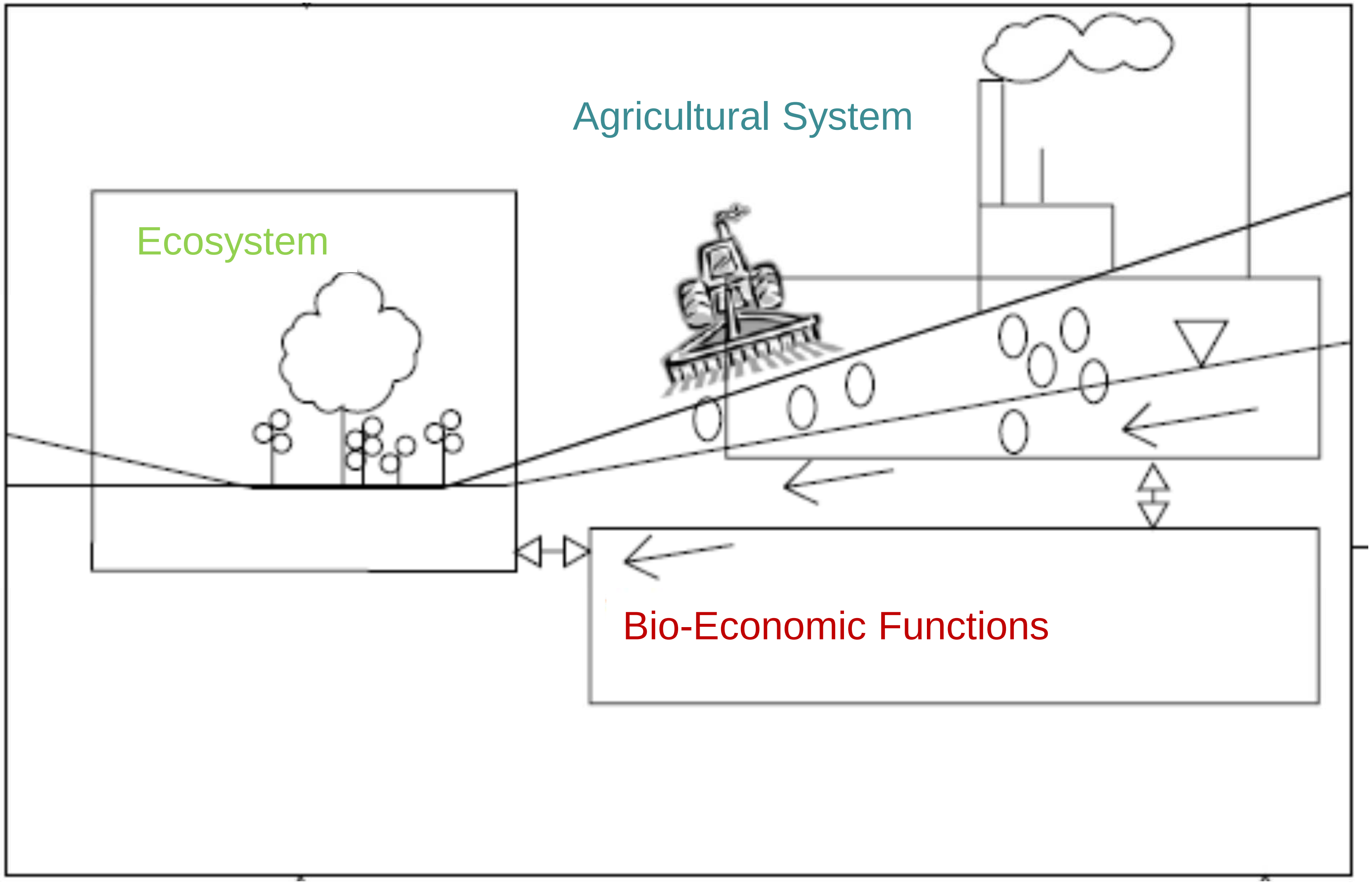
Ökonomische Modellierung von Agrarumweltverhalten auf Betriebsebene

Johannes Sauer

Professor and Chair
Agricultural Production and Resource Economics

Center of Life and Food Sciences
Technical University Munich



Agricultural System
Ecosystem
Bio-Economic Functions

relevance

- growing literature on the societal relevance and valuation of ecosystem services
- understanding and modelling the underlying processes leading to service provision is essential for predicting and managing change in ecosystem services (e.g. Nicholson et al. 2009)

→ study I - modelling of agri-env linkages at farm level

- considerable policy interest in the performance of agri-environmental measures
- an increasing debate among academics and policy makers as to whether schemes as currently implemented actually deliver the expected outcomes (e.g. Ferraro/Pattanayak 2006, Butler et al. 2009, Hodge/Reader 2010, Sauer/Walsh 2010)

→ study II - identification/measurement of policy effects

I. Marketed Outputs and Non-Marketed Ecosystem Services

(with A. Wossink)

II. Technology, Treatment and Change?

(with J. Walsh and D. Zilberman)

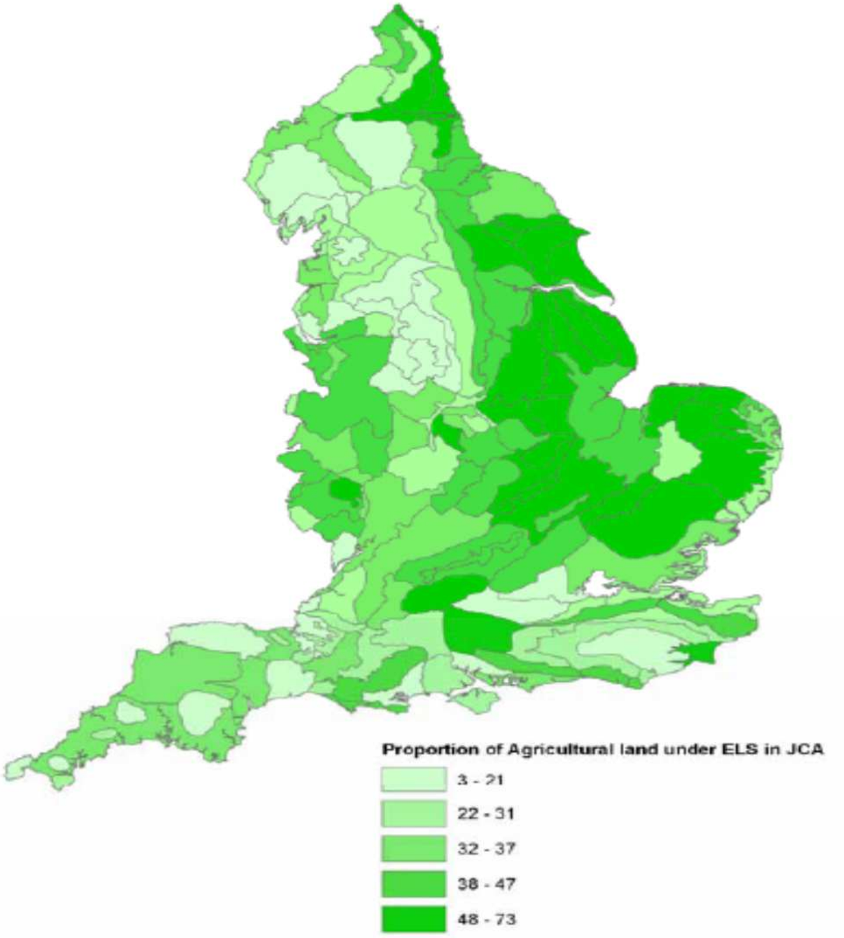
Marketed Outputs and Non-Marketed Ecosystem Services

? how to determine the cost of marginal ecosystem changes and the effectiveness of green payments based on an empirical analysis of the bio-economic production relationships at the micro (farm) level ?

- supply curves should be estimated at a low level of aggregation accounting for biophysical and socio-economic variability
- linkages between marketed output and non-marketed ES, assessment of direct and opportunity costs at the margin
- empirical analysis based on a sound theoretical (microeconomic) framework

approach

- new theoretical approach based on generalized joint production model which allows complementary, substitutive and competitive relationships
- we implement this theoretical framework empirically as a transformation function
- we include farm/farmer specific impacts and use panel data analysis
- we apply our approach to U.K. data on the Environmental Stewardship Scheme (ESS) and the Hill Farm Allowance (HFA)



Geographical Variation in ELS Uptake

ESS - a voluntary-type agreement based ag env scheme

- producers agree to modify their production activities to benefit the environment and are compensated for the costs they so incur
- most modifications imply a reduction in the intensity of production and the loss is usually conceived as income foregone

HIGHER LEVEL STEWARDSHIP OPTIONS MAP

Options	Assigned colour		Applicants colour match
HB		Maintenance of hedgerows of very high environmental value	
HC/OHC		Management of woodland edges	
HC/OHC	6 *	Protection of trees *Number within circle represents number of trees in parcel	6
HC		Options for woodland	
HD/OHD		Maintenance of traditional farm buildings	
HD/OHD		Options for historic and landscape features	
HE/OHE		Options for buffer strips and grass margins	
HF/OHF		Options for arable land	
HG/OHG		Options to encourage a range of crop type	
HJ/OHJ		Options to protect soil and water	
HK/OHK		Options for grassland (HK/OHK 1-4 outside the LFA Severely Disadvantaged Area only. HK/OHK5 inside and outside the SDA)	
HL/OHL		Options for the uplands	
HN	- - - -	Linear Access options	

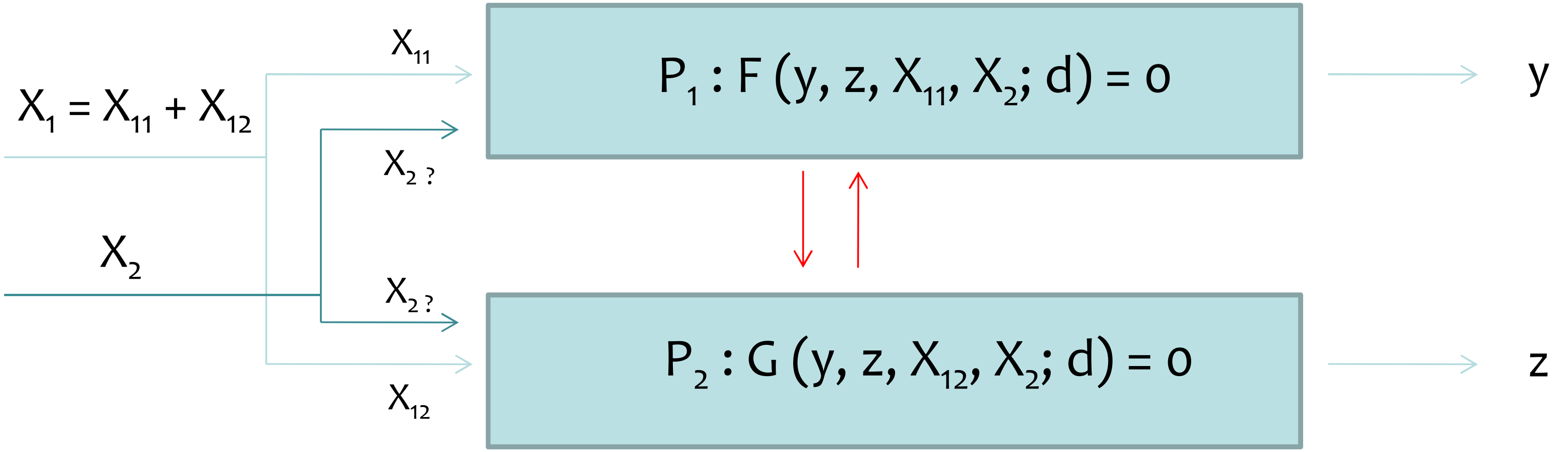
HN		Permissive open access	
HO		Lowland heathland options	
HP		Inter-tidal and coastal options	
HQ		Wetland options	
	OU	Organic Unit (all land under organic management whether fully organic or in conversion)	

Organic options can only be located on field parcels that are registered as organic

	PC GF 4	Capital item
	1234	RLR field number
		Holding parcels (buff coloured parcels are to be marked up on this map. Any grey parcels are covered on other maps)

You must write the specific option codes you have selected in black on the map, e.g. HD2, OHF4, HK12, HP3

modelling



- joint production of multiple outputs described by separate production functions
- change in the supply of marketed output y simultaneously affects the supply of non-marketed ecosystem service z (vice versa)
- inputs X contribute to both outputs
- allows for allocable and nonallocable (joint) inputs and the possibility of varying the proportion of agricultural output and ecosystem service (scale & scope)

→ as a dual problem: $\text{Min}_x \{C = pX - c\}$

s.t. $F(X, z; d) \geq y$ and $G(X; d) \geq z'$

→ z' - constraint on z to establish marginal cost of trade-off y ↔ z

→ envelope theorem and f.o.c. :

$$-p + \lambda_1 F_X + \lambda_2 G_X = 0 \quad \text{or} \quad \frac{\partial C^*}{\partial \overline{Z}} = \lambda_2^* = \frac{p - \lambda_1^* F_{X*}}{G_{X*}}$$

$$F_X = \frac{dF}{dX} = \frac{\partial F}{\partial X} + \frac{\partial F}{\partial Z}\frac{\partial Z}{\partial X}$$

→ λ_1 and λ_2 as Lagrange multiplier for technology and ecosystem service constraints; λ_2 as the shadow price for Z

- individual cereal farm data for 2000-09 based on UK FBS collected and released by Defra, a total sample size of >4,000 obs

- transformation function

$Y_{AO} = F(Z, Y_{NAO}, X, D) =$

$$a_0 + 2a_{0ESS} Z_{ESS,it}^{0.5} + 2a_{0HFA} Z_{HFA,it}^{0.5} + 2a_{0NAO} Y_{NAO,it}^{0.5} + \sum_k 2a_{0k} X_{k,it}^{0.5} + a_{ESSESS} Z_{ESS,it} + a_{HFAHFA} Z_{HFA,it} + a_{NAONAO} Y_{NAO,it} + a_{kk} X_{k,it} + \sum_k \sum_m a_{km} X_{k,it}^{0.5} X_{m,it}^{0.5} + \sum_k a_{kESS} X_{k,it}^{0.5} Z_{ESS,it}^{0.5} + \sum_k a_{kHFA} X_{k,it}^{0.5} Z_{HFA,it}^{0.5} + \sum_k a_{kNAO} X_{k,it}^{0.5} Y_{NAO,it}^{0.5} + b_T t_{it} + b_{TT} t_{it} t_{it} + \sum_k b_{kt} X_{k,it}^{0.5} t_{it} + b_{ESST} Z_{ESS,it}^{0.5} t_{it} + b_{HFAT} Z_{HFA,it}^{0.5} t_{it} + b_{NAOT} Y_{NAO,it}^{0.5} t_{it} + u_{it} \quad with \quad u_{it} = \varphi_i + e_{it}$$

estimated direct and indirect effects – descriptive stats

Effect	*Mean*	*Std. Dev.*	*Min*	*Max*
dYAO/dX	173.978	259.197	-440.066	1591.110
dYAO/dZESS	.372	2.887	-8.233	12.288
dYAO/dZHFA	-2.529	6.310	-39.071	23.947
(dYAO/dZESS)(dZESS/dX)	0.065	0.032	0.006	0.192
(dYAO/dZHFA)(dZHFA/dX)	0.071	0.058	0.007	0.438
(dYAO/dZESS)(dZESS/dZHFA)	-6.61e-04	5.61e-04	-0.004	-7.01e-05
(dYAO/dYNAO)(dYNAO/dZHFA)	9.03e-05	7.74E-05	1.21e-05	5.83e-04
(dYAO/dYNAO)(dYNAO/dZESS)	-5.03e-05	3.09E-05	-2.24e-04	5.24e-06
(dYAO/dYNAO)(dYNAO/dX)	-0.008	0.005	-0.043	-7.11e-04

product / product relationships – number of observations per case

Relation	Agri Out ESS	Agri Out HFA	HFA ESS	ESS HFA
Direct Effect	dYAO/dX	dYAO/dX	dYAO/dZHFA	dYAO/dZESS
Indirect Effect	(dYAO/dZESS)* (dESS/dX)	(dYAO/dZHFA)* (dZHFA/dX)	(dYAO/dZESS)* (dZESS/dZHFA)	(dYAO/dZHFA)* (dZHFA/dZESS)
Case I	**314**	**314**	0	0
Case II	0	0	121	**202**
Case III	79	79	**272**	191
Total Obs.	393	393	**393**	393

how to efficiently reorganise production ?

$Y - Y_{-1}$ relationship	Case 1 – complementary	Case 2 – substitutive	Case 3 – competitive
AO - ESS	+ agricultural output + environm output (314 farms)		(79)
AO - HFA	+ agricultural output + environm output (314)		(79)
HFA - ESS		(121)	+ environm output 2 (272)
ESS - HFA		+ environm output 1 or + environm output 2 (202)	(191)
HFA - NAO	(121)		+ non-agricultural output (272)
ESS - NAO		+ environm output 1 or + non-agricultural output (202)	(191)
AO - NAO		+ agricultural output oder + non-agricultural output (314)	(79)

- the majority of farms produce agricultural output and ecosystem services in a complementary relationship (i.e. $\lambda^*_2 = 0$)
- generation of multiple ecosystem services on the same farm showed either a substitutive or competitive relationship
- changing the composition of the ecosystem services output (HFA, ESS) would have very different implications for individual farms

current work…

… look at spatial patterns

… investigate significant characteristics of the farms being part of the estimated classes I-III

… other modelling approaches (dynamic panel data approach, mixed-effects logistic approach)

Technology, Treatment and Change?

we deliver empirical evidence on the impact of different agri-environment related regulatory instruments on farmers' production behaviour

by measures of

… input intensities

… farm performance

… and output and input substitution relations

treatment evaluation is mostly about adequate identification →
minimizing selection bias

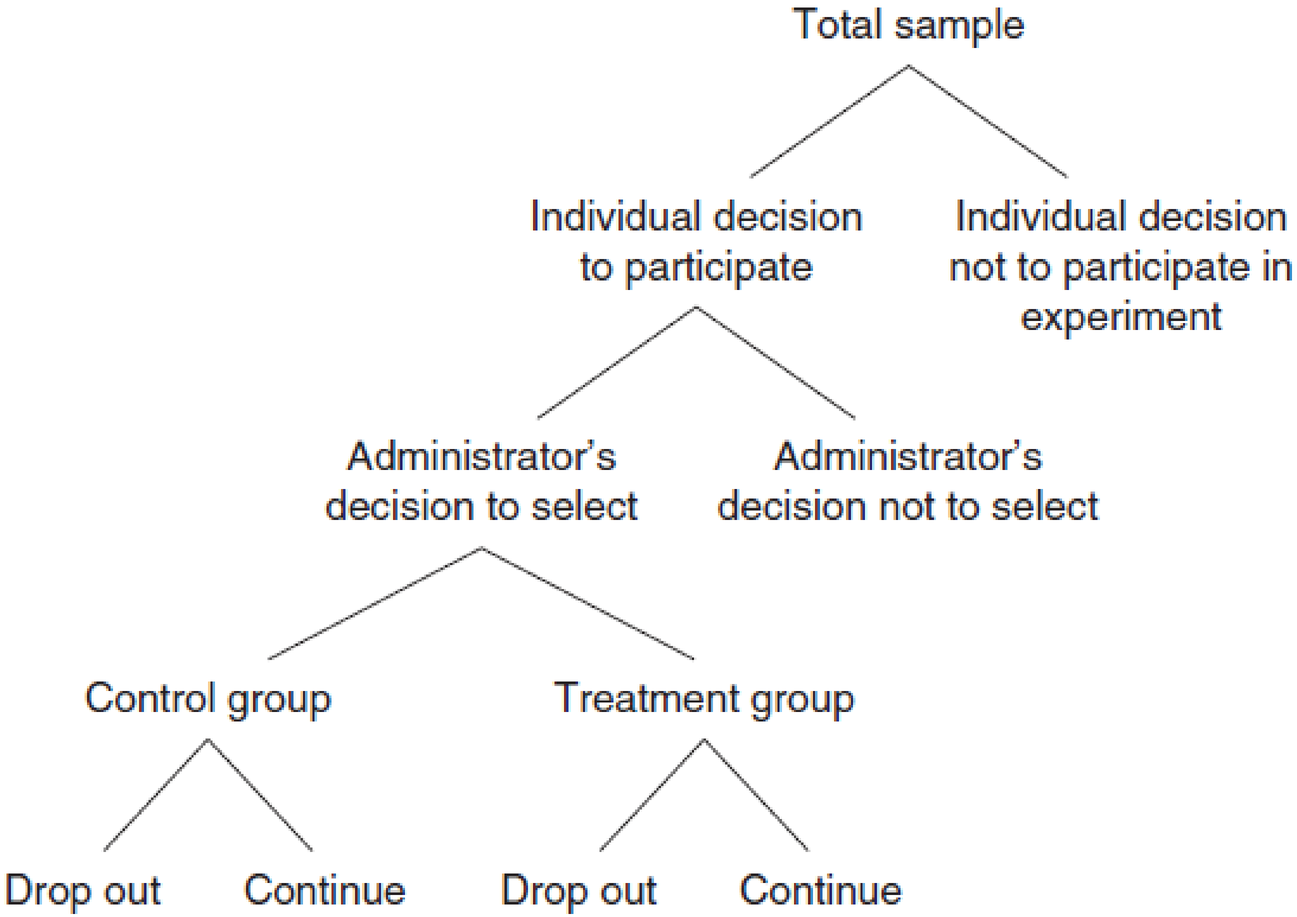
bias ?

… bias caused by choosing non-random data for statistical analysis

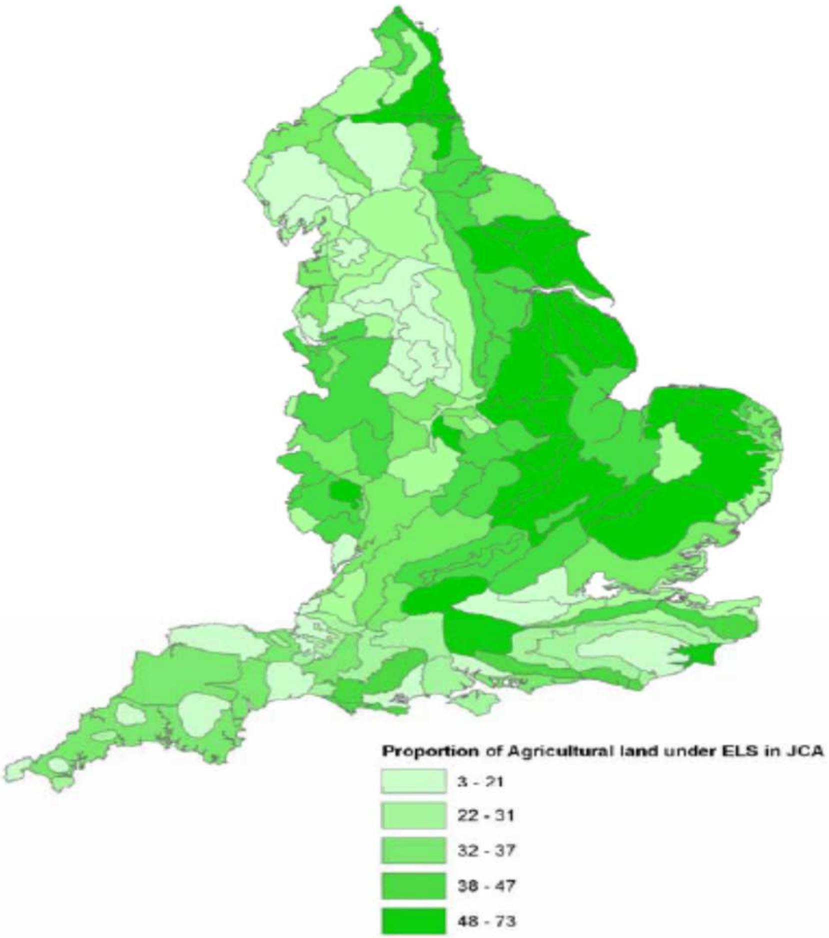
… bias due to a flaw in the sample selection process, where a subset of the data is systematically excluded due to a particular attribute

… exclusion of the subset can influence the statistical significance of the test, or produce distorted results

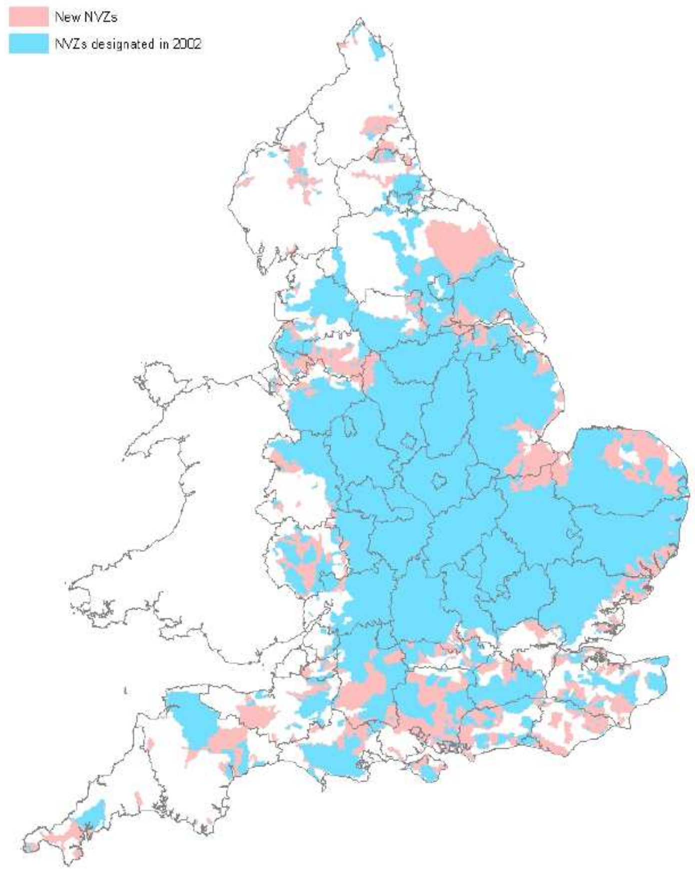
⇨ self-selection bias versus selection bias by analysts


Total sample
Individual decision to participate
Individual decision not to participate in experiment
Administrator's decision to select
Administrator's decision not to select
Control group
Treatment group
Drop out
Continue
Drop out
Continue

Geographical Variation in ELS Uptake



Nitrate Vulnerable Zones (NVZ)



Combinations of Agri-Environmental Scheme Enrollments

		NVZ Scheme (non-voluntary, introduced 1999)	
		1	0
ESS Scheme (voluntary, introduced 2005)	1	A [1,1]	B [1,0]
	0	C [0,1]	D [0,0]

two-stage estimation strategy to address problems of latent heterogeneity and potential endogeneity (Imbens/Wooldridge 2009)

general set-up

1) input intensity indicators
2) partial performance measures and the individual farms' efficiencies
3) estimating the average change in these measures due to AE scheme

1 - estimation of technology

parameterize the dtdf via a flexible transcendental-exponential functional form which we linearize (Blackorby et al. 1978, Faere et al 2010)

$$exp[\vec{D}_T(x, y; g_x, g_y, \theta)] = \sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_{ij}\, exp\left(\frac{x_i}{2}\right) exp\left(\frac{x_j}{2}\right) + \sum_{k=1}^{M}\sum_{l=1}^{M} \beta_{kl}\, exp\left(-\frac{y_k}{2}\right) exp\left(-\frac{y_l}{2}\right) + \sum_{i=1}^{N}\sum_{k=1}^{M} \gamma_{ik}\, exp\left(\frac{x_i}{2}\right) exp\left(-\frac{y_k}{2}\right) + \varepsilon$$

2 - *estimation of treatment*

- use of matching estimators based on counterfactual framework

  (Guo/Fraser 2010, Abadie/Imbens 2006)

- matching estimators impute missing data under the treatment or non-treatment condition based on vector norm

→ to obtain point estimates for various treatment effects, e.g.
sample average treatment effect (SATE):

$$\hat{\tau}^{average} = \frac{1}{N}\sum_{i=1}^{N}\{\hat{Y}_i(1) - \hat{Y}_i(0)\} = \frac{1}{N}\sum_{i=1}^{N}(2W_i - 1)\{1 + K_M(i)\}Y_i$$

$K_M(i)$ as the number of times i is used as a match with M matches per unit i
W_i as the treatment condition for unit i : ESS, NVZ, or both
covariates X_i : crop output, uaa, awu, dep, lu, *fert, chem, var cost*, assets, *ae out (-ESS out), nvz, ess*, county, alt, lfa, age, edu, gender, organic, year
bias-corrected & heteroscedasticity related 2nd matching procedure

→ both schemes are effective in influencing production behaviour at individual cereal farm level

measure *treatment effect at sample mean in mean expenditure per ha (GBP/ha)*	fertilizer per ha mean [min, max]	chemicals per ha mean [min, max]	variable cost per ha mean [min, max]
ESS Scheme	-57.914*** [-90.094; -25.733]	-72.683*** [-112.694; -32.673]	-345.589*** [-549.071; -142.107]
NVZ Scheme	-58.101*** [-96.776; -19.425]	-71.244*** [-118.993; -23.495]	-419.061*** [-654.497; -183.624]
ESS and NVZ Schemes	-58.777*** [-91.424; -26.131]	-74.561*** [-118.989; -38.133]	-541.569*** [-803.236; -279.902]
observed expenditure per ha (GBP/ha)	*122.877* *[0; 1,438.18]*	*145.099* *[0; 1,516.37]*	*861.151* *[1.081; 11,410.0]*

→ both agri-environmental schemes lead to significant effects on productivity

→ labor input now more efficiently used, complementary type services (e.g. buffer strip maintenance)

measure	*performance measure at sample mean*	ESS Scheme *treatment effect at sample mean*	NVZ Scheme *treatment effect at sample mean*	ESS and NVZ Schemes *treatment effect at sample mean*
land productivity (output in GBP per land in ha)	1253.934 [15.313; 720941.6]	-392.043*** [-657.547; -126.540]	-538.297*** [-848.586; -228.008]	-498.223*** [-34.806; -261.64]
labor productivity (output in GBP per labor in awu)	110682.4 [631.764; 1.02e+07]	30255.73*** [8991.682; 51519.78]	38130.55*** [13548.16; 62712.94]	103304.4*** [55219.94; 151388.9]
capital productivity (output in GBP per total assets in GBP)	0.236 [0.007; 2.712]	-0.039** [-0.073; -0.006]	-0.024*** [-0.039; -0.007]	-0.071*** [-0.122; -0.019]

→ treatment effects for technical and allocative efficiency are rather small

measure	*performance measure at sample mean*	ESS Scheme *treatment effect at sample mean*	NVZ Scheme *treatment effect at sample mean*	ESS and NVZ Schemes *treatment effect at sample mean*
technical efficiency (in %)	94.71*** [81.17; 99.49]	0.012*** [0.011; 0.013]	0.001** [-1.115e-04; 0.002]	0.004*** [0.002; 0.006]
allocative efficiency (in %)	59.05*** [0.08; 0.65]	8.82e-04 [-0.001; 0.003]	-4.85e-04 [0.002; 9.91e-04]	-0.009*** [-0.013; -0.004]

→ farms enrolled in agri-environmental schemes are efficiently adjusting their production decisions given the requirements under the scheme

- both schemes are effectively influencing production behaviour at individual farm level
- a voluntary type agri-environmental scheme seems not to have a signficantly higher influence on producer behaviour compared to a non-voluntary scheme
- the joint effect of both agri-environmental schemes on structural production decisions at individual farm level is mixed

current work…

... similar analysis for other farm types

… alternative estimator (difference-in-difference)

… different schemes / countries depending on data

MANY THANKS !