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Agricultural Policy and Structural Change: Analysing (Spatial) Heterogeneity

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114th Seminar of the EAAE, April 15 – 16, 2010, Berlin, Germany

Introduction (1)

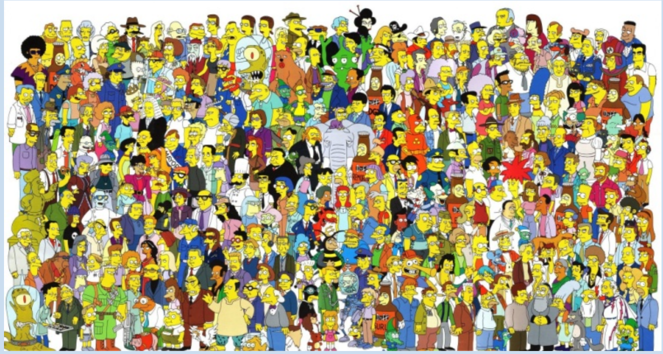
- Google.com

Term	Entries
„structural change“	1,880,000
„structural change in agriculture“	1,210,000
„structral change in agriculture“ & „journal“ & „economics“	122,000

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

Introduction (2)

- Impact of Policy on Structure: Heterogeneity!

Participate (‚treated‘)	Do not participate (‚non treated‘)
	

- 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: $p_i = p_i(\boldsymbol{x_i}, s_{i,t-1})$
  - Regression model: $s_{i,t} = \alpha + \lambda s_{i,t-1} + \beta p_{i,t}(\boldsymbol{x_{i,t}}, s_{i,t-1}) + \boldsymbol{x_{i,t}}\gamma + \varepsilon_{i,t}$
  - ‚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 (5)

- Introduction
- Heterogeneity of Effects
  - within the group of treated (‚heterogeneous treatment effects‛)
  - within the group of non-treated (‚neighborhood effects‛,…)
- Summary

Heterogeneous Treatments (1)

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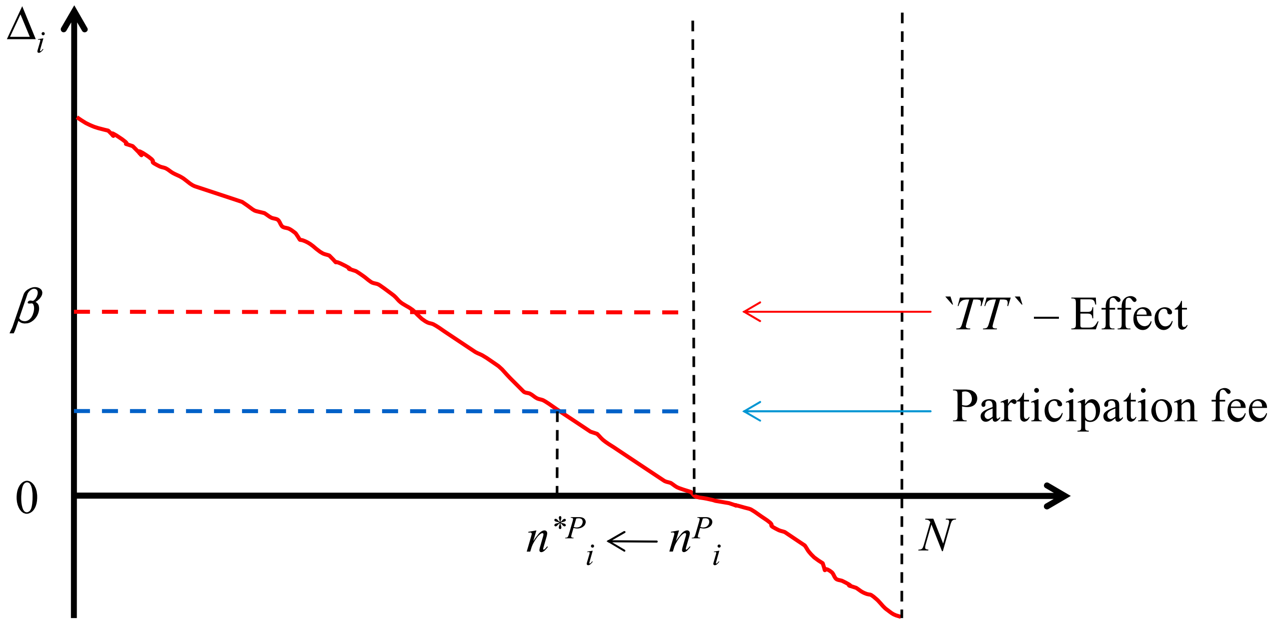
- Why are heterogeneous treatment effects important?
  - Distributional issues
  - Political economy of farm programs
  - Evaluation of farm programs:
    - Random differences between individuals
    - Non-random differences between individuals

Heterogeneous Treatments (2)

- Evaluation of Programs



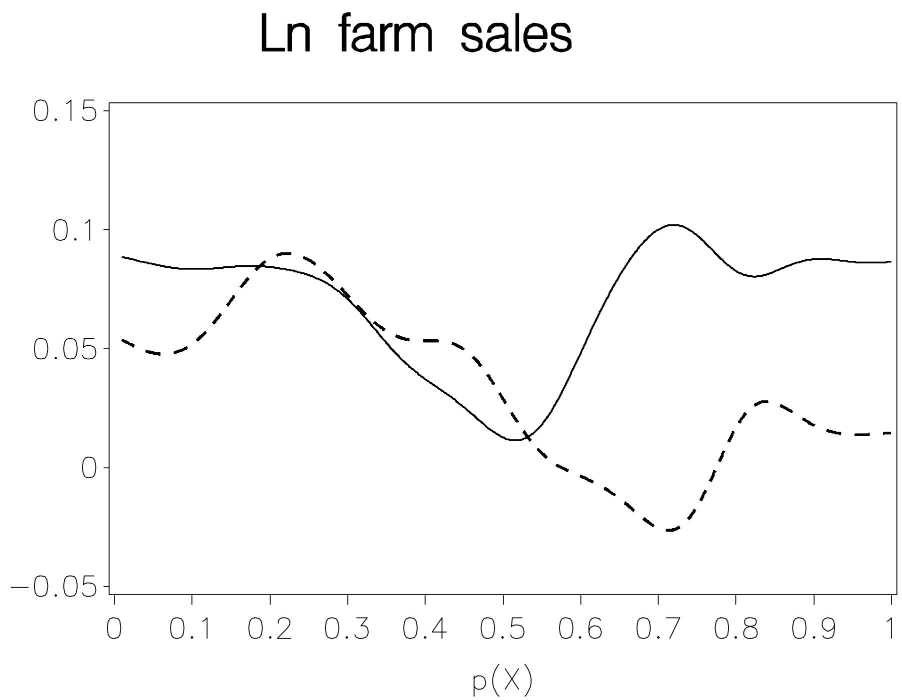
‚Average Treatment Effect‛ (AE) < ‚Treatment Effect on Treated‛ (TT)

Heterogeneous Treatments (3)

- 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)
    - …

Heterogeneous Treatments (4)

Nonparametric regression of the conditional participation probabilities ($p(\boldsymbol{X})$) 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)

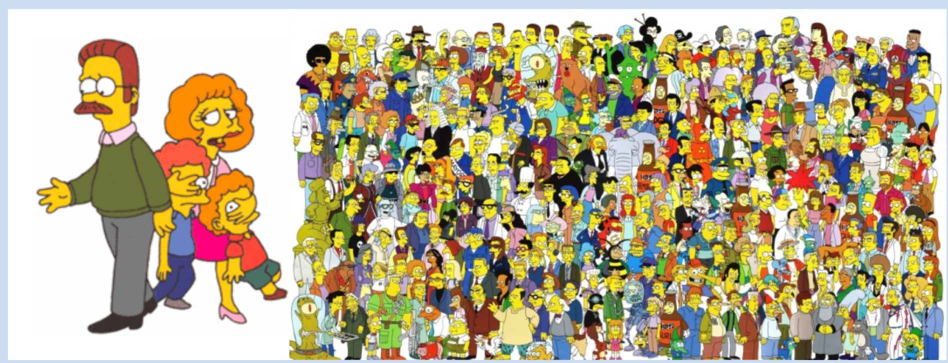
- ‚Stable Unit Treatment Value Assumption' (SUTVA), Rubin (1980, JASA)
- Different forms of interaction (Manski, 2000, JEP)
  - ‚Constraint Interaction'
    - Markets
    - ‚Spill-over effects' (Gutierrez & Gutierrez, 2003, ERAE)
    - Congestion
    - …
  - ‚Preference Interactions'
  - ‚Expectation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

Spatial Interaction (3)

- Treatment effect on (some) non-treated: (spatial) heterogeneity – neighborhood effects

Participate (‚treated‘)	Do not participate (‚non treated‘)
	

- ‘Gibrat’s Law in Space’ – implications for policy evaluation and structural change

Spatial Interaction (4)

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- 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: $q_i(\boldsymbol{x_i})$
- Number n and location η of farms is exogenous
- Set of locations where farm i produces $\vartheta(\boldsymbol{z},\boldsymbol{q})$
- Profits of farm i at η_i:

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

Spatial Interaction (6)

- Observations on $s_i = \frac{1}{t}[q_i(\boldsymbol{x_i}) - W_i\boldsymbol{q}(\boldsymbol{x})] + W_i\boldsymbol{D}$
  - Spatial concentration of farm land
  - Farm size is negatively related to distance-related costs
  - Farm size is positively related to geographical isolation ($\boldsymbol{D}$)
  - Farm size of i depends on characteristics (activities) of i
  - Farm i exits if $q_i(\boldsymbol{x_i}) - r_i < 0$; probability of exit depends on characteristics (activities) of i (Zimmermann et al., 2009, ES&P)

Spatial Interaction (7)

- Observations on $s_i = \frac{1}{t}[q_i(\boldsymbol{x_i}) - W_i \boldsymbol{q}(\boldsymbol{x})] + W_i \boldsymbol{D}$
  - Neighborhood effects (1): farm i exits if $q_i(\boldsymbol{x_i}) < q_j(\boldsymbol{x_j}) - td_{i,j}$
    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

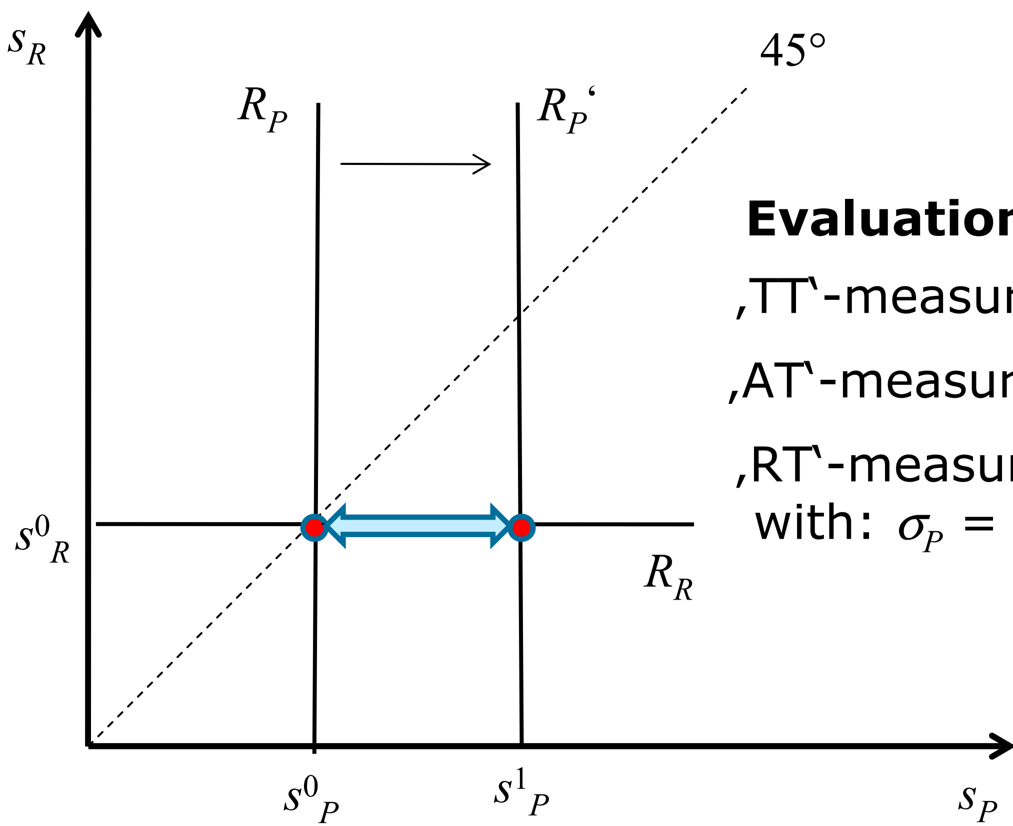
    Manski (2009):
    - „reinforcing interaction": $\frac{\partial s_i}{\partial x_i} > 0, \frac{\partial s_i}{\partial x_j} > 0$
    - „opposing interaction": $\frac{\partial s_i}{\partial x_i} > 0, \frac{\partial s_i}{\partial x_j} < 0$

Spatial Interaction (8)

- Example of two neighbouring farms (p and r)
- Assume $q_i(\boldsymbol{x_i}) = \beta_i x_i$
- Farm size: $s_i = \alpha_i + \frac{1}{2}\alpha_j + \frac{3\beta_i}{4t}x_i - \frac{1}{2}s_j$ 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‘)



Evaluation of policy:

‚TT‘-measure: $s^1_P - s^0_P$

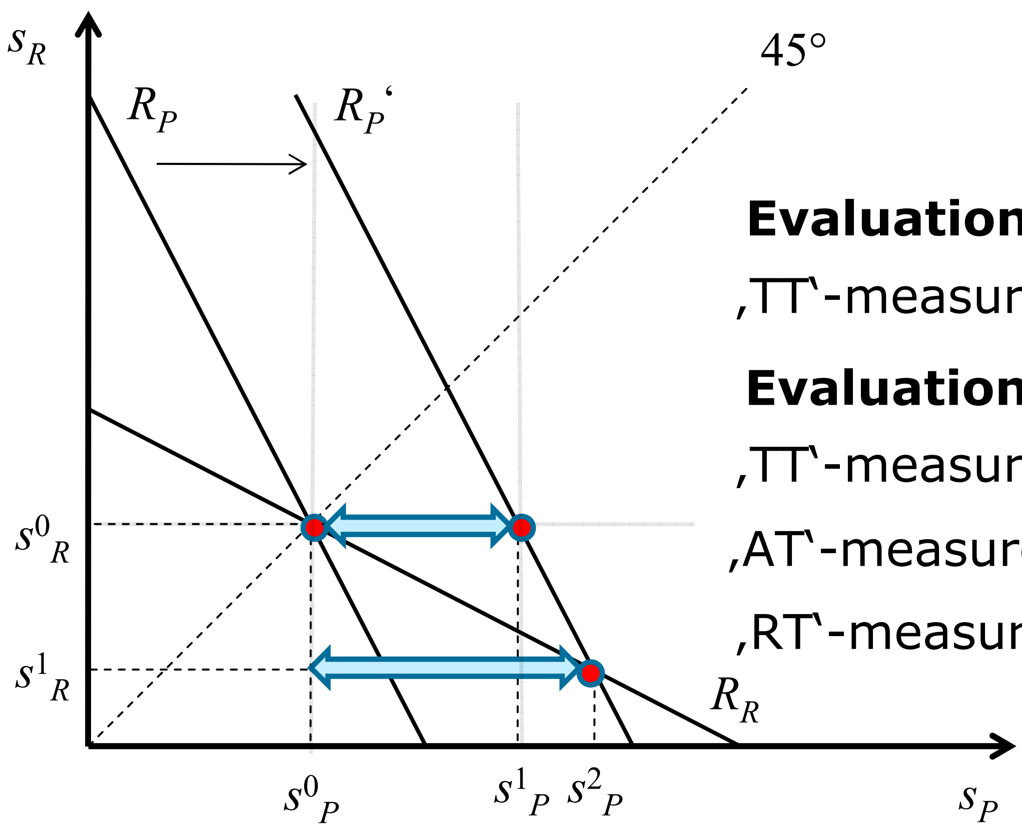
‚AT‘-measure: $s^1_P - s^0_P$ + 0

‚RT‘-measure: $\sigma^1_P - \sigma^0_P$

with: $\sigma_P = s_P/S$

Spatial Interaction (10)

Structural Change with **„Opposing Interactions“**



Evaluation (no interaction):

‚TT‘-measure: $s^1{}_P - s^0{}_P$

Evaluation (with interaction):

‚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 (11)

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- Different Forms of Interaction (Manski, 2000, JEP)
  - ‚Constrain Interaction'
    - Markets
    - ‚Spill-over effects' (Gutierrez & Gutierrez, 2003, ERAE)
    - Congestion
    - …

- So far:
  - ‚Contraint 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)

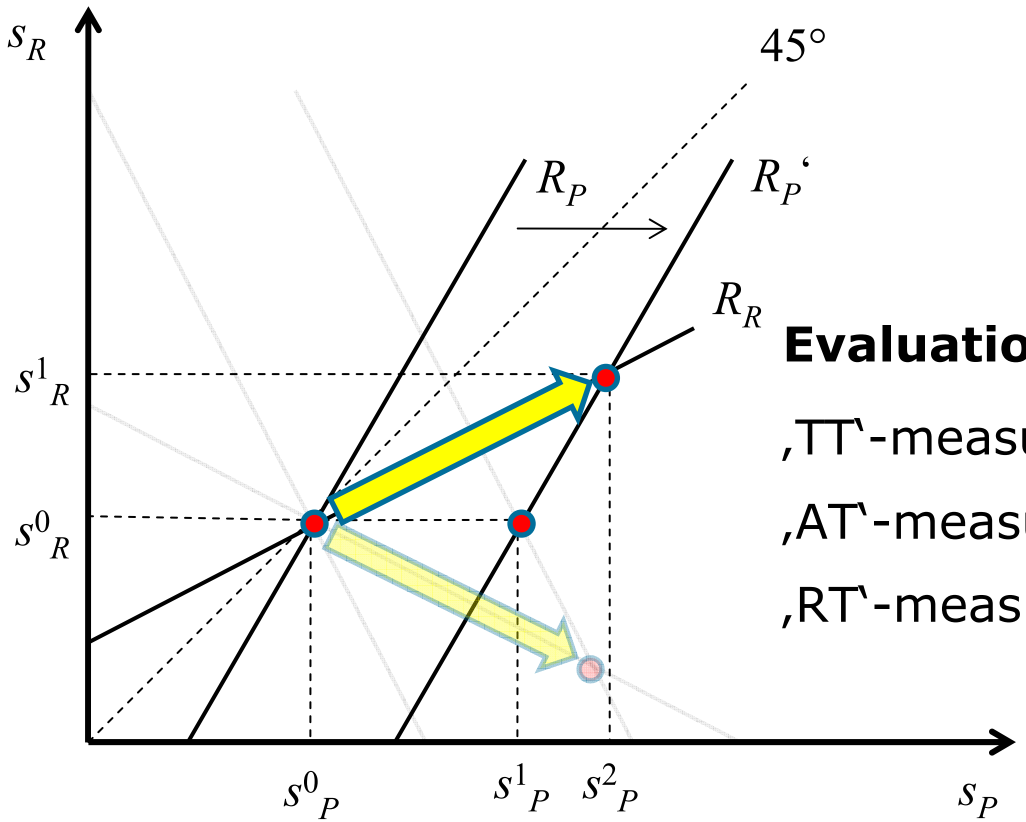
- Farm size:

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

  - „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

Spatial Interaction (15)

- Effects of Policy on Farm Structure

  - When ignoring ‚**opposing interactions**‵:
    - ‚TT‵-effect will be <u>under</u>estimated
    - ‚AT‵-effect will be <u>over</u>estimated
    - ‚RT‵-effect will be <u>under</u>estimated

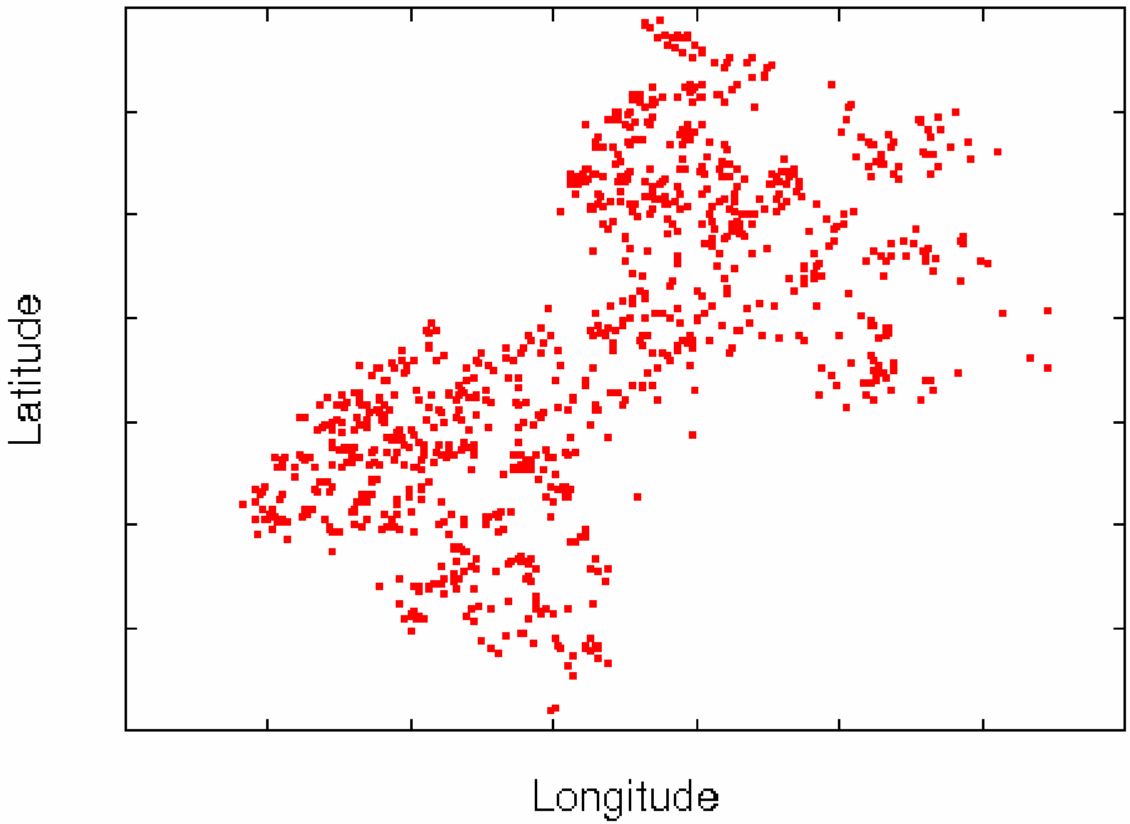
  - When ignoring ‚**reinforcing interactions**‵:
    - ‚TT‵-effect will be <u>under</u>estimated
    - ‚AT‵-effect will be <u>under</u>estimated
    - ‚RT‵-effect will be <u>over</u>estimated

- Empirical Evidence?

Spatial Interaction (16)

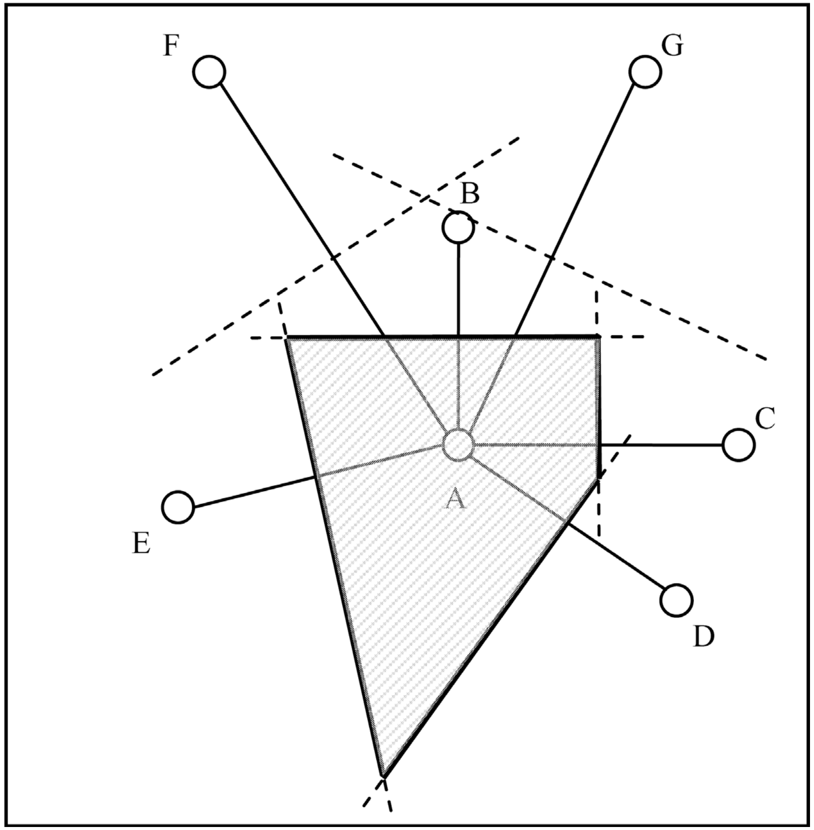
- First (very preliminary) empirical results
- Joint work with **Andrea Pufahl (vTI)** and **Christian Beer (WU)**
- Farm size (area under cultivation, livestock)
- <u>All</u> 931 farms for 2001 and 2005
- Landkreis Soltau-Fallingborstel, Germany
- Geo-codes for each farm
- Distances (as the crow flies)
- Different contiguity matrices
- ‚Border'-effects!!

Spatial Interaction (17)



Spatial Interaction (18)

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)

Estimated Model	OLS	SLM	SCRM	SDM
Constant	-0.04	3.70^{***}	-0.01	-0.01
	(-0.57)	(83.44)	(-0.12)	(-0.13)
Log. Size in 2001	0.99^{***}		0.99^{***}	0.98^{***}
	(53.24)		(49.69)	(49.83)
Log. Neighbor's Size in 2005		-0.08^{***}	-0.03^{***}	0.21^{***}
		(-2.74)	(-2.25)	(3.24)
Log. Neighbor's Size in 2001				-0.24^{***}
				(-3.91)
Moran's I				0.014^{**}
Log-Likelihood		-1194.70	-548.65	-546.79

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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:

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

  Interpretation:

  $$\frac{\partial y}{\partial X} = \tilde{\beta}$$

Spatial Interaction (19)

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- ‚Spatial lag model' (spatial reaction function, Anselin, 1988)

  $$y = \rho W y + X\beta + \varepsilon$$

  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 ε_i (not just x and ε at i)!!

  OLS is biased and inefficient

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

  Interpretation:

  $$\frac{\partial y}{\partial X} = [(1 - \rho W)^{-1}]^T \tilde{\beta}$$

Spatial Interaction (20)

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- 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 ε are residuals from OLS estimation

Spatial Interaction (12)

- Structural change with „opposing interactions"
  - ‚TT'-measure: $\dfrac{\partial s_i}{\partial x_i} = \dfrac{\beta_i}{t}$
  - ‚ATE'-measure: $\dfrac{\partial S}{\partial x_i} = \dfrac{\partial s_i}{\partial x_i} + \dfrac{\partial s_j}{\partial x_i} = \dfrac{\beta_i}{2t}$
  - ‚RTE'-Measure: $\dfrac{\partial \sigma_i}{\partial x_i} = \dfrac{\partial (s_i / S)}{\partial x_i} = \dfrac{1}{S}\dfrac{\beta_i}{t}(1 - \dfrac{\sigma_i}{2})$

  (starting from $\sigma_i = \dfrac{1}{2}$: $\dfrac{\partial \sigma_i}{\partial x_i} = \dfrac{3}{4}\dfrac{1}{S}\dfrac{\beta_i}{t} > 0$

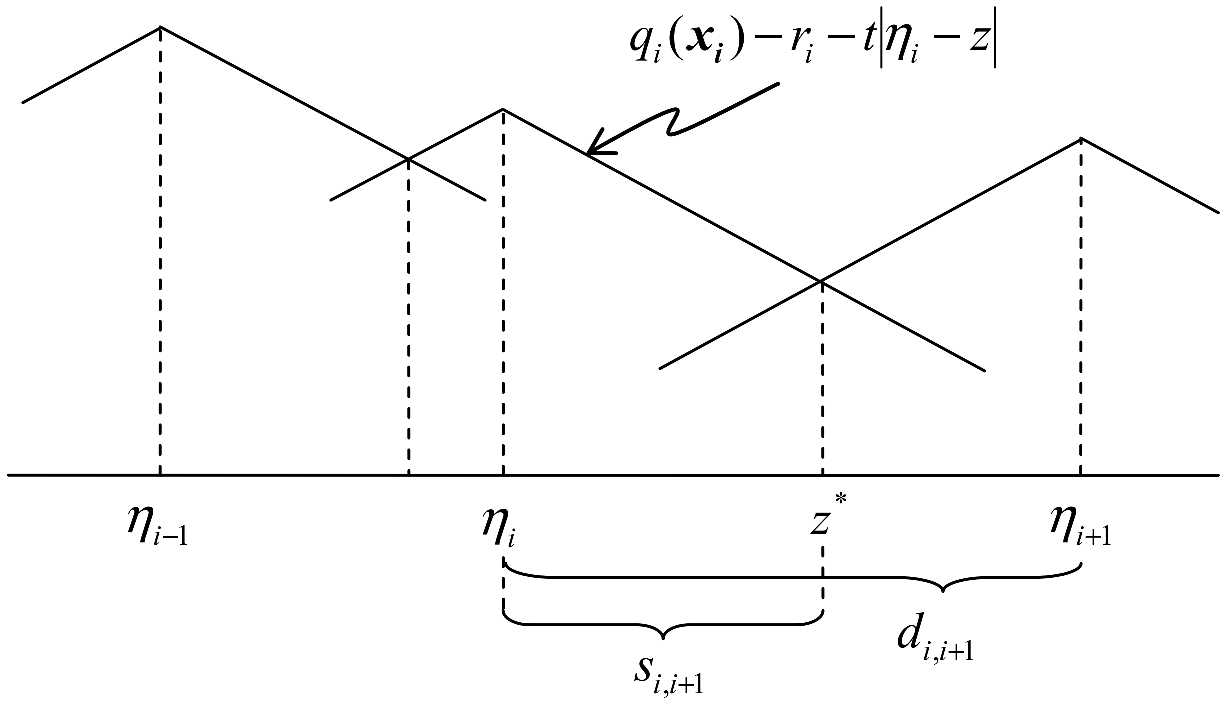
Spatial Interaction (16)

- 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): $\frac{\partial \sigma_i}{\partial x_i} = \frac{1}{S}[\frac{\beta_i}{t}(1+\frac{\sigma_i}{2}) - \sigma_i \frac{\gamma_i}{t}]$

  (starting from $\sigma_i = \frac{1}{2}$: $\frac{\partial \sigma_i}{\partial x_i} = \frac{1}{S}(\frac{3}{4}\frac{\beta_i}{t} - \frac{1}{2}\frac{\gamma_i}{t}) > 0 \quad for \quad \beta_i > \gamma_i$

Spatial Interaction (6)



Spatial Interaction (7)

- Boundary plot z^*:

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

- Amount of land of farm i:

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

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

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

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