Development of Total Factor Productivity in Alpine Farming - A Malmquist index approach

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Share of grassland on agricultural area in Austria (2009)
Share of extensively used grassland on agricultural area in Austria (2009)

Average size of Austrian farms

Source: Gemeindedaten 2009

Source: Gemeindedaten 2010
Changing economic conditions for agriculture

- Increasing volatility of input and output prices
- Increasing demand for renewable energies
- As a consequence of the agrarian reforms farmers must produce increasingly market-orientated
- Increasing impact of climate change
Ungünstige Rahmenbedingungen

Quelle: Kapfer/Ziesel/Kantelhardt (2010)

Structural change in Austrian agriculture

Source: Gemeindedaten 1998 - 2010
Two hypothesis of research

In mountainous regions technical progress is slower in comparison to non-mountainous regions
→ overall model

In mountainous regions less successful farms can more easily follow the technical progress.
→ regional-differentiated model

Data Envelopment Analysis (DEA)

Method developed by FARELL (1957) and CHARNES et al. (1978)
Method calculates the efficiency of farms by comparing their input-output ratio

DEA has been used to ...
• assess the economic competitiveness of farms
  (e.g. Balmann et al., 2001; Lissitsa et al., 2005; Brodersen et al., 1999; Rothe et al., 2005)
• derive best practice farms
  (e.g. Gubi, G., 2006; Reig-Martinez et al., 2004)
• determine farms’ environmental performance
  (e.g. Reinhard et al., 2000; De Koeijer et al., 2002; Roosen et al., 2002, Eckstein, submitted)
Data Envelopment Analysis  
– A two output/one input sample

DEA Envelopment Model  
– Output-oriented Version

\[
\begin{align*}
\max_{\phi, \lambda} & \quad \phi \\
\text{s. t.} & \quad -\phi y_j + Y \lambda \geq 0 \\
& \quad x_i - X \lambda \geq 0 \\
& \quad \lambda \in R^+_n
\end{align*}
\]

where
\( \phi \) is a scalar
\( \lambda \) is a \( N \times 1 \) vector of weights
\( X \) is a \( N \times K \) matrix of input quantities for all \( N \) farms
\( x_i \) is a \( K \times 1 \) vector of input quantities for the \( i \)-th farm
\( Y \) is a \( N \times M \) matrix of input quantities for all \( N \) farms
\( y_i \) is a \( M \times 1 \) vector of input quantities for the \( i \)-th farm

\[ \text{Technical Efficiency} \quad \theta = 1/\phi \]

Source: Cooper et al., 2007; Coelli and Rao, 2000
The DEA Approach

Malmquist-Index by Färe/Grosskopf/Lindgren/Roos

\[ m_o(y_s, x_s, y_t, x_t) = \left[ \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \right]^{1/2} \]

Modified version of the Malmquist-Index

\[ m_o(y_s, x_s, y_t, x_t) = \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)} \times \frac{d_o^t(y_t, x_t)}{d_o^s(y_s, x_s)}^{1/2} \]
The Malmquist Index Approach

Malmquist-Index (modified version)

\[ (\text{tfp}_\text{ch}) = (\text{eff}_\text{ch}) \times (\text{tech}_\text{ch}) \]

\[ (\text{tfp}_\text{ch}) \] Malmquist Total Factor Prod. index change

\[ (\text{eff}_\text{ch}) \] Technical efficiency change

\[ (\text{tech}_\text{ch}) \] Technical change

\[ m_0(y_s, x_s, y_t, x_t) = \frac{d^1_0(y_t, x_t)}{d^0_0(y_s, x_s)} \left[ \frac{d^1_0(y_t, x_t)}{d^0_0(y_s, x_s)} \times \frac{d^1_0(y_s, x_s)}{d^0_0(y_s, x_s)} \right]^{1/2} \]
The Austrian “Mountain Farm Cadastre” (BHK) as an indicator for farm disadvantage

- Steepness of slopes (49 %)
- Accessibility (18 %)
- Temperature (9 %)
- Sea level (9 %)
- Soil fertility (9 %)
- Plot size (7 %)


Data basis

- 1034 Austrian voluntarily bookkeeping farms
- only farms with panel data
- only cash-cropping, pig and poultry, mixed and forage farms
- 7 observation periods (2003-2009)
- deflation of monetary values using price indices
- „Mountain Farm Cadastre“ serves as basis for farm classification
The Austrian “Mountain Farm Cadastre” (BHK) as an indicator for farm disadvantage (2009)

Definition of in- and output indicators for technical efficiency calculation

- Land (ha)
- Expense (EUR)
- Capital Assets (EUR)
- Labour (WU)
- Revenue (EUR)
Overview on input and output variables
(Mean and variation coefficient, year 1)

<table>
<thead>
<tr>
<th></th>
<th>BHK 0</th>
<th>BHK 1</th>
<th>BHK 2</th>
<th>BHK 3</th>
<th>BHK 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farms</td>
<td>406</td>
<td>218</td>
<td>280</td>
<td>87</td>
<td>43</td>
</tr>
<tr>
<td>Land [ha]</td>
<td>26 (0.88)</td>
<td>31 (0.96)</td>
<td>29 (0.70)</td>
<td>42 (0.93)</td>
<td>38 (0.88)</td>
</tr>
<tr>
<td>0.88</td>
<td>0.96</td>
<td>0.70</td>
<td>0.93</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>Labour [WU]</td>
<td>1.6 (0.39)</td>
<td>1.6 (0.37)</td>
<td>1.6 (0.35)</td>
<td>1.7 (0.29)</td>
<td>1.4 (0.41)</td>
</tr>
<tr>
<td>Capital assets [EUR]</td>
<td>214.748 (0.62)</td>
<td>279.942 (0.72)</td>
<td>281.941 (0.60)</td>
<td>264.587 (0.52)</td>
<td>233.058 (0.61)</td>
</tr>
<tr>
<td>Expense [EUR]</td>
<td>38.325 (0.89)</td>
<td>30.108 (0.65)</td>
<td>27.310 (0.62)</td>
<td>22.276 (0.59)</td>
<td>16.979 (0.63)</td>
</tr>
<tr>
<td>Revenue [EUR]</td>
<td>64.965 (0.78)</td>
<td>55.153 (0.61)</td>
<td>50.275 (0.60)</td>
<td>41.391 (0.59)</td>
<td>29.819 (0.71)</td>
</tr>
</tbody>
</table>

Two hypothesis of research

In mountainous regions technical progress is slower in comparison to non-mountainous regions

→ overall model

In mountainous regions less successful farms can more easily follow the technical progress.

→ regional-differentiated model
Overview on input and output variables (Mean and standard deviation)

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<th>sig.</th>
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</thead>
<tbody>
<tr>
<td>eff_ch</td>
<td>0,967</td>
<td>0,974</td>
<td>0,975</td>
<td>0,983</td>
<td>0,977</td>
<td>-</td>
</tr>
<tr>
<td>tech_ch</td>
<td>1,037</td>
<td>1,036</td>
<td>1,031</td>
<td>1,026</td>
<td>1,021</td>
<td>***</td>
</tr>
<tr>
<td>tfp_ch</td>
<td>1,003</td>
<td>1,009</td>
<td>1,005</td>
<td>1,008</td>
<td>0,997</td>
<td>-</td>
</tr>
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Kruskal-Wallis-H-Test; Significance levels: *<0,05; **<0,01; ***<0,001

Naïve comparison of BHK 0 and BHK ...

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<tr>
<td>Δ eff_ch</td>
<td>0,007</td>
<td>0,009*</td>
<td>0,016</td>
<td>0,010</td>
<td></td>
</tr>
<tr>
<td>Δ tech_ch</td>
<td>-0,001</td>
<td>-0,006**</td>
<td>-0,012***</td>
<td>-0,017*</td>
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<td>Δ tfp_ch</td>
<td>0,006</td>
<td>0,003</td>
<td>0,005</td>
<td>-0,006*</td>
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Mann-Whitney-U-Test; Significance levels: *<0,05; **<0,01; ***<0,001
Naïve and matched comparisons

The matching procedure

Matching procedure
Nearest neighbour caliper matching with replacement

Matching variables
farm size (LF), percentage of grassland (%DF)

Literature
Rosenbaum (2010), Caliendo/Kopeining (2008), Sekhon (2011)
Naïve and “matched” comparison of BHK 0 and BHK … results

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<tr>
<td>( \Delta_{\text{eff.ch}} ) Naïve comparison</td>
<td>0.007</td>
<td>0.009*</td>
<td>0.016</td>
<td>0.010</td>
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<tr>
<td>Matched com. LF</td>
<td>-0.006</td>
<td>0.002*</td>
<td>0.022***</td>
<td>-0.008</td>
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<tr>
<td>Matched com. %DF</td>
<td>0.002</td>
<td>0.013***</td>
<td>0.018*</td>
<td>0.007</td>
</tr>
<tr>
<td>Matched com. LF+%DF</td>
<td>-0.006</td>
<td>0.018*</td>
<td>0.017*</td>
<td>0.002</td>
</tr>
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<td>( \Delta_{\text{tech.ch}} ) Naïve comparison</td>
<td>-0.001</td>
<td>-0.006**</td>
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<tr>
<td>Matched com. LF</td>
<td>-0.002</td>
<td>-0.005***</td>
<td>-0.008**</td>
<td>-0.012**</td>
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<tr>
<td>Matched com. %DF</td>
<td>0.002</td>
<td>-0.002</td>
<td>-0.001</td>
<td>-0.008</td>
</tr>
<tr>
<td>Matched com. LF+%DF</td>
<td>0.003</td>
<td>-0.003</td>
<td>-0.003</td>
<td>-0.004</td>
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<td>( \Delta_{\text{tfp.ch}} ) Naïve comparison</td>
<td>0.006</td>
<td>0.003</td>
<td>0.005</td>
<td>-0.006*</td>
</tr>
<tr>
<td>Matched com. LF</td>
<td>-0.008</td>
<td>-0.003</td>
<td>0.015</td>
<td>-0.020*</td>
</tr>
<tr>
<td>Matched com. %DF</td>
<td>0.004</td>
<td>0.011***</td>
<td>0.018*</td>
<td>0.000</td>
</tr>
<tr>
<td>Matched com. LF+%DF</td>
<td>-0.004</td>
<td>0.016*</td>
<td>0.014</td>
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Mann-Whitney-U-Test; Significance levels: *<0.05; **<0.01; ***<0.001

Two hypothesis of research

In mountainous regions technical progress is slower in comparison to non-mountainous regions

\( \Rightarrow \) overall model required

In mountainous regions less successful farms can more easily follow the technical progress.

\( \Rightarrow \) regional-differentiated model
Absolute efficiency change of farms in dependence of initial efficiency score (BHK 2)
Absolute efficiency change of farms in dependence of initial efficiency score (BHK 2)

Relative efficiency change of farms in dependence of initial efficiency score (BHK 2)
Relative efficiency change of farms in dependence of initial efficiency score (BHK 2)
### Comparison of efficiency change on BHK-group level

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<tr>
<td>R²</td>
<td>0.41</td>
<td>0.38</td>
<td>0.24</td>
<td>0.29</td>
<td>0.42</td>
</tr>
<tr>
<td>Significance</td>
<td>***</td>
<td>****</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>Gradient (A)</td>
<td>0.76</td>
<td>0.59</td>
<td>0.45</td>
<td>0.58</td>
<td>0.61</td>
</tr>
<tr>
<td>relative efficiency change at t₀=1 (B)</td>
<td>0.86</td>
<td>0.61</td>
<td>0.67</td>
<td>0.79</td>
<td>0.86</td>
</tr>
<tr>
<td>intersection point (C)</td>
<td>0.40</td>
<td>0.32</td>
<td>0.40</td>
<td>0.50</td>
<td>0.63</td>
</tr>
</tbody>
</table>

### Summary

- Technical change is significantly slower in mountainous regions.

- This does not hold if farm samples are “matched” with regard to percentage of grassland.

- The more unfavourable the regional conditions, the easier less successful farms can follow the technical progress; this applies only in mountainous regions.
Discussion

- DEA and Malmquist index approach are suitable instruments to analyse farm developments

- It is to regard that technical progress does not only mean new technologies but describes the change of the input and output relations of the best-practice farms

- Future studies should also include production-related non-monetary input and output factors