Yield potentials and yield gaps of soybean production in Austria - a biophysical and economic assessment

TradeM Workshop
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outline

• context of analysis:
  • stakeholders. policy relevance: CC and protein crops

• research problem:
  • how large is the yield gap and what can be done

• data
• approaches
• findings
• discussion and outlook
Mostviertel. Austria
Between plains of Danube valley and Alpine region
Higher temperatures. e.g. +1.6 C on both winter and summer

Regional capacities for adaptation/mitig. to CC:

- **Cover crops** - A-E program
- Reduced tillage and direct seed
- Awareness of **soil organic carbon**
- **Alternative crops** emerge: *soy*, *sorghum*, *wine*
- **Irrigation.** Limited to valuable crops

Source: Lehtonen. 2015
yield gap – the concept

Source: Ittersum et al. 2013
yield gap – the concept

Source: Ittersum et al. 2013
explanations for yield gap

• **field experiments:**
  - better management; soils; equipment; information
  - objective: *maximum yield* of specific crop

• **farmers:**
  - less than optimal management; crop-rotation not single crop
  - objective: *farm income*. if risk averse: non-volatile farm income

• **our objective – exploration of yield gap of soy**
  - levels; distribution; time variance
  - reasons and causes
soy bean production in Austria
soy bean production in AT

Source: STAT. Erntestatistik
yield gap soy bean in Austria

observations at experimental stations
observations at experimental stations
yield gap soy bean in Austria

results from
crop model (EPIC)
spatial heterogeneity

HRU Homogenous Response Units

Source: own construction
results from a crop model on farm land
yield gap soy bean in Austria

observations at farm level

FADN
observations at farm level frequency of soy yields

Source: FADN. LBG. BMLFUW. own calculations; observations for 1998-2012
yield gap soy bean in Austria

observations at municipality level
regional production of soy 2012

Source: STAT. Agrarstrukturerhebung 2012
yield at municipality level

\[ y = 0.011x + 2.527 \]
summary of findings

• crop model results
  • trend: yield + 7 kg/ha partly due to higher temperatures
  • yield trend depressed by land expansion
  • based on simulations on 1x1 km grids
  • soy is part of an observed crop rotation

• experimental data
  • trend: yield + 40 kg/ha due to genetics and CC
  • variance between cultivars is increasing
  • at least 5 years until best varieties are adopted on farms
summary of findings

• municipality crop statistics
  • trend: yield + 11 kg/ha likely due to CC and others
  • much lower average yields than model and experiments
  • volatility over time lower than in experiments and model
  • yield trend increase is depressed by land expansion

• FADN crop yield results
  • trend: yield + 32 kg/ha
  • yields of best farms match lower bound of experiments

• yield gap is stochastic
yield gap soy bean in Austria

what explains the yield levels in municipalities
methodology

• meteorological effects
  • unbalanced panel 2001 to 2014, 4891 obs
  • fixed effects: for non-time-varying characteristics
  • linear and non-linear terms with and wo interaction
  • 1x1 km grid: weather (5 variables daily)

• price effects
  • country: prices of soy beans and other crops

• land use shares
  • municipality: yields. prices. acreage soy and maize
## Model Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ertrag1</th>
<th>Ertrag2</th>
<th>Ertrag3</th>
<th>Ertrag4</th>
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</thead>
<tbody>
<tr>
<td>endogene Variable Ertrag Soja</td>
<td>-0.09534 ***</td>
<td>-0.00421 ***</td>
<td>-0.09233 ***</td>
<td>-0.00406 ***</td>
</tr>
<tr>
<td>Fläche_Sojabohnen an gesamter Ackerfläche in Gemeinde (in %)</td>
<td></td>
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<tr>
<td>Anteil Fläche_Sojabohnen an gesamter Ackerfläche in Gemeinde (in %)</td>
<td>-0.09534 ***</td>
<td>-0.00421 ***</td>
<td>-0.09233 ***</td>
<td>-0.00406 ***</td>
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<tr>
<td>Anteil Fläche_Mais an gesamter Ackerfläche in Gemeinde (in %)</td>
<td>-0.02861</td>
<td>-0.00163 *</td>
<td>-0.02974</td>
<td>-0.00169 **</td>
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<td>Fläche (in ha) Ackerland in Gemeinde</td>
<td>-0.00139</td>
<td>-0.00007</td>
<td>-0.00144</td>
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<td>Zahl der Tage zwischen 10. und 30. Juni mit weniger als 12 Grad Tiefstemperatur</td>
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<td>0.02021</td>
<td>0.06439</td>
<td>0.0037 **</td>
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<td>Summe Regen zwischen 1. Juli und 31.08. (Gewichtung: gew_CORINE21)</td>
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<td>0.00005 ***</td>
<td>0.00119 ***</td>
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<td>-0.00196 ***</td>
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<td>Konstante</td>
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<td>0.03398</td>
<td>0.03533</td>
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</tbody>
</table>
summary of findings

- meteorological effects
  - rain matters: good in June and July, bad in late September/October
  - soy is sensitive to high temperatures in July and August

- price effects
  - slight negative effect of soy price t-1
  - slight positive effect of soy price in July
  - slight negative effect of durum wheat price t-1

- land use shares
  - higher share of land → lower yields

- time trend positive and strong
  - depending on model: 60 kg/year and more
drought risk in Austria

Source: Strauss et al. 2013
yield gap soy bean in Austria

efficiency analysis
the scope of farm management
methodology

• stochastic frontier analysis
  • 104 FADN-data with 1082 observations
  • period 1995 to 2011
  • yields on average from 2.0 to 2.5 and up to 4.5 t/ha
## SFA results for soy

|                     | Estimate | Std. Error | z value | Pr(>|z|) |
|---------------------|----------|------------|---------|----------|
| (Intercept)         | -27.91   | 5.76       | -4.85   | 0.00     | ***     |
| log(Mean_Prec_mpss) | 0.39     | 0.13       | 3.07    | 0.00     | **      |
| log(Mean_Rad_mpss)  | 1.54     | 0.36       | 4.33    | 0.00     | ***     |
| log(Mean_Temp_so)   | 0.51     | 0.08       | 6.72    | 0.00     | ***     |
| Z_ESU               | -0.02    | 0.00       | -3.85   | 0.00     | ***     |
| Z_PROTEC            | -0.01    | 0.00       | -3.43   | 0.00     | ***     |
| sigmaSq             | 1.00     | 0.15       | 6.89    | 0.00     | ***     |
| gamma               | 0.99     | 0.00       | 406.32  | < 2.22e-16 | *** |
summary of findings

• mean efficiency: 0.69
  • low compared to wheat: 0.80 → scope for management

• meteorological effects
  • rain matters
  • temperature matters
  • global radiance matters

• farm specific effects
  • farm size matters
  • model without fertilizer because accumulated by plant
  • expenditures for crop protection substances
discussion

• yield gap analysis is a daunting task
• what can be learned
  • economics matters: prices of crop and other crops
  • land expansion: more land becoming more marginal
  • management matters a lot but – not directly observable in data
  • significant knowledge gaps still there
• way forward:
  • look at other crops
  • explore options to improve management
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