Comparing the Technical Efficiency of Hospitals in Italy and Germany: Non-parametric Conditional Approach

TRACKING REGIONAL VARIATION IN HEALTH CARE

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Rudolf Blankart, University of Hamburg
Aleksandra Torbica, University of Bocconi
Jonas Schreyögg, University of Hamburg
Introduction

Methods

Data

Results

Conclusion
Introduction: Literature

- Huge amount of publications on hospital efficiency: about 300 until 2006 (Hollingsworth, 2008) + about 170 after 2006 (database research)

- International comparisons of hospital efficiency
  - NordDRG in Denmark, Finland, Norway und Sweden
    - 6 studies in Scandinavian countries → review by Medin et al. (2013)
    - similar organization of health care
  - Different DRG-systems
    - Dervaux et al. (2004): 1080 hospitals
    - Mobley & Magnussen (1998): 178 hospitals in California and 52 in Norway
    - Steinmann et al. (2004): 105 hospitals in Sachsen, Germany und 251 in Switzerland

OUTPUT

Patient und procedure classifications

INPUT

Personnel classification

Currency systems and prices
Methods: Conceptual Framework

Conditional approach

**Hospital background**
- Bed size category
- Ownership type
- Specialization

**Environmental characteristics**
- Competition
- Urbanization
- Income
- Age structure

**INPUTS**
- LABOR
  - Physicians
  - Nurses
- CAPITAL
  - Hospital beds

**OUTPUTS**
- INDIRECT
  - Adj. inpatient discharges
  - Day cases
### Data: hospital characteristics (calendar year 2010)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Italy: 920</th>
<th></th>
<th>Germany: 1 381</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td><strong>INPUTS</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Beds</td>
<td>244</td>
<td>283</td>
<td>317</td>
<td>300</td>
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<td>Physicians</td>
<td>133</td>
<td>169</td>
<td>109</td>
<td>180</td>
</tr>
<tr>
<td>Nurses</td>
<td>288</td>
<td>400</td>
<td>355</td>
<td>413</td>
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<tr>
<td><strong>OUTPUTS</strong></td>
<td></td>
<td></td>
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<tr>
<td>Adj. inpatient discharges</td>
<td>8 324</td>
<td>9 967</td>
<td>12 198</td>
<td>12 448</td>
</tr>
<tr>
<td>Day cases</td>
<td>3 220</td>
<td>5 462</td>
<td>1 800</td>
<td>2 697</td>
</tr>
</tbody>
</table>

*Discharges are adjusted on the basis of length of stay [Herr (2008)](Herr2008) using the weights across 130 diagnoses ([International Shortlist for Hospital Morbidity Tabulation](ISHMT)), OECD Health Data.*
Regional data: urbanization, income, age structure

OECD Regional Data → Territorial Level 3 (Germany: 96 spatial planning regions, Italy: 110 provinces)
## Results: Efficiency values

<table>
<thead>
<tr>
<th></th>
<th>Obs.</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>1st Qu.</th>
<th>Mdn</th>
<th>3rd Qu.</th>
<th>Max</th>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Total sample</td>
<td>2301</td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>1.10</td>
<td>1.34</td>
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<tr>
<td>Italy</td>
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<td></td>
<td></td>
<td></td>
<td>1.00</td>
<td>1.00</td>
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<td>1.52</td>
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<td></td>
<td></td>
<td>0.99</td>
<td>1.07</td>
<td>1.23</td>
<td>6.50</td>
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<tr>
<td><strong>Bandwidths for hospital characteristics</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>Bed size category</td>
<td>2301</td>
<td>0.11</td>
<td>0.21</td>
<td>0</td>
<td>0</td>
<td>0.01</td>
<td>0.04</td>
<td>0.76</td>
</tr>
<tr>
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<td>2301</td>
<td>0.39</td>
<td>0.1</td>
<td>0</td>
<td>0.33</td>
<td>0.38</td>
<td>0.5</td>
<td>0.51</td>
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<td>Specialization</td>
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<td>1.10E+05</td>
<td>0.02</td>
<td>0.11</td>
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<td>0.37</td>
<td>3.60E+06</td>
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<tr>
<td><strong>Bandwidths for regional characteristics</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Competition</td>
<td>2301</td>
<td>3.10E+04</td>
<td>1.00E+05</td>
<td>0.03</td>
<td>0.22</td>
<td>0.35</td>
<td>2.74E+04</td>
<td>2.70E+06</td>
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<tr>
<td>Urbanization</td>
<td>2301</td>
<td>0.56</td>
<td>0.21</td>
<td>0</td>
<td>0.46</td>
<td>0.57</td>
<td>0.76</td>
<td>0.76</td>
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<tr>
<td>Income</td>
<td>2301</td>
<td>0.59</td>
<td>0.16</td>
<td>0</td>
<td>0.51</td>
<td>0.57</td>
<td>0.76</td>
<td>0.76</td>
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<tr>
<td>Age structure</td>
<td>2301</td>
<td>5.20E+05</td>
<td>1.90E+06</td>
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<td>2.69</td>
<td>4.5</td>
<td>4.00E+05</td>
<td>5.90E+07</td>
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<tr>
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<td>0.1</td>
<td>0</td>
<td>0.04</td>
<td>0.05</td>
<td>0.14</td>
<td>0.38</td>
</tr>
<tr>
<td><strong>Conditional efficiency</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Total sample</td>
<td>2301</td>
<td></td>
<td></td>
<td></td>
<td>0.91</td>
<td>1.03</td>
<td>1.25</td>
<td>12.13</td>
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<tr>
<td>Italy</td>
<td>920</td>
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<td>0.94</td>
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<td>1.41</td>
<td>12.13</td>
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<tr>
<td>Germany</td>
<td>1381</td>
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<td></td>
<td></td>
<td>0.90</td>
<td>1.01</td>
<td>1.16</td>
<td>6.68</td>
</tr>
</tbody>
</table>

*Italy → 19% inefficiency*  
*Germany → 7% inefficiency*  
*Italy → 9% inefficiency*  
*Germany → 1% inefficiency*
Results: Regional variation in hospital efficiency (median values)
Results: Non-parametric regression

The ratios of conditional to unconditional efficiencies were non-parametrically regressed on the environmental variables (Racine & Li, 2004):

\[
\hat{R}_i^z = f(z_i) + \epsilon_i, \text{ where } \\
\hat{R}^z(x, y | z) = \frac{\hat{\lambda}_{m,n}(x, y | z)}{\hat{\lambda}_{m,n}(x, y)}
\]

Variable | Value
--- | ---
**Hospital characteristics**
Bed size category | <2e-16 ***
Ownership | <2e-16 ***
Specialization | <2e-16 ***

**Regional characteristics**
Competition | 0.078 .
Urbanization | 0.071 .
Income | 0.096 .
Age structure | 0.067 .
Country dummy | <2e-16 ***
Results: Partial regression plots

\[
\hat{R}^z(x, y \mid z) = \frac{\hat{\lambda}_{m,n}(x, y \mid z)}{\hat{\lambda}_{m,n}(x, y)} = \frac{\text{Conditional efficiency}}{\text{Unconditional efficiency}}
\]
Conclusion

- Methods
  - Non-parametric conditional efficiency method allows to consider external factors
  - Case-mix adjustment based on length of stay in different diagnostic groups is easily applicable to hospital data in different countries

- Regional variation
  - German hospitals are on average more efficient than Italian hospitals
  - New states of Germany and states in the North are more efficient than Southern Germany
  - No clear geographical pattern emerged in Italy

- Factors associated with efficiency
  - Hospital size (55% of Italian hospitals have up to 150 beds)
  - Ownership (72% of Italian beds are in public ownership)
  - Specialization (economies of scope)

- Further research
  - In order to explore the role of institutions the analysis should be expanded to include more countries
Thank you for your attention!

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References

BACK-UP
## Country facts

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Italy</th>
<th>Germany</th>
</tr>
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<tbody>
<tr>
<td>Health system type</td>
<td>National Health Service</td>
<td>Social Health Insurance</td>
</tr>
<tr>
<td>Financing of health expenditure¹</td>
<td>80% taxes</td>
<td>70% social security contributions</td>
</tr>
<tr>
<td></td>
<td>18% out-of-pocket</td>
<td>13% out-of-pocket</td>
</tr>
<tr>
<td></td>
<td>1% private health insurance</td>
<td>9% private health insurance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7% taxes</td>
</tr>
<tr>
<td>DRG adoption</td>
<td>1994</td>
<td>2004</td>
</tr>
<tr>
<td>Acute care beds per 1,000 pop.¹</td>
<td>2.93 (-48%)</td>
<td>5.33 (-20%)</td>
</tr>
<tr>
<td>Average LOS¹</td>
<td>6.7 days (-27%)</td>
<td>8.1 days (-35%)</td>
</tr>
<tr>
<td>Discharges per 100,000 pop.¹</td>
<td>13,130 (-22%)</td>
<td>24,000 (19%)</td>
</tr>
<tr>
<td>Hospital ownership, % beds²</td>
<td>72% public</td>
<td>46% public</td>
</tr>
<tr>
<td></td>
<td>20% private for-profit</td>
<td>17% private for-profit</td>
</tr>
<tr>
<td></td>
<td>8% private non-profit</td>
<td>37% private non-profit</td>
</tr>
</tbody>
</table>

Source: ¹Data for 2010, source: OECD Regional Statistics 2010, the values in parentheses represent the percentage change from 1994. ²Estimates for 2010 from our dataset.
METHODS
Non-parametric methodology

Most frequently used non-parametric methods (Hollingsworth, 2008):

- Data Envelopment Analysis (DEA)
- Free Disposal Hull (FDH)

Graphical illustration

- Input = Physicians
- Output = Adj. inpatient discharges
Outlier problem

Non-parametrically estimated production possibility frontiers

- VRS_{θ}
- CRS_{θ}
- FDH_{θ}
Order-m frontier (Cazals et al. 2002, Daraio & Simar 2005)

Non-parametrically estimated production possibility frontiers
Limitations of the conventional non-parametric analysis (DEA, FDH):

- Sensitive to outliers
- “The curse of dimensionality”
- Difficulty to incorporate environmental variables
- Interpretation of the environmental variables

Partial order-m frontier

- Robust to outliers
- Conditional methodology
- Takes into consideration environmental factors

Cinzia Dario: only one environmental variable

Kristof De Witte: multiple environmental factors
The methodology of partial frontier analysis

- **Conventional assumption**: all observations belong to the production set: \( \text{prob}\{(x, y) \in \Psi\} = 1 \).

- The **FDH estimator** for a given DMU \((x, y)\):
  \[
  \hat{\lambda}_{FDH,n}(x, y) = \max_{i | x_i \leq x} \left\{ \min_{j=1,...,q} \frac{y^j_i}{y_j} \right\}
  \]

- **Order-**\(m\): compare a unit \((x, y)\) to \(m\) randomly selected with replacement peers from the population of units producing more output than \(y\).

- **The probabilistic formulation** of the production process, output-oriented efficiency of order-\(m\):
  \[
  \hat{\lambda}_{m,n}(x, y) = \int_0^\infty (1 - (1 - \hat{S}_{Y,n}(uy|x))^m) du
  \]
  where \(\hat{S}_{Y,n}(y|x) = \frac{\sum_{i=1}^n \mathbb{I}(x_i \leq x, y_i \geq y)}{\sum_{i=1}^n \mathbb{I}(x_i \leq x)}\) is the conditional survivor function.

- **Output-oriented efficiency conditional on the set of environmental variables** \(\mathbb{Z}^r\):
  \[
  \hat{\lambda}_{m,n}(x, y|z) = \int_0^\infty (1 - (1 - \hat{S}_{Y,n}(uy|x,z))^m) du
  \]
  where \(\hat{S}_{Y,n}(y|x,z) = \frac{\sum_{i=1}^n \mathbb{I}(x_i \leq x, y_i \geq y) K_h(z,z_i)}{\sum_{i=1}^n \mathbb{I}(x_i \leq x) K_h(z,z_i)}\), \(K(\cdot)\) is a kernel function, \(\hat{h}\) hat is the bandwidth.

Non-parametric assessment of environmental influences:
  \[
  \hat{R}_i^z = f(z_i) + \epsilon_i,
  \]
  where \(\hat{R}_i^z(x, y | z) = \frac{\hat{\lambda}_{m,n}(x, y|z)}{\hat{\lambda}_{m,n}(x, y)}\) is the ratio of conditional to unconditional efficiency measures.
m selection

Source: Hammerschimdt et al. (2009) Methoden zur Lösung grundlegender Probleme der Datenqualität in DEA-basierten Effizienzanalysen. DBW 69
The influence of $m$ on the partial frontier

Non-parametrically estimated production possibility frontiers
Alpha selection

Source: Tauchmann (2011) **orderalpha**: non-parametric order-alpha Efficiency Analysis for Stata
Main assumptions of conventional non-parametric analyses

A1  Free disposability. We can produce less with more: that is, $(x, y) \in T, x' \geq x$, and $y' \leq y \Rightarrow (x', y') \in T$

A2  Convexity. Any weighted average of feasible production plans is feasible as well: $(x, y) \in T, (x', y') \in T, \alpha \in [0, 1] \Rightarrow \alpha(x, y) + (1 - \alpha)(x', y') \in T$

A3  $\gamma$-returns to scale. Production can be scaled with any of a given set of factors: $(x, y) \in T, \kappa \in \Gamma(\gamma) \Rightarrow \kappa \cdot (x, y) \in T$

Table 4.1 DEA model assumptions

<table>
<thead>
<tr>
<th>Model</th>
<th>A1 Free disp.</th>
<th>A2 Convexity</th>
<th>A3 $\gamma$ return</th>
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<td>FDH</td>
<td>√</td>
<td>√</td>
<td>$\kappa = 1$</td>
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<tr>
<td>VRS</td>
<td>√</td>
<td>√</td>
<td>$\kappa = 1$</td>
</tr>
<tr>
<td>DRS (NIRS)</td>
<td>√</td>
<td>√</td>
<td>$\kappa \leq 1$</td>
</tr>
<tr>
<td>IRS (NDRS)</td>
<td>√</td>
<td>√</td>
<td>$\kappa \geq 1$</td>
</tr>
<tr>
<td>CRS</td>
<td>√</td>
<td>√</td>
<td>$\kappa \geq 0$</td>
</tr>
<tr>
<td>FRH</td>
<td>√</td>
<td></td>
<td>$\kappa = 1$</td>
</tr>
</tbody>
</table>

Non-parametrically estimated production possibility frontiers
Outlier problem

- The non-parametric approach presents several limitations:
  - the difficulty in carrying out statistical inference;
  - the curse of dimensionality;
  - sensitivity to extreme values and outliers
- Wrong record:
  - 7.8 instead of 78 FTE physicians
- Such extreme values can have a heavy impact on the upper boundary of the frontier
- All DMUs would be benchmarked according to this one erroneous record
Wilson (1993) proposed a method employing an influence function based on the geometric volume spanned by the sample observations, and the sensitivity of this volume with respect to deletions of singletons, pairs, triplets, etc. from the sample.

- Stopping point: i=1
- Observations: 7
Outlier detection

- Wilson (1993) proposed a method employing an influence function based on the geometric volume spanned by the sample observations, and the sensitivity of this volume with respect to deletions of singletons, pairs, triplets, etc. from the sample.

- Stopping point: \( i = 2 \)
- Observations: 7, 19
Wilson (1993) proposed a method employing an influence function based on the geometric volume spanned by the sample observations, and the sensitivity of this volume with respect to deletions of singletons, pairs, triplets, etc. from the sample.

- Stopping point: $i=3$
- Observations: 7, 19, 23

**Outlier detection**

![Non-parametrically estimated production possibility frontiers](image)
Outlier detection

Problems

- The stopping point, $i$, for the outlier analysis is arbitrary
- Should be large enough to allow for masking produced by several observations in the data
- Extremely slow for $i$ larger than 3 or 4
- Becomes intractable for larger data sets (samples larger than a few hundred observations)
- Rarely implemented empirically
RESULTS
### Descriptive Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Italy</th>
<th>Germany</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
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<tr>
<td><strong>Input variables</strong></td>
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<tr>
<td>Beds</td>
<td>244</td>
<td>283</td>
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<tr>
<td>Physicians</td>
<td>133</td>
<td>169</td>
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<td>Nurses</td>
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<td><strong>Output variables</strong></td>
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<td>8,324</td>
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<td>Day cases</td>
<td>3,220</td>
<td>5,462</td>
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<tr>
<td><strong>Hospital background characteristics</strong></td>
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<tr>
<td>Bed size category</td>
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<tr>
<td>1: (24,50]</td>
<td>98</td>
<td>0.22</td>
</tr>
<tr>
<td>2: (50,150]</td>
<td>404</td>
<td>0.22</td>
</tr>
<tr>
<td>3: (150,400]</td>
<td>257</td>
<td>0.22</td>
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<tr>
<td>4: (400, 650]</td>
<td>76</td>
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<td>5: (650, 3213]</td>
<td>85</td>
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<tr>
<td>Specialization</td>
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<td>0.22</td>
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<tr>
<td>Ownership type</td>
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<td>1: Public</td>
<td>500</td>
<td>54%</td>
</tr>
<tr>
<td>2: Private for-profit</td>
<td>357</td>
<td>39%</td>
</tr>
<tr>
<td>3: Private non-profit</td>
<td>63</td>
<td>7%</td>
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<td><strong>Environmental variables</strong></td>
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<td>Market concentration</td>
<td>0.27</td>
<td>0.19</td>
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<tr>
<td>Degree of urbanization</td>
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</tr>
<tr>
<td>1: Rural remote</td>
<td>36</td>
<td>4%</td>
</tr>
<tr>
<td>2: Rural close to a city</td>
<td>68</td>
<td>7%</td>
</tr>
<tr>
<td>3: Intermediate</td>
<td>422</td>
<td>46%</td>
</tr>
<tr>
<td>4: Urban</td>
<td>394</td>
<td>43%</td>
</tr>
<tr>
<td>Quartile of income</td>
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</tr>
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<td>1: 1st quartile</td>
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<td>47%</td>
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<tr>
<td>2: 2nd quartile</td>
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<td>19%</td>
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<td>3: 3rd quartile</td>
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<td>4: 4th quartile</td>
<td>140</td>
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<td>Population age 65+, %</td>
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<tr>
<td>Observations</td>
<td>920</td>
<td>100%</td>
</tr>
</tbody>
</table>
Boxplot conditional efficiency

Excludes outside values
Notes: Efficiency.ratio = the ratio of conditional efficiency estimates to unconditional efficiency estimates. In the output-oriented framework, increasing line (for continuous variables) or higher bar (for categorical variables) imply a favorable effect on production efficiency. Bed size category: 1=[25,50], 2=(50,150], 3=(150,400], 4=(400,650], 5=(650,3213]; ownership: 1=public, 2=private for-profit, 3=private non-profit; degree of urbanization: 1=rural remote, 2=rural close to a city, 3=intermediate, 4=urban; quartile of income: 1=1st quartile, 2=2nd quartile, 3=3rd quartile, 4=4th quartile.
Limitations

- Complexity of data collection: language barrier, data protection

- Further variables to describe the production process

  **INPUTS:**
  - Other personnel categories, medical equipment, expenses

  **OUTPUTS:**
  - Outpatient visits, research and teaching

- Quality

- Conditional methodology does not examine causal effects

- Computational burden