Productivity growth in electric energy retail in Colombia.
A bootstrapped Malmquist indices approach

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Colombia’s electric energy industry was split into four activities early in the 90s: generation, transmission, retail and distribution.

Transmission and distribution have kept their natural monopoly character, while competence is allowed in generation and retail.

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There are several options for productivity estimation: index numbers, econometric and Data Envelopment Analysis (DEA) - Malmquist.

DEA has drawn attraction into productivity estimation for regulatory purposes thanks to:
- Allow several inputs-outputs
- Ease of understanding
- Direct identification of highly efficient/productive production units
- Theoretical soundness (microeconomics and producer theory)

However, standard DEA lacks statistical properties to assess efficiency and productivity measures. Particularly questionable with few observations or data collection problems.

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DEA efficiency

\[ \partial \hat{X}(y) \]

\[ \hat{\delta}(x_f, y) \]

\[ \hat{\delta}(x_g, y) \]

\[ \hat{x}_g(y) \]

\[ \delta(x_f, y) \]

\[ \delta(x_g, y) \]

\[ x_1 \]

\[ x_2 \]
DEA efficiency in $t + 1$
Productivity

\[ x_2 \]

\[ \partial \hat{X}(y) \]

\[ \partial \hat{X}(y)_+ \]

\[ f \]

\[ a_{+1} \]

\[ \hat{\delta}(x_f, y) \]

\[ b \]

\[ b_{+1} \]

\[ \hat{x}_g(y) \]

\[ c \]

\[ c_{+1} \]

\[ \hat{\delta}(x_g, y) \]

\[ d \]

\[ d_{+1} \]

\[ \hat{\delta}(x_g, y) \]

\[ e \]

\[ e_{+1} \]
Productivity

\[ M_i(t_1, t_2) = \frac{\delta_{t_2}^{t_1} | t_2}{\delta_{t_1}^{t_2} | t_1} \times \left( \frac{\delta_{t_2}^{t_1} | t_1}{\delta_{t_2}^{t_1} | t_2} \times \frac{\delta_{t_1}^{t_1} | t_1}{\delta_{t_1}^{t_1} | t_2} \right)^{\frac{1}{2}} \]
Bootstrapping DEA

- Resampling to re-create appropriately the Data Generating Process (DGP).
- Source of variability in DEA lies on the efficiency measures. The bootstrap is performed upon a initial set of efficiency measures $\hat{\delta}$, used to regenerate a new sample of input-output data.
- A non-parametric Gaussian process is used for the random sampling with replacement.
- The $b$ bootstrapped samples, with the appropriate aggregation rule, allows to obtain a media and confidence intervals to assess if efficiency and productivity growth is significantly different from 0 or not.
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Data

- 18 retail firms covering geographically distinctive markets from 2005 to 2009.
- Input variables: Assets, employment and operational costs.
- Output variables: Service queries, complaints and appeals (QCA); cuentas por cobrar; No. of users; electricity consumption.
- Data obtained from public, not very accurate, database from Colombias utilities superintendency, not the energy markets regulator.
- Focus on malmquist productivity change, efficiency change and technical change.

\[
\Delta M_{i}(t_{1}, t_{2}) = \delta_{i}^{t_{2}|t_{1}} \times \left( \delta_{i}^{t_{1}|t_{2}} \delta_{i}^{t_{2}|t_{1}} \right)^{1/2}
\]

\(\Delta M\): Malmquist - TFP

\(\Delta \text{ Efficiency}\): Efficiency change

\(\Delta \text{ Technology}\): Technical change
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- $\Delta$ Malmquist - TFP
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3,000 repetitions.

High variance and inability to determine any productivity, efficiency or technology change.
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High variance and inability to determine any productivity, efficiency or technology change.
Efficiency growth
Efficiency growth + CI

Year

Efficiency index

CI
Malmquist productivity

Year
Malmquist productivity + CI

Year

- Malmquist index
- CI
An industry aggregate figure is what the regulator needs.

**Cuadro 1.** Malmquist, efficiency and technical change (mean and median)

<table>
<thead>
<tr>
<th>Year</th>
<th>Malmquist</th>
<th>Efficiency</th>
<th>Technology</th>
<th>Malmquist</th>
<th>Efficiency</th>
<th>Technology</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
<td>Median</td>
<td>Median</td>
<td>Median</td>
</tr>
<tr>
<td>2006</td>
<td>1.0258</td>
<td>1.0056</td>
<td>1.0466</td>
<td>1.0001</td>
<td>1.0046</td>
<td>1.0051</td>
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<tr>
<td>2007</td>
<td>1.1138</td>
<td>0.9498</td>
<td>1.2168</td>
<td>1.1301</td>
<td>0.9084</td>
<td>1.2351</td>
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<tr>
<td>2008</td>
<td>1.0605</td>
<td>1.1443</td>
<td>0.9526</td>
<td>0.9998</td>
<td>1.155</td>
<td>0.9385</td>
</tr>
<tr>
<td>2009</td>
<td>1.0329</td>
<td>1.3165</td>
<td>0.8606</td>
<td>1.0325</td>
<td>1.1501</td>
<td>0.8625</td>
</tr>
</tbody>
</table>
Box plot bootstrapped Malmquist productivity
Conclusion

- A measurement of performance and productivity is basic for incentive regulation.
- Malmquist indices from DEA is a good option, the bootstrap methodology can inform us of how far are we from a significant change.
- Such assessment of the measurement is a lot more helpful than a single estimate.
- For the case of Colombia, no change can be attributed to productivity.
- Energy retail firm’s productivity is not widely known and this estimation can help to set a starting point.
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Siglas

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**DGP**  Data Generating Process