Agricultural Policy and Structural Change: Analysing (Spatial) Heterogeneity

Christoph Weiss

114th Seminar of the EAAE, April 15 – 16, 2010, Berlin, Germany
Introduction (1)

- Google.com

<table>
<thead>
<tr>
<th>Term</th>
<th>Entries</th>
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<tbody>
<tr>
<td>„structural change“</td>
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<td>„structural change in agriculture“</td>
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</tr>
<tr>
<td>„structural change in agriculture“ &amp; „journal“ &amp; „economics“</td>
<td>122,000</td>
</tr>
</tbody>
</table>

- “long-term changes in the composition of economic aggregates” (Streissler, 1982, p.2).
- long-term / heterogeneity
**Introduction (2)**

- Impact of Policy on Structure: Heterogeneity!

<table>
<thead>
<tr>
<th>Participate ('treated')</th>
<th>Do not participate ('non treated')</th>
</tr>
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</table>

- Heterogeneity of effects between groups
- Heterogeneity of effects within treated
- Heterogeneity of effects within non-treated
Introduction (3)

- The Evaluation Problem
- Randomized Experiments
  - Individuals $i = 1, ..., N$
  - Random assignment (participation) $p_i = 1$ or $p_i = 0$
  - Outcome $y_i^1$ or $y_i^0$
  - Policy (size) effect: $\Delta_i = y_i^1 - y_i^0 = s_i^1 - s_i^0$
  - Randomized Experiments in
    - Sciences
    - Labour economics, development economics, behavioural economics
    - In agricultural economics?
Introduction (4)

- **Observational Studies (Natural Experiments)**
  - Non-random assignment: \( p_i = p_i(x_i, s_{i,t-1}) \)
  - Regression model: \( s_{i,t} = \alpha + \lambda s_{i,t-1} + \beta p_{i,t}(x_{i,t}, s_{i,t-1}) + x_{i,t} \gamma + \varepsilon_{i,t} \)
  - 'Gibrat’s Law'-type model
  - Parameters measure 'Treatment on the Treated' effects
  - Survey in Zimmermann et al. (2009, ES&P)

- **Assumptions:**
  - Effect on treated: 'Common effect assumption' \( \Delta_{i,t} = \Delta = \beta \)
  - Effect on non-treated: No effect ('SUTVA')
Introduction

- Introduction

- Heterogeneity of Effects
  - within the group of treated (‘heterogeneous treatment effects’)
  - within the group of non-treated (‘neighborhood effects’,...)

- Summary
Heterogeneous Treatments (1)

- Why are heterogeneous treatment effects important?
  - Distributional issues
  - Political economy of farm programs
  - Evaluation of farm programs:
    - Random differences between individuals
    - Non-random differences between individuals
Heterogeneous Treatments (2)

- Evaluation of Programs

\[ \Delta_i \]

\[ \beta \]

\[ n^P_i \]

\[ n^*P_i \]

\[ N \]

'Average Treatment Effect' (AE) < 'Treatment Effect on Treated' (TT)
How to account for heterogeneous treatments?

- Matching estimators (Rubin, 1970s; Imbens & Wooldrige, 2009, JEL))
- But also: Random Coefficient Model, ...
- Empirical evidence for structural change in agriculture
  - Pufahl & Weiss (2009, ERAE)
  - ...

Empirical evidence for structural change in agriculture
Nonparametric regression of the conditional participation probabilities ($p(X)$) on the outcome variable (in log differences) for AE programs (Pufahl & Weiss, 2009, p. 92)

Effect of agri-environment programs for 9.138 program participants (= solid line) and 7.195 non-participants (= dotted line) in Germany 2001 – 2005.
Spatial Interaction (1)

- 'Stable Unit Treatment Value Assumption' (SUTVA), Rubin (1980, JASA)
- Different forms of interaction (Manski, 2000, JEP)
  - 'Constraint Interaction'
    - Markets
    - 'Spill-over effects' (Gutierrez & Gutierrez, 2003, ERAE)
    - Congestion
    - ...
  - 'Preference Interactions'
  - 'Expectation Interactions'
Spatial Interaction (2)

- 'Constraint Interactions' via markets
  - Perfectly competitive global markets
  - Imperfectly competitive local (land) markets
  - First Law of Geography: 'Everything is correlated with everything else, but close things are more correlated than things that are far away' (Tobler, 1970)
  - Imperfect competition (strategic interaction) in the land market (Ciaian and Swinnen, 2006, AJAE; Huettel and Margarian, 2009, AE)
  - Inherently spatial nature of agricultural production – spatial linkages ('neighborhood effects')
- Treatment effect on (some) non-treated: (spatial) heterogeneity – neighborhood effects

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- ‘Gibrat’s Law in Space’ – implications for policy evaluation and structural change
Spatial Interaction (4)

- Spatial Effects in Agricultural Economics (selection)
  - Agent-based simulation models (Ballman, 1997, ERAE; Happe et al., 2008, JEBO)
  - Land-use changes and the rural-urban interface (survey in Bell and Dalton, 2007, JAE)
  - Technology adoption (Abdulai & Huffman, 2005, AJAE)
  - Relationship between commodity prices (Florkowski and Sarmiento, 2005, Appl.E.)
  - Spatial effects on land prices (Breustedt and Habermann, 2009; Kirwan, 2009, JPE)
  - Spatial yield predictions (Anselin et al., 2004, AJAE)
Spatial Interaction (5)

- Land market is circle, points (plots) in clockwise direction are $z \in [0,1]$
- Land is homogeneous, output per plot depends of farm characteristics: $q_i(x_i)$
- Number $n$ and location $\eta$ of farms is exogenous
- Set of locations where farm $i$ produces $\vartheta(z,q)$
- Profits of farm $i$ at $\eta_i$:

$$\pi_i = \int_{z \in \vartheta(z,q)} [q_i(k_i) - r_i - t|\eta_i - z|]dz$$
Spatial Interaction (6)

- Observations on \( s_i = \frac{1}{t} [q_i(x_i) - W_i q(x)] + W_i D \)

- Spatial concentration of farm land
- Farm size is negatively related to distance-related costs
- Farm size is positively related to geographical isolation \((D)\)
- Farm size of \( i \) depends on characteristics (activities) of \( i \)
- Farm \( i \) exits if \( q_i(x_i) - W_i q(x) < 0 \);
  probability of exit depends on characteristics (activities) of \( i \)
  
  (Zimmermann et al., 2009, ES&P)
Spatial Interaction (7)

- Observations on \( s_i = \frac{1}{t} [q_i(x_i) - W_i q(x)] + W_i D \)

- Neighborhood effects (1): farm \( i \) exits if \( q_i(x_i) < q_j(x_j) - td_{i,j} \)
  i.e. probability of exit of farm \( i \) depends on characteristics (activities) of \( j \)

- Neighborhood effects (2): farm size of \( i \) depends on characteristics (activities) of \( j \)
  Manski (2009):
  - „reinforcing interaction“: \( \frac{\partial s_i}{\partial x_i} > 0, \frac{\partial s_i}{\partial x_j} > 0 \)
  - „opposing interaction“: \( \frac{\partial s_i}{\partial x_i} > 0, \frac{\partial s_i}{\partial x_j} < 0 \)
Spatial Interaction (8)

- Example of two neighbouring farms \((p \text{ and } r)\)
- Assume \(q_i(x_i) = \beta_i x_i\)

- Farm size: 
  \[ s_i = \alpha_i + \frac{1}{2} \alpha_j + \frac{3\beta_i}{4t} x_i - \frac{1}{2} s_j \quad \text{for } i \neq j \]

- Analogy to 'reaction functions' in IO (McCorriston, 2002, ERAE)
- 'Gibrat’s Law in Space' – Implications
Spatial Interaction (9)

Structural Change with No Interactions (‘SUTVA’)
Spatial Interaction (10)

Structural Change with "Opposing Interactions"

Evaluation (no interaction):
\( \text{TT}'\)-measure: \( s^1_p - s^0_p \)

Evaluation (with interaction):
\( \text{TT}'\)-measure: \( s^2_p - s^0_p \)
\( \text{AT}'\)-measure: \( s^2_p - s^0_p + s^1_R - s^0_R \)
\( \text{RT}'\)-measure: \( \sigma^2_p - \sigma^0_p \)
Different Forms of Interaction (Manski, 2000, JEP)

- Constrain Interaction
  - Markets
  - Spill-over effects (Gutierrez & Gutierrez, 2003, ERAE)
  - Congestion
  - ...

So far:
- Contrain Interaction via land market
  => opposing interaction

Add spill-over effect: $q_i = \beta_i x_i + \gamma_j x_j$ with $\beta_i > \gamma_j$
Spatial Interaction (12)

- Farm size:

\[ s_i = \alpha_i + \frac{\beta_j - 2\gamma_j}{2\beta_j} \alpha_j + \frac{4\beta_i \beta_j (2\gamma_j - \beta_j)(\beta_i - 2\gamma_i)}{4\beta_j t} x_i - \frac{\beta_j - 2\gamma_j}{2\beta_j} s_j \]

- „opposing interaction“ for: \( 0 < 2\gamma_j < \beta_j \)

- „reinforcing interaction“ for: \( 2\gamma_j > \beta_j \)
Spatial Interaction (13)

Structural Change with „Reinforcing Interactions“

Evaluation measures:

- TT'-measure: $s^2_P - s^0_P$
- AT'-measure: $s^2_P - s^0_P + s^1_R - s^0_R$
- RT'-measure: $\sigma^2_P - \sigma^0_P$
Spatial Interaction (14)

- Effects of policy on farm structure
  - “the effect of structural policies might have been overestimated in earlier studies without consideration of the strategic interaction among farms” (Huettel & Margarian, 2009, p. 768)

**Policy Measure:**
- Direct effect of program on size of those who participate (‘TT’)
- Effect of program on size of all farms (‘AT’)
- Effect of program on relative sizes of farms (‘RT’): convergence/divergence
Effects of Policy on Farm Structure

When ignoring 'opposing interactions':
- $TT'$-effect will be underestimated
- $AT'$-effect will be overestimated
- $RT'$-effect will be underestimated

When ignoring 'reinforcing interactions':
- $TT'$-effect will be underestimated
- $AT'$-effect will be underestimated
- $RT'$-effect will be overestimated

Empirical Evidence?
First (very preliminary) empirical results
Joint work with Andrea Pufahl (vTI) and Christian Beer (WU)
Farm size (area under cultivation, livestock)
All 931 farms for 2001 and 2005
Landkreis Soltau-Fallingborstel, Germany
Geo-codes for each farm
Distances (as the crow flies)
Different contiguity matrices
'BORDER'-effects!!
Spatial Interaction (17)
Binary contiguity matrix: Thiessen-Polygons (defines an area around each location such that all points in this area are closer to this location than to any other location. Application in Müller and Zeller (2002, AE)
### Spatial Interaction (19)

Dependent variable: $\ln(s_{2005})$. Binary contiguity matrix (Thiessen-Polygons)

<table>
<thead>
<tr>
<th>Estimated Model</th>
<th>OLS</th>
<th>SLM</th>
<th>SCRM</th>
<th>SDM</th>
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<tr>
<td><strong>Constant</strong></td>
<td>-0.04</td>
<td>3.70***</td>
<td>-0.01</td>
<td>-0.01</td>
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<tr>
<td></td>
<td>(-0.57)</td>
<td>(83.44)</td>
<td>(-0.12)</td>
<td>(-0.13)</td>
</tr>
<tr>
<td><strong>Log. Size in 2001</strong></td>
<td>0.99***</td>
<td>0.99***</td>
<td>0.98***</td>
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</tr>
<tr>
<td></td>
<td>(53.24)</td>
<td>(49.69)</td>
<td>(49.83)</td>
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</tr>
<tr>
<td><strong>Log. Neighbor’s Size in 2005</strong></td>
<td>-0.08***</td>
<td>-0.03***</td>
<td>0.21***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-2.74)</td>
<td>(-2.25)</td>
<td>(3.24)</td>
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</tr>
<tr>
<td><strong>Log. Neighbor’s Size in 2001</strong></td>
<td></td>
<td></td>
<td></td>
<td>-0.24***</td>
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<td></td>
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<td>(-3.91)</td>
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<tr>
<td><strong>Moran’s I</strong></td>
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<td>0.014**</td>
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<td><strong>Log-Likelihood</strong></td>
<td>-1194.70</td>
<td>-548.65</td>
<td>-546.79</td>
<td></td>
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Spatial Interaction (17)

- ‘Wonderland of no spatial dimensions’
  \[ y = X\beta + \varepsilon \]

- ‘Spatial cross-recursive model’
  \[ y = X\beta + WX\gamma + \varepsilon \]
  with \( y \) is \( n \times 1 \); \( W \) is \( n \times n \); \( X \) is \( n \times k \); \( \beta, \gamma \) are \( k \times 1 \); \( \varepsilon \) is \( n \times 1 \)
  neighbour structure expressed in spatial weights \( W \)
  OLS is unbiased estimator \( \tilde{\beta} = (X^T X)^{-1} X^T y \)

  Interpretation: \( \frac{\partial y}{\partial X} = \tilde{\beta} + W\tilde{\gamma} \)
Spatial Interaction (18)

- 'Spatial error model' (Anselin, 1988)

\[ y = X\beta + \varepsilon \]

with \( \varepsilon = \lambda W\varepsilon + u \)

neighbour structure expressed in spatial weights \( W \)

\[ y = X\beta + (I - \lambda W)^{-1} u \]

OLS is unbiased but inefficient

GLS estimator:

\[ \hat{\beta} = \left[ (X - \lambda WX)^T (X - \lambda WX) \right]^{-1} (X - \lambda WX)^T (y - \lambda Wy) \]

Interpretation:

\[ \frac{\partial y}{\partial X} = \hat{\beta} \]
Spatial Interaction (19)

- "Spatial lag model" (spatial reaction function, Anselin, 1988)
  
  \[ y = \rho Wy + X\beta + \varepsilon \]

  neighbour structure expressed in spatial weights \( W \)

  \[ y = (I - \rho W)^{-1} X\beta + (I - \rho W)^{-1} \varepsilon \]

  with \((I - \rho W)^{-1}\) is a 'spatial multiplier'\

  Note: \( y_i \) is 'linked' to all \( x_i \) and \( \varepsilon_i \) (not just \( x \) and \( \varepsilon \) at \( i \))!!

  OLS is biased and inefficient

  ML estimator: \( \hat{\beta} = (X^T X)^{-1} X^T (I - \rho W) y \)

  Interpretation:

  \[
  \frac{\partial y}{\partial X} = [(1 - \rho W)^{-1}]^T \hat{\beta}
  \]
Spatial Interaction (20)

- Specification of $W$ (particularly important for studies on micro level)
  - Binary contiguity matrix: $w_{ij} = \begin{cases} 1 & \text{if } i \text{ and } j \text{ are neighbours} \\ 0 & \text{else} \end{cases}$
  - Distance based matrix: $w_{ij} = \exp(-\alpha d_{ij})$
    where $d_{ij}$ is distance between $i$ and $j$.

- Specification tests
  - Moran’s I: $I = \varepsilon^T W \varepsilon [\varepsilon^T \varepsilon]^{-1}$
    where $\varepsilon$ are residuals from OLS estimation
Spatial Interaction (12)

- Structural change with „opposing interactions“

  - \( \frac{\partial s_i}{\partial x_i} = \frac{\beta_i}{t} \)
  - \( \frac{\partial S}{\partial x_i} = \frac{\partial s_i}{\partial x_i} + \frac{\partial s_j}{\partial x_i} = \frac{\beta_i}{2t} \)
  - \( \frac{\partial \sigma_i}{\partial x_i} = \frac{\partial (s_i/S)}{\partial x_i} = \frac{1}{S} \frac{\beta_i}{t} (1 - \frac{\sigma_i}{2}) \)

(stating from \( \sigma_i = \frac{1}{2} : \frac{\partial \sigma_i}{\partial x_i} = \frac{3}{4} \frac{1}{S} \frac{\beta_i}{t} > 0 \))
Spatial Interaction (16)

- Structural change with „reinforcing interactions“
  - ’TT‘-measure (unchanged): \( \frac{\partial s_i}{\partial x_i} = \frac{\beta_i}{t} \)
  - ’ATE‘-measure (increased): \( \frac{\partial S}{\partial x_i} = \frac{\beta_i}{2t} + \frac{\gamma_i}{t} \)
  - ’RTE‘-Measure (decreased): \( \frac{\partial \sigma_i}{\partial x_i} = \frac{1}{S} \left[ \frac{\beta_i}{t} \left( 1 + \frac{\sigma_i}{2} \right) - \sigma_i \frac{\gamma_i}{t} \right] \)

(starting from \( \sigma_i = \frac{1}{2} \))

\( \frac{\partial \sigma_i}{\partial x_i} = \frac{1}{S} \left( \frac{3 \beta_i}{4t} - \frac{1}{2} \frac{\gamma_i}{t} \right) > 0 \) for \( \beta_i > \gamma_i \)
Spatial Interaction (6)

$$q_i(x_i) - r_i - t|\eta_i - z|$$
Spatial Interaction (7)

- **Boundary plot** $z^*$:

  \[ q_i(x_i) - r_{i,i+1} - ts_{i,i+1} = q_i(x_{i+1}) - r_{i,i+1} - t(d_{i,i+1} - s_{i,i+1}) \]

- **Amount of land of farm** $i$:

  \[ s_{i,i+1} = \frac{1}{2t} \left[ q_i(x_i) - q_{i+1}(x_{i+1}) + td_{i,i+1} \right] \]

  \[ s_{i,i-1} = \frac{1}{2t} \left[ q_i(x_i) - q_{i-1}(x_{i-1}) + td_{i,i-1} \right] \]

- **Farm size** $s_i \equiv s_{i,i-1} + s_{i,i+1}$:

  \[ s_i = \frac{1}{t} \left[ q_i(x_i) - W_i q(x) \right] + W_i D \]