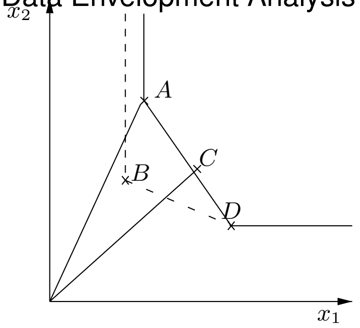
| Author | Country | Method | Least efficient type |
|---|---|---|---|
| Helmig & Lapsley (2001) | Germany | DEA | Private |
| Werblow & Robra (2006) | Germany | DEA | Public |
| Staat (2006) | Germany | DEA | no significant diff. |
| Schreyögg & Tiemann (2008) | Germany | DEA | Private |
| Hollingworth (2003) | mainly US | DEA | mainly Private (for-profit) |
| Zuckerman & Hadley (1994) | USA | Half-normal | Private (for-profit) |
| Folland & Hofler (2001) | USA | Half-normal | Private (for-profit) |
| Farsi & Filippini (2006, 2008) | SW | 2 step, trunc. | no significant diff. |
| Rosko (1999) | USA | 2 step | Private (for-profit) |
| Rosko (2001, 2004) | USA | Truncated | Private (for-profit) |
| Brown (2003) | USA | Truncated | Private (for-profit) |

The base group varies between only non-profit, only public and non-profit and public hospitals.

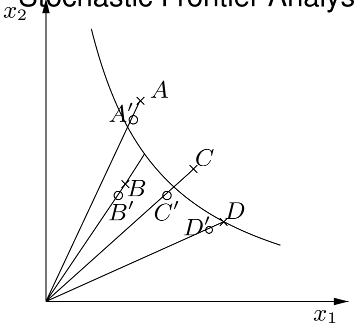
# Outline

# Graphical depiction of DEA and SFA

Data Envelopment Analysis




Stochastic Frontier Analysis




$2$ inputs, $x_1, x_2$, to produce $1$ unit of output $y$
$A, B, C, D$: observed input combinations
$A', B', C', D'$: frontier input combinations (inefficiency $u_i = 0$)
inefficiency: distance between o and x or between $A'$ and $A$, etc.
noise: distance between o and frontier

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- Predict expected efficiency conditional on the estimated composite error (inconsistent with cross sectional data)

# SFA

Cobb-Douglas production function assumed
Log-linear **production model**

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_{ni} + \underbrace{v_i - u_i}_{\epsilon_i},$$

where $y_i$ is a single output, $x_i = [x_{1i}, \ldots, x_{Ni}]'$ is the vector of inputs, $v_i$ is random noise and $\beta = [\beta_1, \ldots, \beta_N]'$ is the vector of parameters to estimate. $u_i \geq 0$ is the output decreasing inefficiency.

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Distributional assumptions

$$v_i \sim N[0, \sigma_v^2],$$
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firm-specific (time variant) variables $z_i = [z_{1i}, \ldots, z_{Ki}]'$ account for heterogeneity of the hospitals

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Technical frontier:

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Cost frontier:

- dependent variable
  - total adjusted costs
- independent variables
  - costs per doctor
  - costs per nurse (used for normalisation)
  - costs per other staff
  - medical requirements per bed
  - weighted number of cases as output variable

# Exogenous influences on inefficiency: $z_i$

- ownership type dummies
- non-subsidised dummy:
  interacted with each ownership type and lagged by one year
- east dummy
- female ratio
- ratio of older than 75 years
- ratio of surgeries
- (occupancy rate: $occ\_ratio = days/(beds \cdot 365)$)
- (nurse per bed ratio)
- (death ratio)

Not feasible in hospital statistics

- ratio of privately insured patients
- quality other than death ratio

# Outline

# The hospital statistics

- full set of German hospitals, 1,800 general hospitals
- full set of patient data (17 mio treatments per year) aggregated on diagnosis level (830,000-930,000 observations per year)
- patients statistic contains: age, sex, death, main diagnosis (ICD 9, 3 digits), length of stay (los)
- information about los of each diagnosis treated in each hospital enables construction of case-mix weights

# Descriptive Statistics: Mean values in 2003 and sign of change to 2000

| | Public | | Non-profit | | Private | |
|---|---|---|---|---|---|---|
| **variable** | **2003** | **03/00** | **2003** | **03/00** | **2003** | **03/00** |
| *exogenous variables* | | | | | | |
| no_subsidies | 0.02 | −− | 0.01 | −− | 0.27 | − |
| east | 0.17 | 0 | 0.14 | 0 | 0.26 | 0 |
| female_ratio | 0.55 | − | 0.57 | − | 0.56 | 0 |
| plus75_ratio | 0.21 | ++ | 0.23 | + | 0.17 | ++ |
| surgery_ratio | 0.45 | ++++ | 0.42 | ++++ | 0.44 | ++ |
| *other figures of interest* | | | | | | |
| beds | 345.85 | − | 264.68 | − | 164.58 | − |
| occupancy_rate | 0.76 | − | 0.75 | − | 0.73 | − |
| nurse/bed | 0.56 | − | 0.54 | − | 0.49 | + |
| av. length of stay | 8.57 | −− | 9.53 | −− | 10.09 | −− |
| total_adj_costs/bed [in 1000€] | 96.44 | | 90.21 | | 93.67 | |
| total_adj_costs/case | 2,930 | | 3,160 | | 3,158 | |
| Sample size N | 641 | − | 693 | − | 260 | ++ |

**Table:** The Hospital Statistics: Mean values of the year 2003 and hospital specific changes to 2000 (the latter includes all hospitals having been observed in both years), where +: below 10%, ++: below 20%, +++: below 30%, ++++: below 40%.

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# Results Cost Efficiency

| ln adjusted_costs | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|
| frontier estimates | | | | | | |
| ln price_docs | 0.08 | ** | 0.13 | *** | 0.08 | ** |
| ln price_other_staff | 0.32 | *** | 0.30 | *** | 0.34 | *** |
| ln price_bed | 0.22 | *** | 0.28 | *** | 0.24 | *** |
| ln weighted cases | 1.02 | *** | 0.98 | *** | 1.00 | *** |
| constant | -2.83 | *** | -2.47 | *** | -2.64 | *** |
| effects on inefficiency | | | | | | |
| private | 2.02 | *** | 2.16 | ** | 2.14 | ** |
| nonprofit | 1.09 | ** | 0.96 | * | 1.23 | * |
| $(\text{no\_subs}\times\text{private})_{t-1}$ | 1.89 | *** | 2.73 | *** | 2.81 | ** |
| $(\text{no\_subs}\times\text{nonprofit})_{t-1}$ | 2.66 | *** | 4.28 | *** | 3.60 | ** |
| $(\text{no\_subs}\times\text{public})_{t-1}$ | 3.47 | *** | 3.64 | ** | 3.48 | ** |
| east | 0.69 | ** | 0.66 | | 0.44 | |
| plus75 ratio | 1.33 | | 3.83 | ** | 3.36 | ** |
| surgery ratio | -2.68 | *** | -3.31 | ** | -2.03 | ** |
| female ratio | -4.50 | *** | -4.50 | ** | -5.32 | ** |
| constant | -1.08 | | -2.58 | * | -2.46 | |
| Log likelihood | 234 | | 236 | | 259 | |
| Obs. | 1,556 | | 1,549 | | 1,565 | |

**Table:** Significance level: *** $p < .01$, ** $p < .05$, * $p < .1$. Price for nursing staff used for normalisation of prices and costs.

# Results Technical Efficiency

| In weighted cases | 2001 | | 2002 | | 2003 | |
|---|---|---|---|---|---|---|
| effects on inefficiency | | | | | | |
| private | 3.18 | *** | 2.88 | ** | 2.88 | * |
| nonprofit | 2.14 | ** | 1.82 | ** | 1.95 | * |
| $(\text{no\_subs} \times \text{private})_{t-1}$ | 1.57 | *** | 2.74 | *** | 2.29 | ** |
| $(\text{no\_subs} \times \text{nonprofit})_{t-1}$ | 2.36 | *** | 3.59 | ** | 3.05 | ** |
| $(\text{no\_subs} \times \text{public})_{t-1}$ | 4.41 | *** | 4.34 | ** | 4.23 | * |
| east | 0.00 | | -0.58 | | -1.40 | * |
| plus75 ratio | 1.31 | | 3.97 | ** | 3.35 | ** |
| surgery ratio | -3.49 | *** | -3.34 | ** | -2.38 | ** |
| female ratio | -2.12 | ** | -1.92 | | -1.47 | |
| constant | -3.18 | ** | -4.67 | ** | -4.71 | * |
| Log likelihood | 508 | | 482 | | 519 | |
| Obs. | 1,556 | | 1,549 | | 1,565 | |

**Table:** Significance level: *** $p < .01$, ** $p < .05$, * $p < .1$.

# Panel Data Analysis

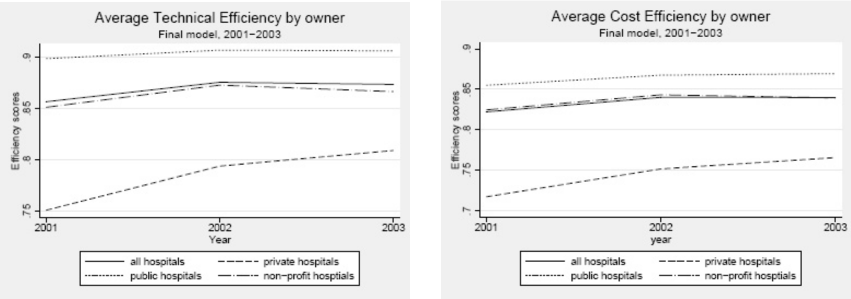
| | CE, 2002-2003 | | TE, 2001-2003 | |
|---|---|---|---|---|
| ln adjusted_costs | Translog | Cobb-Douglas | Translog | Cobb-Douglas |
| frontier estimates +const | 16 coeff. | 6 coeff. | 17 coeff. | 7 coeff. |
| year 2002 dummy (technology) | | | 0.013 ** | 0.012 ** |
| | | | ( 0.005 ) | ( 0.006 ) |
| year 2003 dummy (technology) | -0.004 | -0.004 | 0.011 * | 0.011 * |
| | ( 0.006 ) | ( 0.009 ) | ( 0.006 ) | ( 0.006 ) |
| effects on inefficiency | | | | |
| private | 1.709 *** | 1.342 *** | 2.063 *** | 1.909 *** |
| | ( 0.071 ) | ( 0.137 ) | ( 0.094 ) | ( 0.048 ) |
| nonprofit | 1.145 *** | 0.682 *** | 1.205 *** | 1.169 *** |
| | ( 0.045 ) | ( 0.079 ) | ( 0.049 ) | ( 0.034 ) |
| (no_subs×private)$_{t-1}$ | 1.660 *** | 1.586 *** | 1.454 *** | 1.325 *** |
| | ( 0.109 ) | ( 0.125 ) | ( 0.092 ) | ( 0.045 ) |
| (no_subs×nonprofit)$_{t-1}$ | 3.144 *** | 2.777 *** | 2.344 *** | 2.049 *** |
| | ( 0.155 ) | ( 0.244 ) | ( 0.115 ) | ( 0.106 ) |
| (no_subs×public)$_{t-1}$ | 2.476 *** | 2.221 *** | 3.226 *** | 2.980 *** |
| | ( 0.145 ) | ( 0.210 ) | ( 0.154 ) | ( 0.100 ) |
| east | 0.488 *** | 0.455 *** | -0.258 *** | -0.326 *** |
| | ( 0.033 ) | ( 0.058 ) | ( 0.050 ) | ( 0.031 ) |
| plus75 ratio | 2.600 *** | 3.314 *** | 2.192 *** | 2.292 *** |
| | ( 0.106 ) | ( 0.327 ) | ( 0.080 ) | ( 0.146 ) |
| surgery ratio | -2.084 *** | -1.692 *** | -2.120 *** | -2.181 *** |
| | ( 0.064 ) | ( 0.171 ) | ( 0.078 ) | ( 0.046 ) |
| female ratio | -3.059 *** | -3.867 *** | -1.341 *** | -1.178 *** |
| | ( 0.164 ) | ( 0.325 ) | ( 0.100 ) | ( 0.148 ) |
| death rate | | -5.594 *** | | -2.610 *** |
| | | ( 1.367 ) | | ( 0.652 ) |
| year 2002 dummy (inefficiency) | | | -0.095 ** | -0.129 *** |
| | | | ( 0.040 ) | ( 0.037 ) |
| year 2003 dummy (inefficiency) | -0.044 | -0.040 | -0.138 *** | -0.151 *** |
| | ( 0.031 ) | ( 0.032 ) | ( 0.030 ) | ( 0.026 ) |
| constant | -2.477 *** | -0.768 *** | -2.519 *** | -2.346 *** |
| | ( 0.279 ) | ( 0.188 ) | ( 0.185 ) | ( 0.126 ) |
| Obs. | 3,010 | 3,010 | 4,329 | 4,329 |

Balanced panel. Standard errors in parentheses. Costs are deflated to year 2000 prices.

# Efficiency scores

**Figure:** Mean values of technical (a) and cost (b) efficiency scores by ownership type and year

a) b)




Bootstrapping scores, 500 repetitions: F-test reveals that scores differ significantly between ownership types

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- Pooled truncated normal one-step approach by Battese & Coelli (1995), technological change, change in efficiency
- Translog production (panel: both models, cross section: only technical efficiency)

# Pairwise correlation coefficients of efficiency rankings in 2001 across different models

| Pairwise correlation | Technical Efficiency models | | | | Cost Efficiency Models | | | |
|---|---|---|---|---|---|---|---|---|
| | TE exponential | TE half-normal w/o $z_i$ | TE half-normal with $z_i$ | **TE truncated** | CE exponential | CE half-normal w/o $z_i$ | CE half-normal with $z_i$ | **CE truncated** |
| TE exponential | 1.0000 | | | | | | | |
| TE half-normal w/o $z_i$ | 0.9419 | 1.0000 | | | | | | |
| TE half-normal with $z_i$ | 0.9909 | 0.9337 | 1.0000 | | | | | |
| **TE truncated** | 0.8913 | 0.9569 | 0.8577 | 1.0000 | | | | |
| CE exponential | 0.8066 | 0.8247 | 0.8221 | 0.7247 | 1.0000 | | | |
| CE half-normal w/o $z_i$ | 0.7175 | 0.8039 | 0.7328 | 0.6877 | 0.9647 | 1.0000 | | |
| CE half-normal with $z_i$ | 0.7655 | 0.7917 | 0.7921 | 0.6711 | 0.9906 | 0.9699 | 1.0000 | |
| **CE truncated** | 0.7849 | 0.8633 | 0.7738 | 0.8247 | 0.9423 | 0.9452 | 0.9093 | 1.0000 |
| nonprofit | | -0.0797 | | -0.1633 | | | | |
| Public | 0.0907 | 0.1633 | 0.058* | 0.3024 | 0.061* | 0.0679 | | 0.1688 |
| Private | -0.1712 | -0.1137 | -0.1274 | -0.1948 | -0.1241 | -0.0845 | -0.0845 | -0.1764 |
| Length of stay | -0.5010 | -0.5604 | -0.4865 | -0.5828 | -0.4634 | -0.4776 | -0.4372 | -0.5333 |

The highest efficiency score has the highest rank. Printed correlation coefficients are significant at a 1% level, correlation coefficients marked with $*$ are significant at a 5% level.

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- Results robust with respect to distributional assumptions, specification, sample selection
- Caveats: no good quality measure and insurance type information missing
- Private hospitals may have stronger incentives to keep patients longer under the cost reimbursement system in force until 2003 - do newly introduced capitation fees circumvent this behaviour?

# Finally

Thank you for your attention and your comments!

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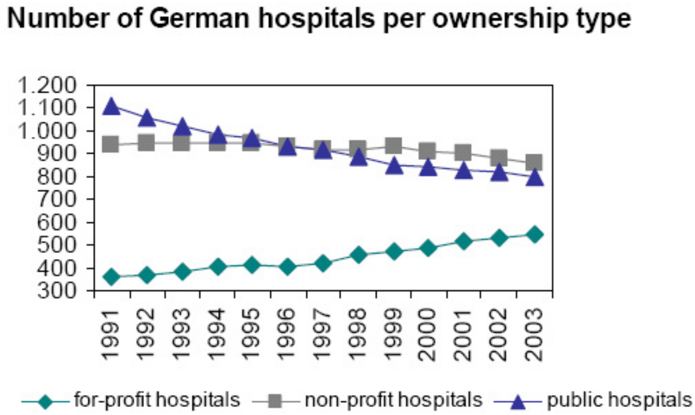
published in: Health Economics, 2008

# The German Hospital Industry



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- DEA needs less assumptions but SFA is more realistic.

# Log likelihood function

Normal Truncated-normal model, Cobb Douglas production function

$$\ln L = \sum_{i=1}^{I} \Big\{ -1/2 \ln(2\pi) - \ln\sigma - \ln\Phi(\mu/\sigma_u) - \frac{1}{2}\left(\frac{s\epsilon_i^j + \mu}{\sigma}\right)^2 + \ln\Phi\left(\frac{\mu}{\lambda\sigma} - s\frac{\lambda\epsilon_i^j}{\sigma}\right)\Big\} \quad (1)$$

where $s = -1, j = c$ in the case of cost efficiency and $s = 1, j = t$ in the case of technical efficiency.

# Case-Mix-Weights

Los for each diagnosis $m = 1, \ldots, M$ over all German hospitals $i = 1, \ldots, I$:

$$los_m = \sum_i days_{mi} / \sum_i cases_{mi}.$$

Mean length of stay over all diagnoses and hospitals:

$$los_G = \frac{1}{M} \sum_m los_m$$

which is 8.9 days in 2003.
The number of weighted cases in hospital $i$:

$$w\_cases_i = \sum_m \frac{los_m}{los_G} cases_{mi} = \sum_m \pi_m cases_{mi}$$

with $\frac{1}{M} \sum_m^M \pi_m = 1$.