Modelling Structural Change in the Agricultural Sector – an Agent-Based Approach Using FADN Data from Individual Farms

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• Model design
  • Number of agents
  • Behaviour of the agents
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SWISSland = Structural change information system for Switzerland
Why SWISSIland?

• To forecast the income of Swiss agriculture
• To forecast the supply of all agricultural products
• To forecast structural change
  • Number of farms, farm-size, farm abandonment, farm succession
• To cover the heterogeneity of agricultural production in Switzerland (regions, farm-types, farm-size).
Model design

• Number of agents
• Behaviour of the agents

Each FADN-farm is characterized by a projection factor

3,300 FADN farms

Projection

Total number of farms = 50,000
Total area = 1,000,000 ha
Solving projection problems

- **Method:**
  - Determining an identical projection factor for each FADN-farm type
  - Recalculating the number of FADN farms agents
    - Adding farm types, which are underrepresented
    - Deleting farm types, which are overrepresented.
  - Solving the problem by a minimization process, taking into account that several sectoral parameters (area, farm size, farm-type) have an adequate representation

**Minimization:**

$$\sum_m \left( \sum_b w_b \frac{M_{mb}}{MSW_m} - 1 \right)^2 \cdot MF_m \rightarrow \min$$

Sum of square deviations

**Constraints:**

$$\sum_{w_{b \in SW_g}} w_b = NSW_g$$

Agents per group

$$w_b \geq 0$$

Weighting factor w

NSW_g \geq NZA_g : w_b \geq 1

For underrepresented FADN-groups: w_b > 0

NSW_g < NZA_g : w_b \leq 1

For overrepresented FADN-groups: w_b < 1

$$uMSW_m \leq \sum_b w_b M_{mb} \leq oMSW_m$$

Constraints
Modelling the agent’s behaviour

- Production planning
- Investment decisions
- Farm succession
- Land renting
Data base

**PRODUCTION**
Economic data from 3300 FADN-farms

**Degree of capacity utilisation**
Data from 1000 farm surveys (Gazzarin, 2008)

**Farm succession**
Representative survey of 776 old farmers (Rossier, 2006)

**Farm entry**
Representative survey of 1023 young farmers (Rossier, 2008)

**Land market**
Spatial data of 10 typical municipalities

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Using FADN-data for the agent-based model SWISSland
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Modelling production and investment decisions

PMP-based Optimization Model

\[
\begin{align*}
\text{Max} & \quad \sum_j c_j X_j \\
\text{s.t.} & \quad \sum_j a_{ij} X_j \leq b_i \quad \text{for all } i \\
& \quad X_j \geq 0 \quad \text{for all } j
\end{align*}
\]

Recursive-dynamic approach

• Investment decisions are taken by annual investment costs

• Investment decisions lead to an increase in building capacities in the future
Information of FADN

- Socio-economic data (age, education)
- Location (zone, canton, municipality)
- Organic, non-Organic, farm-type.
- Land-capacity, labour-capacity
- Farm specific variable costs, yields and prices for every single production line
- Production coefficients
Modelling investment decisions

Life cycle of a family farm

- Investment period
- Improving capacity utilization
- Status quo

- Farm takeover
- 45 years
- 60 years
- Farm abandonment
Modelling the land market

Spatial criteria determine land renting decisions

Restriction:
Land trade takes place only on municipality level. In Switzerland one municipality consists of about 50 farms.
Modelling the land market

Total number of agents: 3 300

Grouped by 27 Cantons

66 SWISSLand-municipalities

Every SWISSLand-municipality gets the spatial structure of one of the 10 reference municipalities
Defining groups of interacting agents

Total number of agents: 3 300
Grouped by 27 Cantons

Every SWISSLand-municipality gets the spatial structure of a one of the 10 reference municipalities

66 SWISSLand-municipalities
Defining rules for farm succession

Farm succession rules

Farmer gets 65 years old

The Farm is transferred to the successor or it is given up
Rules for farms at the retirement age

• Survey on farm succession behaviour in Switzerland (2004)

<table>
<thead>
<tr>
<th>Region</th>
<th>Farm size</th>
<th>Successor: No</th>
<th>Successor: yes</th>
</tr>
</thead>
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<tr>
<td>Tal</td>
<td>0_10_ha</td>
<td>75%</td>
<td>25%</td>
</tr>
<tr>
<td>Tal</td>
<td>10_20_ha</td>
<td>54%</td>
<td>48%</td>
</tr>
<tr>
<td>Tal</td>
<td>&gt;_20ha</td>
<td>32%</td>
<td>68%</td>
</tr>
</tbody>
</table>

Successor takes the farm over, if one criterion is fulfilled:
1) Household Income > Minimal Income
If not, the farm will be given up.

When the farmer reaches the retirement age, the farm will be given up and the land will be leased to neighboring farms.
Modeling land allocation

**Land supply:** Parcels of land from the abandoned farms

**Land demand:** For each parcel, the 5 neighboring farms can be interested in renting the parcels.

**Land allocation**
- Each interested farm is optimized
- The farm which reaches the highest additional income gets the parcel.
- This process is repeated until all parcels are distributed to the neighboring farms.
Technical implementation

*In close collaboration with a software engineering firm*
Prototype for canton Obwalden

General indicators 2008 (BFS)
- 734 farms
- 7862 ha land
- 13 ha land / farms

Prototype
52 agents create one municipality for Obwalden
Canton Obwalden

FADN Farms in Obwalden

- Dairy farms
- Organic farms
- Not skilled farms

Number of farms

- Hill
- Mountain 1
- Mountain 2
- Mountain 3
Model forecast until 2020

• Policy scenario
  • **Status Quo:** Slight tariff reduction until 2011. No changes from 2011 to 2020

  • **Free-Trade EU:** Free trade with the European Union: Tariff reduction from 2011-2017 on the European level

  • No change in direct payments
Price assumptions until 2020

Source: Swiss ministry of agriculture, 2009

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Model results: Average farm income and number of farms until 2020

Status Quo

Free Trade EU

All agents

All agents

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Model results: Average farm income for those without growth until 2020

Status Quo

- 17% of all agents

Free Trade EU

- 47% of all agents

35% of all agents

27% of all agents
Model results: Average farm income of farms with growth until 2020

Status Quo

Free Trade EU

36 % of all agents

35 % of all agents

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Model results: Average farm income for those with investments

Free trade EU

2 agents

farm income - Agricultural area

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Summary and conclusions

• Objective of Swissland: Improving the modeling of reality by taking into account farm variety.
  • Defining an agent population based on FADN data enables this.

• The sectoral scale requires huge amount of data.
  • Therefore a balance between complexity and simplicity is required.

• The prototype show, that the use of different data sources to estimate the agent’s behavior is a feasible approach to get more plausible model results.
Optimizing the agents

- Defining production activities
- Taking into account technical, ecological and financial constraints
- Each agent has a defined objective function
- Maximizing the household income
- Data-base: FADN-data
- Splitting up total costs of FADN-farms to single production activities
  - Labour costs are split up by standard labour requirements factors
Modelling realistic production decisions

Positive mathematical programming (PMP)

Optimization model

$$\text{Max } Z_t = \sum_z p_{zt}x_{zt} - \sum_z d_{zt}x_{zt}$$

$$Ax_{zt} < b_{zt}$$

$$x_{zt} > [0]$$

• The agent’s behaviour in terms of production planning is more realistic than using linear programming
Estimating the marginal cost function of the agent

\[ \eta \lambda + x / c(Q) \]

Quelle: Darstellung in Anlehnung an Schmitz (1994).
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Conclusions

• FADN data as an important future source for agent-based models
• Do data requirements have to be changed due to this new application?
Agent-based models...

(Parker et al. 2002)
Agent-based models...

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Agent-based models...

(Parker et al. 2002)