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Evaluating the Effects of Farm Programs: Results from Propensity Score Matching*

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Abstract — *The paper applies a non-parametric propensity score matching approach to evaluate the effects of two types of farm programs (agri-environment (AE) programs and the less favoured area (LFA) scheme) on input use and farm output of individual farms in Germany. The analysis reveals a positive and significant treatment effect of the LFA scheme for farm sales and the area under cultivation. Participants in AE schemes are found to significantly increase the area under cultivation (in particular grassland), resulting in a decrease of livestock densities. Furthermore, participation in AE programs significantly reduced the purchase of farm chemicals (fertilizer, pesticide). We also find substantial differences in the treatment effect between individual farms (heterogeneous treatment effects). Farms which can generate the largest benefit from the program are most likely to participate.*

Keywords: evaluation, farm programs, propensity score matching
JEL-Classification: O12; O18; C21

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1. Introduction

The impact of government programs on agricultural output and farm structure is a key policy issues in the ongoing international trade negotiations on agriculture. Fostered by the fact that more and more data become available on a micro (individual farm) level, recent years have seen a substantial growth in the number of empirical studies on the consequences of farm policies for individual farms (Salhofer und Streicher, 2005; Shaik und Helmers, 2006), as well as for different regions (Ahearn, Yee und Korb, 2005; Goetz und Debertin, 2001; Kim et al., 2005). This literature mainly focuses on the consequences of policy measures for farm exit rates, farm output and growth as well as adjustments in on-farm and off-farm labour markets. Despite the fact that these topics now rank high on the agenda of economists and policy makers, Ahearn, Yee, and Korb (2005, p. 1182) conclude that 'our understanding of how government policies have affected the structure of agriculture, or how future policies could be designed to promote specific outcomes remains limited.'

In practice, policy interventions turn out to be difficult to evaluate. For one thing, government programs frequently have different (sometimes even conflicting) objectives which are difficult to conceptualize, and each program often uses a large set of diverse instruments to accommodate these goals: programs might stimulate demand for agricultural output (export subsidies), regulate output prices directly (price support programs) or influence production processes (environmental programs or land retirement programs). Again other programs aim at maintaining the number of family farms in a particular region by providing direct income transfers.

Even when researchers aim at evaluating one specific program and/or focus on one specific instrument only, the evaluation of its consequences is difficult since policy measures not only impact individual farmers directly but also can trigger indirect effects through a variety of mechanisms. Key and Roberts (2006), for example, argue that farms receiving relatively high direct payments may be able to bid up the price of land and other fixed resources. Direct transfers to individual farms thus will have indirect effects on other farms via the adjustment of input prices. In addition, the authors sketch possible indirect effects of governmental payments on farm businesses through capital market mechanisms

if farmers' are liquidity is constrained. Given the very complex effects and interactions, economic theory often provides only limited guidance with respect to the 'correct' specification of an econometric model (where all relevant variables are included and the functional form is adequate).[1]

The dominance of family businesses is another important characteristic of the farm sector, which complicates the theoretical and empirical analysis of the impact of farm programs. The unique relationship between the farm household and the farm business implies that decisions relating to production, consumption, as well as labour supply and leisure for all family members must be made simultaneously. The optimal response to a particular governmental program will thus not only depend on the characteristics of the individual farm but also on the size and structure of the farm family. We should not expect to find the response to farm programs to be homogenous across individual farms.

Finally, participation in farm programs typically is voluntary. An individual farmer will participate only if the additional benefits exceed the costs of participation. Costs and benefits will differ between individuals depending on specific characteristics of the farm as well as the farm family, some of which, however, may not fully be observed (unobserved heterogeneity). The existence of systematic differences between program participants and non-participants requires separation of the 'true' effect of program participation ('causal effect') from the effect of initial differences in characteristics of the two groups ('selection effect')[2]. To distinguish between the two effects, an evaluator has to answer the following question: 'How much did farms participating in the program benefit compared to what they would have experienced without participating in the program?' The fact that this counterfactual situation can not be observed constitutes the 'classical evaluation problem'.

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[1] In an early attempt to rigorously evaluate the impact of farm programs in a theoretical model, Leathers (1992) concludes: 'The impact of alternative agricultural programs on the structure of agriculture depends on certain conditions which cannot be predicted by theory alone' (p. 298).

[2] This problem is highlighted in Salhofer and Streicher (2005) in the case of participation in agri-environmental programs in Austria: '... critics might argue that there is a large self-selection bias, i.e. only those farmers participate in extensification programmes which are not producing very intensively anyway' (p. 9). Windfall profits (due to selection effect) reduce the efficiency of policy measures and lead to an overestimation of the 'true' effects of a particular policy.

The present paper applies a non-parametric propensity score matching approach to evaluate the effects of two types of farm programs (agri-evironmental programs and the less favoured area scheme) for individual farms in Germany. The matching approach is widely used when evaluating labour market policies (see e.g. Heckman; LaLonde und Smith, 1999). According to our knowledge, Lynch et al. (2007) is the only application evaluating agricultural policy measures. The key advantage of matching (over standard regression methods) is that it is less demanding with respect to the modelling assumptions. Specifically, matching does not require functional form assumptions for the outcome equation (it is non-parametric).[3] Further, with matching, there is no need for the assumption of constant additive treatment effects across individuals. Instead, the individual causal effects are unrestricted and individual effect heterogeneity in the population is permitted. By applying a matching estimator, we thus hope to mitigate some of the difficulties of evaluating the consequences of farm policies mentioned above. Note, however, that the aim of this analysis is not to evaluate the effectiveness of a policy in terms of the degree to which a particular (often vaguely defined) policy objective has been realized. Instead, we follow previous studies and aim at assessing the effects of policy measures with respect to input use (land, labour, farm chemicals) and farm output (sales).

The following Section 2 briefly describes the policy measures to be evaluated. The estimation method and the data used are outlined in Section 3. Section 4 presents the empirical results along with a number of extensions and robustness checks considering statistical methods and data reliability. Section 5 concludes the paper.

[3] Dehejia and Wahba (1999) and Smith and Todd (2005) directly compare the results of matching and regression estimates and show that avoiding functional form assumptions can be important to reduce bias.

2. The Agri-environmental and Less Favoured Area Program

Total expenditures of the Common Agricultural Policy (CAP) reached 54.6 Billion Euro in 2006. Direct payments and price policies account for the largest share (78 %) of CAP expenditures. A minor but increasing part of the CAP budget (22%) is allocated to rural development policies (EU Commission, 2006). Agri-environment programs (AE-programs) and the less favoured area scheme (LFA) account for 57 % of total public expenditures for rural development in the EU (Agrar CEAS Consulting, 2005). These figures illustrate that both schemes became core instruments of the rural development policies within the EU and are no longer of solely marginal importance within the CAP framework.

AE programs and the LFA scheme are directly targeted to farm enterprises. Support for naturally less-favoured areas was introduced in 1975 on 30 % of total farmland in Germany, and expanded to 55 % of farmland in 2005. Since 2000, a similar scheme (also classified as a LFA program) is available in areas with environmental restrictions. It accounts for a small portion (< 5 %) of the LFA land area (IEEP, 2006, p. 55). Farms located in designated LFAs are eligible for support. The core objective of the LFA scheme is the maintenance of the agricultural land use within these regions (Reg. (EC) No 1257/1999, Article 13a). The share of granted farmland on total farmland was highest in the southern part of Germany, followed by western and eastern states (Plankl et al., 2005). LFA support has little relevance in the north of Germany due to superior natural conditions for agricultural production. The average proportion of total farmland classified as LFA is 55 % in the EU-15.[4] In Finland, Portugal, Luxembourg, Spain and Greece more than 70 % of the farmed land were classified as LFAs in 2003, while the share of LFAs is marginal in The Netherlands (0 %), Belgium (20 %) and Denmark (0 %) (IEEP, 2006, p. 153).

The EU's agri-environmental programs were introduced as 'Accompanying Measures' of the 1992 Mac Sharry Reform of the CAP, since the 2000 CAP reform (EC No 1257/1999),

[4] A European perspective of the implementation, evolvement and effects of the LFA program is provided by the IEEP (2006).

agri-environmental programs are categorized as 'second pillar' policies. Farmers receive compensation payments for the adoption of environmentally favourable production technologies. Agri-environment payments are meant to cover the income foregone and additional costs for compliance. The incentive component may not exceed 20 % of the premia.

Participation in the programs is voluntary and varies significantly between EU member states[5] as well as between different regions within member states. While more than two thirds of the total agricultural area is covered by at least one AE-program in Austria, Finland, Sweden, and Luxemburg, the average share is around 25 % in Germany (Salhofer und Glebe, 2006, p. 3). Similar to the LFA scheme, participation in AE programs is very high in the South (70 % of total farm land), moderate in the West and East (20 %) and marginal in the North (5 %) of Germany. More than 100 different sub-programs[6] are available within the framework of the AE scheme on the state level. Support for reduced inputs on grassland and arable land and organic farming account for the largest share of AE expenditures in Germany (Osterburg, 2004).

Besides natural and environmental conditions, institutional settings play an important role for the regional distribution of LFA and AE-programs. Both programs are implemented on the national and state level with shared responsibilities with respect to finances and contents. Thus, the share of LFA and AE-programs does reflect the political relevance placed upon them, as well as the financial capability of the federal and state governments.

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[5] Causes for spatial heterogeneity in the uptake of agri-environmental programs across Europe are analysed in Glebe and Salhofer (2006).

[6] Unfortunately, our data do not allow us to distinguish among sub programs of the AE programs. Organic farms are identified by a specific code but are too few in numbers for a separate analysis.

3. Estimation method and data

(a) Evaluation problem and matching

Evaluation studies attempt to estimate the mean effect of participating in a program (treatment). This requires making an inference about the outcome that would have been observed for the treated ('treatment group') if they had not been treated ('control group'). The key advantage of experimental studies (over non-experimental methods) is the ability to generate a control group that has the same distribution of characteristics as the treatment group. In this case, the treatment effect can be calculated as the difference of mean outcomes. In non-experimental studies on the other hand, subjects usually self-select into treatment groups. Treated and controls differ with respect to their participation status but also with respect to many other characteristics. Calculating the treatment effect as the difference of mean outcomes between the two groups would yield biased results (selection bias).

Matching is a widely-used non-experimental method of evaluation that can be used to estimate the average effect of a particular program.[7] This method compares the outcomes of program participants with those of matched non-participants, where matches are chosen on the basis of similarity in observed characteristics. Suppose there are two groups of farmers indexed by participation status $P = 0/1$, where 1 (0) indicates farms that did (not) participate in a program. Denote by Y_i^1 the outcome (performance of farm) conditional on participation ($P = 1$) and by Y_i^0 the outcome conditional on non-participation ($P = 0$).

The most common evaluation parameter of interest is the mean impact of treatment on the treated, $ATT = E\left(Y_i^1 - Y_i^0 \mid P_i = 1\right) = E\left[Y_i^1 \mid P_i = 1\right] - E\left[Y_i^0 \mid P_i = 1\right]$, which answers the following question: 'How much did farms participating in the program benefit compared to what they would have experienced without participating in the program?' Data on $E(Y_i^1 \mid P = 1)$ are available from the program participants. An evaluator's 'classic problem'

[7] A detailed discussion of the matching approach as well as a survey on its applications in labour-market evaluation studies is available in Heckman, LaLonde and Smith (1999), Caliendo (2006) as well as Caliendo and Kopeinig (2007).

is to find $E(Y_i^0 | P=1)$, since data on non-participants enables one to identify $E(Y_i^0 | P=0)$ only. So the difference between $E(Y_i^1 | P=1)$ and $E(Y_i^0 | P=1)$ cannot be observed for the same farm.

The solution advanced by Rubin (1977) is based on the assumption that given a set of observable covariates $\boldsymbol{X}$, potential (non-treatment) outcomes are independent of the participation status (conditional independence assumption-CIA): $Y_i^0 \perp S_i \mid \boldsymbol{X}$. Hence, after adjusting for observable differences, the mean of the potential outcome is the same for $P = 1$ and $P = 0$ ($E(Y_i^0 | P=1, \boldsymbol{X}) = E(Y_i^0 | P=0, \boldsymbol{X})$). This permits the use of matched non-participating farms to measure how the group of participating farms would have performed, had they not participated.

This procedure assumes that after conditioning on a set of observable characteristics, outcomes are conditionally mean independent of program participation. Heckman, Ichimura and Todd (1997) stress that, for a variety of reasons, there may be systematic differences between participant and non-participant outcomes, even after conditioning on observables. Such differences may occur, for example, because of program selectivity on unmeasured characteristics or because of level differences in outcomes ($(E(Y_i^1 - Y_i^0 \mid P_i = 1))$ that might arise when participants and non-participants reside in different regions. To improve the results of the matching procedure, the authors suggest a conditional difference-in-difference matching estimator (d-i-d). Let *t* represent a time period after the program start date and *t'* a time period before the program. The conditional d-i-d estimator compares the conditional before-after outcomes of program participants with those of non-participants: $E\left(Y_{it}^1 - Y_{it'}^0 \mid P_i = 1, \boldsymbol{X}\right) - E\left(Y_{it}^0 - Y_{it'}^0 \mid P_i = 0, \boldsymbol{X}\right)$. The d-i-d is attractive because, unlike conventional matching estimators, it permits selection to be based on potential program outcomes at time *t'* and allows for selection on unobservables.[8]

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[8] In their analysis of the effectiveness of matching estimators, Smith and Todd (2005) found difference-in-difference matching estimators to perform much better than cross-sectional methods in cases where participants and non-participants were drawn from different regional labour markets. Since program participation differs significantly between regions in the present context as well, the d-i-d estimator will be used.

Instead of conditioning on $\boldsymbol{X}$, Rosenbaum and Rubin (1983) suggest conditioning on a propensity score ('propensity score matching'). The propensity score is defined as the probability of participation for farm i given a set $\boldsymbol{X} = \boldsymbol{x}_i$ of farm characteristics $p(\boldsymbol{X}) \equiv \Pr(P_i = 1 \mid \boldsymbol{X} = \boldsymbol{x}_i)$. In the present context with multiple treatments (AE programs and LFA scheme), the propensity scores are derived from two logit models where participation in the AE and LFA program serve as endogenous variables. The estimated propensity scores are then used to construct the comparison groups. A Greedy algorithm employing nearest available pair matching without replacement will be applied (Parson, 2001). Compared to other matching algorithms, the Greedy algorithm performs well in the sense of producing balanced matched samples (Gu und Rosenbaum, 1993, p. 405).[9]

(b) Data and definition of variables

The empirical analysis is based on a panel data set ('LAND-Data') of more than 32,000 bookkeeping farms in Germany for the period 2000 to 2005[10]. 'LAND-Data' provides information on farm characteristics (area under cultivation, sales, labour inputs, capital endowment and expenditures for farm chemicals ...) and also includes information on the participation in the AE and LFA program. From these 32,000 farms in the original data set, roughly one third had to be eliminated due to incomplete and missing data. To evaluate the effect of programme participation with the conditional d-i-d estimator, we focus only on those farms, that did not participate in the program in the initial time period (2000). The selection of data and the definition of the participation variables is described in Table 1 (for additional information on variable definition and data source see Table A1 in the appendix).

Table 1

Sample Selection Criteria and Program Participation

[9] The different propensity score matching schemes used in the empirical literature are discussed in more detail in Heckman, Ichimura and Todd (1997), Smith and Todd (2005) as well as Becker and Ichino (2002). Since there is no consensus on the best matching estimator to adopt, we compare the outcomes with those from alternative estimators to assess the stability of our results.

[10] The sample comprises 8 % of all farm enterprises in Germany. Note that the sample is not representative for Germany as large-scale and full-time farm enterprises are over represented.

	AE programs	LFA scheme
Total number of farms with continuous records from 2000 to 2005	32,503	
Omitted due to missing observations for some variables	10,390	8,594
Number of remaining farms	22,113	23,909
Program Participation in base year (2000)	557	9,695
Non-participation in base year (2000)	21,556	14,214
Continuous program participation (2001 – 2005):		
Dummy variable (P_{AE}) is set equal to 1 for farms which continually participate in the Agri-environmental program from 2001 until 2005 (for five years)	**9,138**	
Dummy variable (P_{LFA}) is set equal to 1 for farms which continually participate in the Less Favoured Area scheme starting from 2001, 2002 or 2003 until 2005 (at least for three years)		**502**
Program participation in some years only (these observations will not be used for the empirical analysis):		
Number of farms participating in the Agri-environmental program for some years only (less than five years)	5,223	
Number of farms participating in the Less Favoured Area scheme for few years only (less than three years)		637
Non-participation (2001 – 2005):		
Dummy variable (P_{AE}) is set equal to 0 for farms which never participated in the Agri-environmental program between 2001 and 2005	**7,195**	
Dummy variable (P_{LFA}) is set equal to 0 for farms which never participated in the Less Favoured Area scheme between 2001 and 2005		**13,075**

The basis for the empirical analysis (propensity score difference-in-difference matching estimator) of AE programs are those 21,556 farms that did not participate in AE programs in the base year 2000. From those farms, 9,138 farms (42.4 %) continually participate in AE programs during the following five year period from 2001 until 2005 (the dummy variable P_{AE} is set equal to one). The dummy variable is set equal to zero for the 7,195 farms (33.4 %) which never participate in AE programs between 2001 and 2005. Note that 5,223 farms (24.2 %) participate in some years only. These farms will not be used for the empirical analysis.

A dummy variable for program participation in the 'less favoured area program' (LFA) is defined in a similar way. In the initial period 2000, 14,214 farms did not participate in the

LFA program. Note that in the case of the LFA program, the number of farms continually participating in the program in all five years (from 2001 until 2005) and not participating in the base year 2000 is very small (only 109 farms). Since this number is too small to carry out a matching analysis, we have chosen a less restrictive classification criterion in this case. A dummy variable (P_{LFA}) is set equal to one for those farms (502 or 3.5 %) which participate in the program from 2001, 2002 or 2003 until 2005 (for at least for three years). The majority of farms (13,075 or 92.0 %) never participate in the LFA scheme. The dummy variable P_{LFA} is set equal to zero in this case. The remaining 637 farms, which participate in a few years only are eliminated from the empirical analysis. Given that the selection into the treatment group is less restrictive for the LFA scheme, we expect to find a weaker causal effect of this program. Whether program participation (P_{AE} = 1 or P_{LFA} = 1) has significant effects on farm performance rates will be evaluated in the following section.

4. Empirical results

(a) Propensity Scores and Matching

Conditional probabilities for participation in AE and LFA programs are computed by estimating two logit models. Table A2 in the appendix reports the parameter estimates for both models, the results are only briefly discussed here. The estimated models are statistically significant at the 1 % level or better, as measured by the likelihood ratio test. The empirical model for the AE-program (the LFA scheme) correctly classifies 87.79 % (96,61 %) of all observations. From the parameter estimates of the logit models, the unbounded propensity scores are calculated for every farm which are then used for the matching analysis.[11]

Matching is considered successful when significant differences of covariates among participants and non-participants are removed. Table 2 reports unadjusted and adjusted

[11] We use the unbounded $x_i'\hat{\beta}$ rather than the bounded propensity score $\Phi\left(x_i'\hat{\beta}\right)$ because of its preferable distribution properties (Hujer; Mauerer und Wellner, 1997).

mean differences of covariates among participants and non-participants of AE and LFA programs for the pre-treatment status (2000).[12]

Table 2

Mean comparison of selected variables (Frequencies for Dummy Variables) in the pre-treatment year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.781	**4.783**	4.776	4.742	**4.807**	4.783
Ln on-farm labour	0.365	**0.307**	0.363	0.427	**0.326**	0.464
Ln off-farm labour	1.080	1.118	1,083	0.723	**1.159**	0.740
Ln area under cultivation	4.053	**3.932**	4.039	3.955	3.941	3.971
Ln share of grassland	3.066	**2.920**	3.047	2.850	**2.304**	2.783
Ln share of rented land	3.792	**3.698**	3.798	3.745	3.712	3.749
Ln farm sales (per ha)	0.728	**0.850**	0.737	0.787	**0.866**	0.812
Farm income	20.159	**18.466**	18.554	21.140	18.836	19.950
Ln farm capital (per ha)	2.301	**2.349**	2.319	2.521	2.414	2.493
Ln cattle livestock units	3.247	**3.135**	3.227	2.995	**2.553**	2.926
Ln cattle livestock density	0.489	**0,545**	0.494	0.511	**0.474**	0.501
Ln fertilizer expend. (per ha)	-2.522	**-2.443**	-2.532	-2.925	**-2.409**	-2.641
Ln pesticide expend. (per ha)	-2.970	**-2.952**	-2.992	-2.640	**-2.617**	-2.871
Dummy North	593	**2,970**	541	6	**4,865**	5
Dummy West	711	**3,545**	751	108	**4,313**	108
Dummy South	451	**581**	463	334	**3,718**	337
Dummy East	52	**95**	52	4	179	2
Number of observations	1,807	7,195	1,807	452	13,075	452

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Prior to the matching analysis, farms participating in AE and/or LFA programs significantly differ from non-participants with respect to nearly all characteristics shown in Table 2. A comparison between column (1) and (2) indicates that farms enrolled in AE programs are characterized by a larger area under cultivation and higher farm incomes, for example. These differences in farm characteristics between program participants and non-

[12] The percentage reduction of the selection bias are reported in Table A3 and A4 in the appendix. The graphical distribution of propensity scores *p(X)* of potential treatment and controls are displayed in Figure A1.

participants are significantly different from zero. Table 2 also reports significant differences between treatments and potential controls in the case of participation in the LFA program (compare column (4) and (5)).

Columns (3) and (6) report the means of the relevant variables for the control group after the matching procedure has been applied. From the 9,138 (502) farms with participation in AE (LFA) programs, 1,807 (452) were matched to farms with no participation but similar propensity scores. The differences to columns (1) and (4) are now much smaller and in no case significantly different from zero at the 5 % level. We can thus conclude that all differences in means between treatments and controls have been removed through matching in the initial period 2000 (before program participation).

(b) Treatment Effects

The average effect of the participation in AE and LFA programs is estimated by comparing the changes in individual outcomes (farm characteristics) between participants ($\Delta Y_i^1 = Y_{i,2005}^1 - Y_{i,2000}^1$) and their matched counterparts ($\Delta Y_i^0 = Y_{i,2005}^0 - Y_{i,2000}^0$) between 2000 and 2005 (d-i-d analysis). The impact of treatment on the treated ('causal effect' of program participation) is estimated by computing mean differences across both groups:

$$ATT = \frac{1}{N_1}\left(\sum_{i=1}^{N_1}\Delta Y_i^1 - \sum_{i=1}^{N_1}\Delta Y_i^0\right).$$

A positive (negative) value of ATT suggests, that farms with participation in AE and/or LFA programs have higher (lower) growth rates of variable *Y* than non-participants. Table 3 displays mean growth rates for the treatment and control group as well as the difference between both (the ATT).

Table 3

Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 to 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.073	0.048	0.025	1.72	(*)
Ln on-farm labour	0.007	-0.012	0.019	1.95	(*)
Ln off-farm labour	-0.003	-0.001	-0.002	-0.55	
Ln area under cultivation	0.077	0.042	0.035	5.32	(***)
Ln share of grassland	-0.046	-0.098	0.052	3.13	(***)
Ln share of rented land	0.004	-0.018	0.022	1.52	
Ln cattle livestock units	-0.187	-0.187	0.001	0.03	
Ln cattle livestock density	-0.108	-0.048	-0.060	-3.30	(***)
Ln farm sales (per ha)	-0.004	0.006	-0.010	-0.70	
Ln farm capital (per ha)	0.035	0.047	-0.012	-0.79	
Ln fertilizer expenditures (per ha)	0.037	0.131	-0.094	-4.57	(***)
Ln pesticide expenditures (per ha)	-0.025	0.022	-0.047	-1.97	(**)
Less Favoured Area Program					
Ln farm sales	0.144	0.056	0.088	2.96	(***)
Ln on-farm labour	0.001	-0.012	0.013	0.83	
Ln off-farm labour	-0.008	0.000	-0.008	-1.11	
Ln area under cultivation	0.114	0.060	0.054	3.64	(**)
Ln share of grassland	-0.041	-0.048	0.007	0.28	
Ln share of rented land	0.043	0.011	0.032	1.06	
Ln cattle livestock units	-0.102	-0.147	0.046	1.09	
Ln cattle livestock density	-0.095	-0.088	-0.007	-0.26	
Ln farm sales (per ha)	0.030	-0.004	0.034	1.17	
Ln farm capital (per ha)	0.000	-0.011	0.011	0.34	
Ln fertilizer expenditures (per ha)	0.132	0.169	-0.037	-0.91	
Ln pesticide expenditures (per ha)	-0.012	0.037	-0.049	-0.92	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level.

The d-i-d estimator suggests a significant and positive causal impact of program participation on farm sales. During the period of investigation (from 2000 until 2005) sales of farms participating in AE programs have been growing by 7.3 %, while non-participants report a positive growth rate in sales of 4.8 % on average. The difference (ATT = 2.5 %) is different from zero at the 10 % level of significance. The slight positive effect of AE programs on farm sales is surprising insofar as participation in this program requires the adoption of less intensive production methods which could be expected to reduce farm output and thus farm sales, ceteris paribus. No such adjustment in production methods is required for participation in the LFA program. Consistently, we observe that the causal

effect of program participation in the LFA program is much stronger. Sales of non-participants have been growing by 5.6 % on average during the period from 2000 until 2005. Participation in the LFA program caused the growth rate of sales to increase by more than twice this rate. The growth rate of participating farms is 14.4 % on average, the average treatment effect on the treated (ATT = 8.8 %) is significantly different from zero at the 1 % level. Where does this significant increase in farm sales come from?

Existing empirical studies found significant effects of government payments on farm labour. Mishra and Goodwin (1997), Weiß (2006) and Hofer (2002) provide empirical evidence for a negative effect of government payments on off-farm labour supply and a positive effect of the farm hours worked. '[L]arger receipts of government farm programme payments were significantly correlated with less off-farm work by farmers and their spouse'(Mishra und Goodwin, 1997, p. 886). Ahearn et. al (2006) and Serra et. al (2005) point out that both coupled and decoupled payments negatively affect off-farm employment. However, Ahearn, Yee and Korb (2005, p. 1187) suggest that the negative effects of conservation payments – such as AE and LFA schemes - on off-farm employment are considerably smaller than those of commodity payments. The results reported in Table 3 reject the idea that the additional growth in farm sales is significantly related to adjustments in farm labour. On-farm labour increases only moderately as a consequence of participation in AE programs (ATT = 1.9 %), no significant effect is reported with respect to off-farm labour. The average treatment effect of the LFA program with respect to on-farm (off-farm) labour is marginal (0.13 % and -0.8 % respectively) and not significantly different from zero. Changes in labour allocation can not explain observable changes in farm sales.

A significant increase in farm sales is paralleled by an increase in the area under cultivation. These results comply with findings of Key et al. (2005, p. 1217f), Osterburg (2004) and Reiter et al. (2003). Average growth rates of the area under cultivation differ significantly among program participants and non-participants. On average, participation in AE programs causes farm growth rates to double. Whereas the area under cultivation for non-participants has been growing by 4.2 %, participants report a growth rate of 7.7 % on average. The average treatment effect on the treated (ATT) of 3.5 % is significantly different from zero at the 1 % level.

Higher farm land growth rates of participants in AE programs can be explained by the adjustment process of farms induced by program eligibility criteria. Farms with participation to certain AE programs (low input grassland management, for example) are, among others, required not to exceed a certain cattle livestock density (livestock units per forage area). In order to meet this criteria, farm operators predominantly choose to expand the forage area, while total cattle livestock units per farm are kept stable. Results in Table 3 illustrate this adjustment process. The number of livestock units is not affected by programme participation (ATT = 0 %). The cattle livestock density is, on average, reduced by 10.8 % in farms with program participation compared to a decrease of 4.8 % in farms with non-participation. The ATT with respect to the cattle livestock density is –6 % and significantly different from zero at the 1 % level.

The causal effect of the LFA scheme on farm land growth is of similar magnitude as for the AE programs. Scheme participation increases growth in the area under cultivation from 6.0 % to 11.4 % (ATT = 5.4 %). No significant causal effect is observed with respect to the amount of cattle livestock units or density. For the LFA scheme, the changes in farm land are very similar in magnitude to the figures reported for farm sales. Given the fact that LFA payments are granted on a per-acreage base, the increase of farmed land eligible for LFA payments seems to be a reasonable strategy to maximize benefits from participation.

An important objective of agri-environmental policy in Germany is the maintenance of grassland. Land eligible for AE support is mainly grassland, whereas both, arable land and grassland are eligible for LFA support. Neither AE nor LFA support resulted in an increase of the share of grassland in farms with program participation. We find that the share of grassland decreases significantly less in farms participating in AE programs (-4.6 %) than in those with non-participation (-9.8 %). The ATT of 5.2 % is significantly different from zero. The effect of the LFA program on the share of grassland is almost zero. We conclude that current AE programs slow down the decrease of grassland while they are not able to stop or reverse this process.

The results reported in Table 3 further suggest that farm growth is only partly achieved by renting additional land. With respect to the growth of the share of rented land the ATT is not significantly different from zero for either program. This seems to suggest that farm

adjustments with respect to land input are not only temporary effects (for the time of program participation) but might extend to the post-program period.

Table 3 does not suggest a significant treatment effect of AE programs on productivity (sales per hectare), the causal effect of the LFA program is positive but not significantly different from zero. This result corresponds to Salhofer and Streicher (2005) who also observe an insignificant productivity effect of participation for ten different farm programs in Austria. The same holds for the capital endowment on farms with program participation, which does not change significantly compared to the control group.

Participants in the AE program are required to reduce or abandon the use fertilizers and pesticides, while no such eligibility criteria are in place for the LFA scheme. Consequently, the causal effect of program participation with respect to expenditures for fertilizer and pesticides per hectare differ remarkably between the two programs. The amount of expenditures for fertilizers (pesticides) per hectare changes in farms with participation in AE programs by 3.7 % (-2.5 %). At the same time, expenditures for fertilizers (pesticides) in the control group increase by 13.1 % (2.2 %). The ATT of -9.4 % (fertilizers) and -4.7 % (pesticides) indicate that farms participating in AE significantly reduced the purchase of farm chemicals compared to the control group. The ATT is significantly different from zero at the one percent (fertilizers) and five percent (pesticides) levels. No significant treatment effect is observed for the LFA program with respect to expenditures for farm chemicals.

(c) Heterogeneity of Effects and Robustness of Results

The response to a specific policy will differ between individual observations (heterogeneity of treatment effects) for various reasons. First, it is plausible to expect that the treatment effect increases with the probability of participation in the project; that is, farmers who can generate the largest benefit from the program are most likely to participate. Second, the magnitude of the treatment effect might be influenced by the amount of program payments per hectare, by farm size and the duration of program participation.

To check these hypotheses, we follow and extend the approach suggested in Lechner (2002).[13] The expectation of the outcome variable conditional on the conditional selection probability ($p(\boldsymbol{X})$) in the pool of participants and non-participants is shown in Figure 1. The comparison is based on kernel-smoothed regressions for program participants in AE programs (solid line) versus non-participants (dotted line) for those outcome variables, where Table 3 suggested a significant ATT. The results for all other outcome variables as well as for participation in the LFA scheme are reported in an appendix.

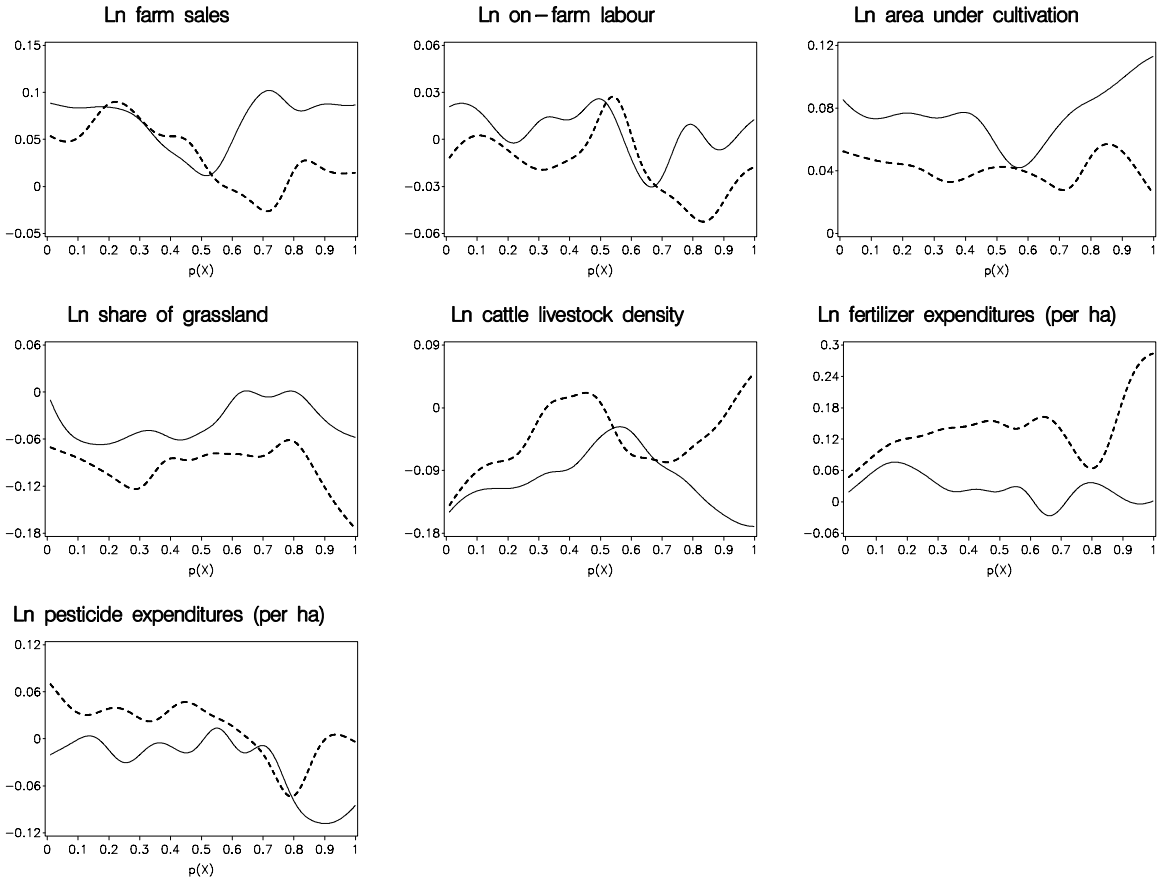
Figure 1 clearly supports the idea of heterogeneous treatment effects. The causal effect of the farm program, which is the difference between the two curves at any point, fluctuates over the support of participation probabilities. The outcomes for the program participants (solid line) are higher for farm sales, on-farm labour, area under cultivation, share of grassland; and lower for cattle livestock density, expenditures for fertilizer and pesticides at (almost) all points, which is consistent with the significant average treatment effect of AE programs for these variables reported in Table 3.[14]

[13] Splitting the sample along some characteristics and performing a disaggregate analysis is another possibility to find more subgroup heterogeneity of the effects. Due to the smaller number of observations which would result from this procedure, this route is not followed any further in this paper.

[14] The treatment effect reported in Table 3 is a weighted average of the differences of these regression lines, with weights determined by the distribution of the respective participant.

Figure 1

Nonparametric regression of the conditional participation probabilities ($p(\boldsymbol{X})$) on the outcome variable for the AEP



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. The solid (dotted) line represents the outcome variable for participants (non-participants) in AE programs.

The causal effect of program participation on farm sales, fertilizer expenditures and the share of grassland increases with the conditional participation probability ($p(\boldsymbol{X})$). Figure 1 does not suggest a clear relationship between the individual treatment effect (difference between the two lines) and the conditional probability of participation in AE programs for changes in on-farm labour, area under cultivation, cattle livestock density and pesticide expenditures. Heterogeneous treatment effects are also evident for the LFA program. The results (reported in Figure A3 in the appendix) suggest a positive relationship between the probability of program participation and the effects on farm sales and the area under cultivation.

Further sources of heterogeneous treatment effects can be observed with respect to the amount of program payments per hectare. Figures A4 and A5 in the appendix suggest substantial fluctuations of the causal effects over the support of transfers from AE and LFA programs. However, no clear increasing or decreasing pattern can be observed for most variables. Similarly, no clear relationship between the causal effect and farm size (as measured by the area under cultivation) is observed in Figures A6 and A7.

To assess the robustness of our results, we carried out a number of additional estimation experiments with different matching estimators. In some of these experiments the differences of covariates among participants and non-participants can not be removed. In these cases, the treatment effect is not computed as it would be biased by unobserved heterogeneity. When matching successfully removes differences between the two groups, we conclude that by and large our results remain unchanged. The results are reported in Tables A5 – A10 in the appendix.

Finally, it is interesting to compare the results from propensity-score matching with those from a naive estimator (without controlling for differences in pre-treatment characteristics). A comparison of the ATT reported in Table 3 and the results from a naive estimator (reported in Table A11) reveals the existence of substantial selection effects. The calculated effect of AE programs on farm sales (the area under cultivation) is overestimated by the naive model by a factor of 2.2 (1.2). Distinguishing between a 'selection effect' and a 'causal effect' is key for an appropriate evaluation of farm programs.

5. Conclusions and extensions

Evaluating the effects of farm programs on farm output is a key policy issues since this determines whether programs are condemned as trade distorting or can be classified as 'decoupled' and conform with WTO regulations. An empirical evaluation of the effects of farm programs, however, faces a number of challenges: First, economic theory often provides limited guidance with respect to the appropriate specification of an econometric model. Second, farms self-select into program participation and participants and non-participants thus differ significantly in important characteristics (selection bias). Third, factors that determine the selection into the program and/or influence outcome variables

may not fully be observed (unobserved heterogeneity). Further it remains unknown how participants would have performed if they had not participated in the program, as counterfactuals cannot be observed in non-experimental studies. Finally, the optimal response to governmental programs will not be homogenous across individual farms (heterogeneity in response).

The present paper addresses these issues by applying a non-parametric propensity score matching approach (difference-in-difference estimator). Specifically, we investigate the effects of two farm programs – agri-environment (AE) programs and the less favoured area (LFA) scheme – with respect to farm size (area under cultivation), farm output (sales), labour supply (on- and off-farm), productivity (sales per hectare), purchase of farm chemicals (pesticides, fertilizers) and livestock densities in Germany for the period 2000 to 2005.

The analysis reveals a positive and significant treatment effect of the LFA programs on farm sales. Growth rates in farm sales are significantly higher (on average) for farms participating in the LFA program compared to non-participants. Changes in labour allocation can not explain this effect. The increase in farm sales observed is paralleled by an increase in the area under cultivation. Since LFA payments are granted on a per-acreage basis, an increase in land eligible for support seems to be a reasonable strategy to maximize benefits from participation.

We also observe a significant positive effect of the AE program on the area under cultivation. The increase in farm size can be explained by the need to reduce livestock densities (livestock units per forage area) in order to become eligible for AE payments. Stocking densities are predominantly reduced by renting in new land. Compared to non-participation, AE participants reduce expenditures for farm chemicals (fertilizer, chemicals). The share of grassland per farm continues to decrease in farms with participation in AE programs, although at a lower rate than in farms with non-participation. No significant effect on farm productivity (sales per ha), capital endowment per ha, off-farm labour, total cattle livestock units (per farm) can be found for AE or LFA programs.

The propensity score matching analysis reveals substantial differences in the treatment effects between individual farms (heterogeneous treatment effects). Farmers who can generate the largest benefit from the program (in terms of additional sales, for example) are most likely to participate. Other sources of heterogeneous treatment effects are found to be the duration of program participation and, to a smaller extent, the amount of program payments per hectare. Heterogenous treatment effects have not yet been addressed in greater detail in empirical evaluation studies. This remains an important area to be explored in future research. It would be interesting to see whether the response to farm programs is the same for full-time and part-time farms, for example. Similarly, the evaluation and comparison of the effects of farm programs in various regions (within Germany but also between different EU member states) could improve our knowledge about the farmers' response to specific farm policies. The matching estimator applied in the present paper turns out to be a useful technique for the empirical evaluation of farm programs, the results obtained can provide an important contribution to the analysis of policy implications and the design of policies to promote desired outcomes.

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Appendix

Table A1:

Variable definition and data sources

Variables	Unit	Year	Source
Participation in AE programs	0=no, 1=yes	2000-2005	LAND-Data
Participation in the LFA scheme	0=no, 1=yes	2000-2005	LAND-Data
Farm characteristics			
Area under cultivation	ha	2000-2005	LAND-Data
Farm sales	1000 Euro	2000-2005	LAND-Data
Share of grassland	%	2000-2005	LAND-Data
Share of rented land	%	2000-2005	LAND-Data
On-farm labour units (1 LU = 2720 working hours per year)	LU	2000-2005	LAND-Data
Off-farm labour (farmer couple)	LU	2000-2005	LAND-Data
Farm capital (per ha)	1000 Euro	2000-2005	LAND-Data
Fertilizer expenditures (per ha)	1000 Euro	2000-2005	LAND-Data
Pesticide expenditures (per ha)	1000 Euro	2000-2005	LAND-Data
Commodity payments, livestock (per ha)	1000 Euro	2000-2005	LAND-Data
Commodity payments, arable (per ha)	1000 Euro	2000-2005	LAND-Data
AE payments (per ha)	Euro	2000-2005	LAND-Data
LFA payments (per ha)	Euro	2000-2005	LAND-Data
Livestock units (all livestock) (1 LSU = 1 milk cow)	LSU	2000-2005	LAND-Data
Cattle livestock units	LSU	2000-2005	LAND-Data
Cattle livestock density (LSU per ha grassland, fodder crops)	LSU		
Livestock farm	0=no, 1=yes	2000-2005	LAND-Data
Pig & poultry farm	0=no, 1=yes	2000-2005	LAND-Data
Soil index (< 30 = very poor, 100 = best)	Index	2000-2005	LAND-Data
Regional characteristics			
Unemployment rate	%	2000-2005	ZAV (2005)
Farmland rent (per ha)	Euro	2000-2005	LAND-Data
Land price (per sqm)	Euro	Ø 2000-2002	BBR (2004)
Share of rural population	%	2001	BBR (2004)
Share of farms ≤ 20 ha	%	1999	STAT (2005)
Share of farms ≥ 20 < 50 ha	%	1999	STAT (2005)
Change in the number of farms ≥ 20 < 50 ha (between 1999 and 2003)	%	1999, 2003	STAT (2005)
Gross value added in agriculture	1000 Euro	2000-2004	STAT (2005)
Share of gross value added in agriculture	1000 Euro	2000-2004	STAT (2005)
Gross domestic product (per capita)	1000 Euro	2000-2004	STAT (2005)
Share of livestock farms	%	1999	STAT (2005)
Share of arable farms	%	1999	STAT (2005)
Share of pig & poultry farms	%	1999	STAT (2005)
Share of mixed farms	%	1999	STAT (2005)
Dummy North	0=no, 1=yes	2000-2005	LAND-Data
Dummy West	0=no, 1=yes	2000-2005	LAND-Data
Dummy South	0=no, 1=yes	2000-2005	LAND-Data

Abbreviations: AE = Agri-Environmental Programs, LFA = Less Favoured Areas Program, ha = hectare, sqm = square meter, LU = Labour units, LSU = Livestock units

Notes: 'Regional characteristics' refer to the characteristics of the 440 administrative districts of Germany.

Table A2:

Parameter estimates of logit-models explaining program participation

	Agri-Environmental Programs			Less Favoured Area Program		
Variables	Estimate	Wald Chi^2	(Sign.)	Estimate	Wald Chi^2	(Sign.)
Intercept (P_{AE}=1, P_{LFA}=1)	-2.176	2.094		-3.677	6.438	(**)
Farm characteristics						
Ln area under cultivation	1.367	4.987	(**)	1.007	54.441	(***)
Ln area under cultivation (sq.)	-0.041	0.336				
Ln share of grassland	0.367	82.946	(***)	0.306	17.668	(***)
Ln share of rented land	0.105	9.443	(***)	-0.064	1.288	
Ln farm sales (per ha)	-0.058	0.959				
Ln off-farm labour				-0.072	8.114	(***)
Ln farm capital (per ha)	-0.046	0.910				
Ln fertilizer expenditures (per ha)	-0.419	73.219	(***)	-0.312	10.496	(***)
Ln pesticide expenditures (per ha)				-0.315	19.673	(***)
Commodity payments, livestock (per ha)	1.247	5.394	(**)	0.010	12.543	(***)
Commodity payments, arable (per ha)	0.821	5.814	(**)			
Ln livestock units (per 100 ha)	0.000	4.906	(**)	0.169	13.493	(***)
Ln cattle livestock units	-0.106	7.526	(***)	-0.223	20.031	(***)
Ln cattle livestock density	-0.118	2.075				
Cattle livestock units ≥ 0.3 <1.4	0.566	43.543	(***)			
Livestock farm	-0.206	8.548	(***)			
Pig & poultry farm	-0.312	7.039	(***)			
Participation in the LFA scheme	0.118	2.255				
Soil index	-0.011	18.705	(***)	-0.074	136.287	(***)
Regional characteristics						
Unemployment rate	0.042	8.750	(***)			
Ln farmland rent (per ha)	-0.954	69.433	(***)	-1.097	27.942	(***)
Land price (per sqm)	-0.004	106.379	(***)	-0.003	13.724	(***)
Share of rural population	-0.018	145.188	(***)			
Share of farms ≤ 20 ha	0.003	0.670				
Share of farms ≥ 20 < 50 ha	0.041	32.767	(***)			
Change in the number of farms ≥ 20 < 50 ha	-0.062	20.546	(***)	-0.083	4.504	(**)
Gross value added in agriculture	0.002	10.430	(***)			
Share of gross value added in agriculture				0.120	8.471	(***)
Gross domestic product (per capita)	0.010	17.084	(***)	0.013	35.207	(***)
Share of livestock farms	-0.022	105.809	(***)			
Share of arable farms				-0.024	28.685	(***)
Share of pig & poultry farms				-0.160	117.619	(***)
Share of mixed farms	0.047	22.385	(***)	0.297	129.552	(***)
Dummy North	-1.885	22.447	(***)			
Dummy West	-1.151	4.281	(**)			
Dummy South	1.326	5.303	(**)			
Interaction						
Ln area under cultivation*Dummy North	0.073	0.686		-3.209	17.032	(***)
Ln area under cultivation*Dummy West	-0.153	1.497		2.918	19.839	(***)
Ln area under cultivation*Dummy South	0.654	21.170	(***)	3.484	27.243	(***)
Number of observations		16,333			13,577	
LR chi-squared		12,288.91	(***)		1,606.55	(***)
Pseudo R^2 rescaled		0.71			0.41	
% Correct predictions		87.79			96.61	
Non-Participants		90.81			99.54	
Participants		85.41			20.32	

Notes: For variable definition and abbreviation see Table A1. Asteriks denote statistical significance at 1 % (***), 5 % (**), or 10 % (*) level.

Table A3:

Test Statistics for variables explaining program participation:

Standardized Bias (SB) in unmatched and matched subsamples

	Agri-environmental Programs			Less Favoured Area Program		
Variables	SB unmatched	SB matched	SB reduced %	SB unmatched	SB matched	SB reduced %
Farm characteristics						
Ln area under cultivation	-15.305	2.359	116.80	-12.020	-2.768	76.44
Ln area under cultivation (sq.)	-14.347	2.615	120.17			
Ln share of grassland	-11.604	1.555	112.87	-21.908	4.686	122.82
Ln share of rented land	-18.899	-0.525	97.17	-15.772	-0.393	97.09
Ln farm sales (per ha)	29.767	-1.334	104.78			
Ln off-farm labour				-12.026	-0.774	93.81
Ln farm capital (per ha)	-7.726	-2.193	69.16			
Ln fertilizer expenditures (per ha)	36.134	1.623	95.54	-8.760	0.133	101.57
Ln pesticide expenditures (per ha)				10.820	-4.766	144.11
Commodity payments, livestock (per ha)	16.993	0.269	98.330			
Commodity payments, arable (per ha)	-6.480	1.064	116.63	-2.939	-2.569	12.00
Ln livestock units (per 100 ha)	31.121	-1.700	107.50	5.216	-0.010	100.20
Ln cattle livestock units	-5.830	1.148	120.10	-21.683	3.705	118.62
Ln cattle livestock density	8.573	-0.797	110.25			
Cattle livestock units ≥ 0.3 <1.4	-16.452	5.549	137.04			
Livestock farm	-5.762	-1.998	65.36			
Pig & poultry farm	12.015	-2.318	117.86			
Participation in the LFA scheme	-23.508	-2.012	90.75			
Soil index	14.459	1.035	93.01	75.590	-6.926	109.53
Regional characteristics						
Unemployment rate	86.638	1.126	98.38			
Ln farmland rent (per ha)	42.374	-3.233	108.22	33.629	0.538	98.45
Land price (per sqm)	-41.411	2.518	108.06	30.205	-2.478	109.36
Share of rural population	-28.874	-1.599	94.41	-23.209	4.063	117.55
Share of farms ≤ 20 ha	-71.648	1.655	102.60			
Share of farms ≥ 20 < 50 ha	-23.508	-2.012	90.75			
Change of numbers of farms ≥ 20 < 50	-9.057	0.905	111.33	23.510	3.245	87.43
Gross value added in agriculture	44.334	0.553	98.69			
Share of gross value added in agriculture				-7.632	3.080	140.27
Gross domestic product (per capita)	-24.630	-0.047	99.87	11.577	-5.583	138.85
Share of livestock farms	-5.195	-1.303	74.70			
Share of arable farms				1.909	-2.842	244.83
Share of pig & poultry farms				4.028	3.273	17.49
Share of mixed farms	-24.194	-2.189	91.31	-15.790	0.903	105.84
Dummy North	92.006	6.203	91.62	-1.900	2.018	202.74
Dummy West	100.984	-4.510	105.54	3.382	0.000	100.00
Dummy South	-225.915	-1.527	99.10	1.110	-1.516	233.83
Mean	-4.322	-0.023	101.72	2.606	-0.395	116.95
Median	-6.480	-0.047	99.87	-0.226	-0.005	107.60

Notes: For variable definition see Table A1. The standardized bias (SB) is defined as the difference of the means in the respective sub-samples divided by the square root of the average standard deviation of covariates of treated and controls * 100. SB can be interpreted as the bias in percent of the average standard deviation (see Baser, 2006). The standardized bias is calculated for those variables only, which were used as explanatory variables in the logit analysis (see Table A2).

Table A4:
Descriptive Statistics and test results for propensity score before and after matching

	Agri-environmental programs				Less Favoured Area Program			
	Mean	Std. Dev.	t-value (Significance)		Mean	Std. Dev.	t-value (Significance)	
Potential treatments	0.833	0.266			0.2807	0.259		
Potential controls	0.212	0.203	168.93	(***)	0.0276	0.0673	21.87	(***)
Selected treatments	0.391	0.285			0.2257	0.2039		
Selected controls	0.391	0.285	0.00		0.2243	0.2034	0.10	

Notes: Asterisks denote statistical significance at 1 % (***). The t-value is calculated from a test of differences in means between line 1 and 2 as well as 3 and 4 respectively.

Table A5(a):
Results from 1:1 Matching with replacement (common support, 5 % trimming)

(a) Mean comparison of selected variables in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.683	**4.783**	**4.605**	4.750	4.807	4.746
Ln on-farm labour	0.419	**0.307**	**0.384**	0.430	**0.326**	0.450
Ln off-farm labour	0.962	**1.055**	0.929	0.687	**1.159**	0.727
Ln area under cultivation	3.988	**3.932**	3.996	3.961	3.941	3.935
Ln share of grassland	3.051	**2.920**	**2.906**	2.835	2.304	2.857
Ln share of rented land	3.864	**3.698**	**3.835**	3.744	3.712	3.764
Ln farm sales (per ha)	0.696	**0.850**	**0.609**	0.788	**0.866**	0.811
Ln farm capital (per ha)	2.433	**2.349**	**2.457**	2.524	2.415	2.495
Ln cattle livestock units	3.221	**3.136**	**2.967**	2.981	**2.553**	2.961
Ln cattle livestock density	0.517	**0.545**	**0.455**	0.507	0.474	0.488
Ln fertilizer expend. (per ha)	-2.602	**-2.436**	**-2.550**	-2.634	**2.405**	2.638
Ln pesticide exp. (per ha)	-2.793	**-2.908**	**2.831**	-2.831	**2.585**	2.830
Dummy North	0.073	**0.413**	0.069	0.013	**0.372**	0.015
Dummy West	0.098	**0.493**	0.099	0.243	**0.330**	0.208
Dummy South	0.814	**0.081**	0.820	0.735	**0.284**	0.768
Dummy East	0.015	0.013	0.012	0.009	0.137	0.009
Number of observations	8,682	7,195	8,682	456	13,075	456

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A5(b):
Results from 1:1 Matching with replacement (common support, 5 % trimming)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales					
Ln on-farm labour					
Ln off-farm labour					
Ln area under cultivation		No treatment effects have been calculated since matching did **not** eliminate differences in covariates between participants and non-participants.			
Ln share of grassland					
Ln share of rented land					
Ln farm sales (per ha)					
Ln farm capital (per ha)					
Ln cattle livestock units					
Ln cattle livestock density					
Ln fertilizer expenditures (per ha)					
Ln pesticide expenditures (per ha)					
Less Favoured Area Program					
Ln farm sales	0.153	0.016	0.137	3.97	(***)
Ln on-farm labour	0.006	-0.015	0.021	1.22	
Ln off-farm labour	-0.008	0.004	-0.011	-1.67	
Ln area under cultivation	0.114	0.039	0.075	4.50	(***)
Ln share of grassland	-0.042	-0.068	0.026	0.91	
Ln share of rented land	0.042	0.002	0.040	1.18	
Ln farm sales (per ha)	0.039	-0.023	0.063	1.88	(*)
Ln farm capital (per ha)	0.004	0.020	-0.016	-0.42	
Ln cattle livestock units	-0.104	-0.203	0.100	1.95	(**)
Ln cattle livestock density	-0.091	-0.093	0.001	0.04	
Ln fertilizer expenditures (per ha)	0.129	0.211	-0.082	-1.71	(*)
Ln pesticide expenditures (per ha)	-0.016	0.127	-0.143	-2.48	(***)

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Common support' indicates that those observations from the treatment group are eliminated, for which the propensity score is higher than the maximum or less than the minimum propensity score of controls. '5 %-trimming' imposes common support by dropping 5 percent of the treatment observations at which the propensity score density of the control observations is the lowest (see Sianesi, 2001).

Table A6(a):
Results from 1:5 Matching with replacement (common support, 5 % trimming)

(a) Mean comparison of selected variables in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.685	**4.783**	**4.608**	4.745	4.807	4.794
Ln on-farm labour	0.421	**0.307**	**0.403**	0.420	**0.326**	0.432
Ln off-farm labour	0.959	**1.055**	**0.881**	0.667	**1.159**	0.660
Ln area under cultivation	4.000	**3.932**	3.999	3.988	3.941	4.018
Ln share of grassland	3.060	**2.920**	**2.880**	2.922	2.304	2.908
Ln share of rented land	3.870	**3.698**	**3.793**	3.774	3.712	3.779
Ln farm sales (per ha)	0.686	**0.850**	**0.609**	0.756	**0.866**	0.776
Ln farm capital (per ha)	2.421	**2.349**	**2.483**	2.475	2.415	2.449
Ln cattle livestock units	3.233	**3.136**	**2.905**	3.065	**2.553**	3.078
Ln cattle livestock density	0.510	**0.545**	**0.466**	0.510	0.474	0.482
Ln fertilizer expend. (per ha)	-2.607	**-2.436**	-2.598	-2.675	**2.405**	2.687
Ln pesticide expend. (per ha)	-2.797	**-2.908**	2.813	-2.913	**2.585**	2.945
Dummy North	0.071	**0.413**	0.066	0.012	**0.372**	0.015
Dummy West	0.095	**0.493**	0.100	0.253	**0.330**	0.257
Dummy South	0.818	**0.081**	0.821	0.727	**0.284**	0.722
Dummy East	0.016	0.013	0.014	0.008	0.137	0.006
Number of observations	8,978	7,195	8,978	501	13,075	501

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A6(b):
Results from 1:5 Matching with replacement (common support, 5 % trimming)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales					
Ln on-farm labour					
Ln off-farm labour					
Ln area under cultivation		No treatment effects have been calculated since matching did **not** eliminate differences in covariates between participants and non-participants.			
Ln share of grassland					
Ln share of rented land					
Ln farm sales (per ha)					
Ln farm capital (per ha)					
Ln cattle livestock units					
Ln cattle livestock density					
Ln fertilizer expenditures (per ha)					
Ln pesticide expenditures (per ha)					
Less Favoured Area Program					
Ln farm sales	0.159	0.046	0.113	4.32	(***)
Ln on-farm labour	0.012	0.004	0.008	0.49	
Ln off-farm labour	-0.010	0.001	-0.011	-1.61	
Ln area under cultivation	0.115	0.053	0.062	4.93	(***)
Ln share of grassland	-0.040	-0.086	0.046	1.71	(*)
Ln share of rented land	0.047	0.013	0.035	1.31	
Ln farm sales (per ha)	0.045	-0.007	0.051	2.03	(*)
Ln farm capital (per ha)	0.003	0.004	0.000	-0.02	
Ln cattle livestock units	-0.100	-0.191	0.091	2.27	(**)
Ln cattle livestock density	-0.099	-0.080	-0.019	-0.67	
Ln fertilizer expenditures (per ha)	0.150	0.186	-0.037	-0.94	
Ln pesticide expenditures (per ha)	0.004	0.097	-0.093	-1.92	(**)

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Common support' indicates that those observations from the treatment group are eliminated, for which the propensity score is higher than the maximum or less than the minimum propensity score of controls. '5 %-trimming' imposes common support by dropping 5 percent of the treatment observations at which the propensity score density of the control observations is the lowest (see Sianesi, 2001).

Table A7(a):
Results from 1:1 Matching with replacement (Caliper 0.0001)

(a) Mean comparison of selected variables in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.730	**4.783**	**4.654**	4.782	4.807	4.777
Ln on-farm labour	0.402	**0.307**	**0.370**	0.410	**0.326**	0.426
Ln off-farm labour	0.936	**1.055**	0.993	0.856	**1.159**	0.857
Ln area under cultivation	4.022	**3.932**	4.024	3.932	3.941	3.848
Ln share of grassland	3.052	**2.920**	**2.880**	2.648	2.304	2.581
Ln share of rented land	3.873	**3.698**	**3.805**	3.668	3.712	3.730
Ln farm sales (per ha)	0.708	**0.850**	**0.631**	0.850	**0.866**	0.929
Ln farm capital (per ha)	2.380	**2.349**	**2.424**	2.584	2.415	2.550
Ln cattle livestock units	3.252	**3.136**	**2.945**	2.815	**2.553**	2.675
Ln cattle livestock density	0.518	**0.545**	**0.455**	0.519	0.474	0.523
Ln fertilizer expend. (per ha)	-2.565	**-2.436**	2.561	-2.546	**2.405**	2.476
Ln pesticide expend. (per ha)	-2.824	**-2.908**	2.845	-2.662	**2.585**	2.612
Dummy North	0.169	**0.413**	0.155	0.023	**0.372**	0.026
Dummy West	0.186	**0.493**	0.201	0.253	**0.330**	0.211
Dummy South	0.630	**0.081**	0.633	0.709	**0.284**	0.751
Dummy East	0.015	0.013	0.012	0.015	0.137	0.011
Number of observations	3,113	7,195	3,113	265	13,075	265

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A7(b):
Results from 1:1 Matching with replacement (Caliper 0.0001)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales					
Ln on-farm labour					
Ln off-farm labour					
Ln area under cultivation					
Ln share of grassland		No treatment effects have been calculated since matching did **not** eliminate differences in covariates between participants and non-participants.			
Ln share of rented land					
Ln farm sales (per ha)					
Ln farm capital (per ha)					
Ln cattle livestock units					
Ln cattle livestock density					
Ln fertilizer expenditures (per ha)					
Ln pesticide expenditures (per ha)					
Less Favoured Area Program					
Ln farm sales	0.132	0.054	0.078	1.98	(**)
Ln on-farm labour	0.019	-0.015	0.034	1.63	
Ln off-farm labour	-0.013	0.004	-0.017	-1.58	
Ln area under cultivation	0.121	0.064	0.058	3.27	(***)
Ln share of grassland	-0.062	-0.077	0.016	0.44	
Ln share of rented land	0.069	0.027	0.043	1.05	
Ln farm sales (per ha)	0.011	-0.010	0.020	0.52	
Ln farm capital (per ha)	-0.003	-0.002	-0.001	-0.01	
Ln cattle livestock units	-0.084	-0.098	0.013	0.33	
Ln cattle livestock density	-0.084	-0.098	0.013	0.33	
Ln fertilizer expenditures (per ha)	0.109	0.131	-0.022	-0.47	
Ln pesticide expenditures (per ha)	-0.020	0.035	-0.054	-0.83	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Caliper 0.0001' indicates the value for maximum difference of the propensity score between treatments and controls (see Sianesi, 2001).

Table A8(a):
(a) Results from 1:1 matching without replacement (Caliper 0.0001)

(a): Mean comparison of selected variables in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.807	**4.783**	4.790	4.783	4.807	4.784
Ln on-farm labour	0.375	**0.307**	0.357	0.406	**0.326**	0.430
Ln off-farm labour	0.978	**1.055**	0.958	0.879	**1.159**	0.823
Ln area under cultivation	4.032	**3.932**	4.011	3.931	3.941	3.855
Ln share of grassland	3.010	**2.920**	2.979	2.632	2.304	2.624
Ln share of rented land	3.776	**3.698**	3.786	3.673	3.712	3.714
Ln farm sales (per ha)	0.776	**0.850**	0.779	0.853	**0.866**	0.929
Ln farm capital (per ha)	2.321	**2.349**	2.3464	2.582	2.415	2.554
Ln cattle livestock units	3.217	**3.136**	3.154	2.830	**2.553**	2.746
Ln cattle livestock density	0.523	**0.545**	0.503	0.526	0.474	0.542
Ln fertilizer expend. (per ha)	-2.480	**-2.436**	2.512	-2.549	**2.405**	2.480
Ln pesticide expend. (per ha)	-2.903	**-2.908**	2.944	-2.650	**2.585**	-2.615
Dummy North	0.358	**0.413**	0.320	0.023	**0.372**	0.027
Dummy West	0.389	**0.493**	0.423	0.260	**0.330**	0.221
Dummy South	0.229	**0.081**	0.236	0.702	**0.284**	0.740
Dummy East	0.024	0.013	0.021	0.016	0.137	0.012
Number of observations	1,401	7,195	1,401	244	13,075	244

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A8(b):
(a) Results from 1:1 matching without replacement (Caliper 0.0001)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value	
Agri-Environmental Programs					
Ln farm sales	0.082	0.062	0.020	1.47	
Ln on-farm labour	0.001	-0.013	0.015	1.33	
Ln off-farm labour	-0.006	-0.000	-0.005	-1.06	
Ln area under cultivation	0.078	0.043	0.035	5.03	(***)
Ln share of grassland	-0.048	-0.102	0.054	2.74	(***)
Ln share of rented land	0.018	-0.020	0.038	2.25	(**)
Ln farm sales (per ha)	0.004	0.018	-0.015	-1.10	
Ln farm capital (per ha)	0.048	0.036	0.012	0.73	
Ln cattle livestock units	-0.195	-0.173	-0.022	-0.75	
Ln cattle livestock density	-0.112	-0.055	-0.057	-2.97	(***)
Ln fertilizer expenditures (per ha)	0.049	0.123	-0.074	-3.12	(***)
Ln pesticide expenditures (per ha)	-0.001	0.044	-0.045	-1.67	(*)
Less Favoured Area Program					
Ln farm sales	0.130	0.048	0.082	2.13	(**)
Ln on-farm labour	0.023	-0.024	0.046	2.25	
Ln off-farm labour	-0.013	0.004	-0.017	-1.60	
Ln area under cultivation	0.120	0.064	0.056	3.22	(***)
Ln share of grassland	-0.059	-0.072	0.013	0.36	
Ln share of rented land	0.061	0.035	0.026	0.66	
Ln farm sales (per ha)	0.010	-0.016	0.026	0.67	
Ln farm capital (per ha)	-0.001	-0.008	0.006	0.14	
Ln cattle livestock units	-0.105	-0.151	0.046	0.76	
Ln cattle livestock density	-0.085	-0.105	0.020	0.50	
Ln fertilizer expenditures (per ha)	0.111	0.123	-0.012	-0.26	
Ln pesticide expenditures (per ha)	-0.024	0.027	-0.051	-0.80	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Caliper, 0.0001' indicates the value for maximum difference of the propensity score between treatments and controls (see Sianesi, 2001).

Table A9(a):
Results from Kernel Matching
(Kernel type biweight, bandwidth 0.06 for AE programs and 0.005 for the LFA scheme)

(a) Mean comparison of selected variables in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.687	**4.783**	**4.584**	4.744	4.807	4.788
Ln on-farm labour	0.425	**0.307**	**0.383**	0.420	**0.326**	0.433
Ln off-farm labour	0.958	**1.055**	1.012	0.666	**1.159**	0.725
Ln area under cultivation	4.015	**3.932**	**3.949**	3.988	3.941	4.029
Ln share of grassland	3.070	**2.920**	**2.832**	2.924	2.304	2.905
Ln share of rented land	3.879	**3.698**	**3.750**	3.774	3.712	3.795
Ln farm sales (per ha)	0.672	**0.850**	**0.635**	0.756	**0.866**	0.759
Ln farm capital (per ha)	2.406	**2.349**	**2.545**	2.476	2.415	2.436
Ln cattle livestock units	3.237	**3.136**	**2.837**	3.068	**2.553**	3.072
Ln cattle livestock density	0.499	**0.545**	**0.453**	0.511	0.474	0.486
Ln fertilizer expend. (per ha)	-2.623	**-2.436**	**2.597**	-2.676	**2.405**	2.702
Ln pesticide expend. (per ha)	-2.803	**-2.908**	2.786	-2.913	**2.585**	2.959
Dummy North	0.070	**0.413**	0.064	0.012	**0.372**	0.065
Dummy West	0.094	**0.493**	0.099	0.253	**0.330**	0.252
Dummy South	0.821	**0.081**	0.823	0.727	**0.284**	0.675
Dummy East	0.016	0.013	0.014	0.008	0.137	0.008
Number of observations	9,135	7,195	9,135	502	13,075	502

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A9(b):
Results from Kernel Matching
(Kernel type biweight, bandwidth 0.06 for AE programs and 0.005 for the LFA scheme)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales					
Ln on-farm labour					
Ln off-farm labour					
Ln area under cultivation					
Ln share of grassland		No treatment effects have been calculated since matching did **not** eliminate differences in covariates between participants and non-participants.			
Ln share of rented land					
Ln farm sales (per ha)					
Ln farm capital (per ha)					
Ln cattle livestock units					
Ln cattle livestock density					
Ln fertilizer expenditures (per ha)					
Ln pesticide expenditures (per ha)					
Less Favoured Area Program					
Ln farm sales	0.159	0.055	0.104	3.94	(***)
Ln on-farm labour	0.012	-0.001	0.013	0.74	
Ln off-farm labour	-0.010	0.001	-0.011	-1.32	
Ln area under cultivation	0.115	0.046	0.068	5.54	(***)
Ln share of grassland	-0.040	-0.075	0.035	1.24	
Ln share of rented land	0.047	0.002	0.045	1.64	
Ln farm sales (per ha)	0.045	0.009	0.036	1.41	
Ln farm capital (per ha)	0.004	0.007	-0.003	-0.09	
Ln cattle livestock units	-0.100	-0.173	0.073	1.77	(*)
Ln cattle livestock density	-0.098	-0.065	-0.033	-1.20	
Ln fertilizer expenditures (per ha)	0.151	0.200	-0.050	-1.38	
Ln pesticide expenditures (per ha)	0.004	0.079	-0.076	-1.69	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Kerneltype biweight', specifies the biweight kernel function that determines the weight assigned to observations depending on the distance between treatment and controls. The biweight kernel gives the most weight to nearest control observations (see Sianesi, 2001).

Table A10(a):
Results from Greedy Matching (cross-section estimation)

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in year 2005

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.854	**4.823**	4.824	4.886	4.858	4.839
Ln on-farm labour	0.372	**0.298**	0.351	0.428	**0.323**	0.453
Ln off-farm labour	1.154	**1.224**	1.147	0.715	**1.157**	0.740
Ln area under cultivation	4.129	**3.976**	**4.081**	4.070	**3.995**	4.031
Ln share of grassland	3.021	**2.833**	2.948	2.809	**2.231**	2.735
Ln share of rented land	3.796	**3.684**	3.779	3.788	**3.706**	3.760
Ln farm sales (per ha)	0.725	**0.847**	0.743	0.817	**0.863**	0.808
Ln farm capital (per ha)	2.336	2.398	2.366	2.521	2.460	2.483
Ln cattle livestock units	3.060	**2.939**	3.040	2.894	**2.333**	2.779
Ln cattle livestock density	0.381	**0.467**	0.446	0.416	0.384	0.413
Ln fertilizer expend. (per ha)	-2.460	**-2.345**	-2.385	-2.501	**-2.280**	-2.446
Ln pesticide expend. (per ha)	-2.965	-2.911	-2.970	-2.865	**-2.591**	-2.771
Dummy North	593	**2,970**	541	6	**4,865**	5
Dummy West	711	**3,549**	751	108	**4,313**	108
Dummy South	451	**581**	463	334	**3,718**	337
Dummy East	52	95	52	4	179	2
Number of observations	1,807	7.195	1,807	452	13.075	452

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level.

Table A10(b):
Results from Greedy Matching (cross-section estimation)

(b) Average treatment effect (ATT) of the treated for AE and LFA programs (2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	4.854	4.824	0.030	1.06	
Ln on-farm labour	0.372	0.351	0.021	1.33	
Ln off-farm labour	1.154	1.147	0.007	0.08	
Ln area under cultivation	4.129	4.081	0.048	2.34	(**)
Ln share of grassland	3.021	2.948	0.073	1.67	(*)
Ln share of rented land	3.796	3.779	0.017	0.53	
Ln farm sales (per ha)	0.725	0.743	-0.018	-0.73	
Ln farm capital (per ha)	2.336	2.366	-0.030	-1.14	
Ln cattle livestock units	3.060	3.04	0.020	0.32	
Ln cattle livestock density	0.381	0.446	-0.065	-3.40	(***)
Ln fertilizer expenditures (per ha)	-2.460	-2.385	-0.075	-3.43	(***)
Ln pesticide expenditures (per ha)	-2.965	-2.970	0.005	0.12	
Less Favoured Area Program					
Ln farm sales	4.886	4.839	0.047	0.88	
Ln on-farm labour	0.428	0.453	-0.025	-0.83	
Ln off-farm labour	0.715	0.740	-0.025	-0.17	
Ln area under cultivation	4.070	4.031	0.039	0.99	
Ln share of grassland	2.809	2.735	0.074	0.75	
Ln share of rented land	3.788	3.760	0.028	0.43	
Ln farm sales (per ha)	0.817	0.808	0.009	0.19	
Ln farm capital (per ha)	2.521	2.483	0.038	0.75	
Ln cattle livestock units	2.894	2.779	0.115	0.88	
Ln cattle livestock density	0.416	0.413	0.003	0.08	
Ln fertilizer expenditures (per ha)	-2.501	-2.446	-0.055	-1.39	
Ln pesticide expenditures (per ha)	-2.865	-2.771	-0.094	-1.29	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. The ATT in 'cross-section estimation' is computed as the mean difference of mean characteristics of treatment and controls in year 2005.

Table A11(a)

Results from Greedy Matching applying an 'naïve estimator'

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in year 2000

	Agri-Environmental Programs		Less Favoured Area Program	
	(1)	(2)	(3)	(4)
Variable	All Treatments	All Controls	All Treatments	All Controls
Ln farm sales	4.687	**4.783**	4.744	4.807
Ln on-farm labour	0.425	**0.307**	0.420	**0.326**
Ln off-farm labour	1.059	1.118	0.666	**1.159**
Ln area under cultivation	4.015	**3.932**	3.988	3.941
Ln share of grassland	3.070	**2.920**	2.924	**2.304**
Ln share of rented land	3.879	**3.698**	3.774	3.712
Ln farm sales (per ha)	0.672	**0.850**	0.756	**0.866**
Ln farm capital (per ha)	2.406	**2.349**	2.476	2.414
Ln cattle livestock units	3.237	**3.135**	3.067	**2.553**
Ln cattle livestock density	0.499	**0.545**	0.511	0.474
Ln fertilizer expenditures (per ha)	-2.661	**-2.443**	-2.690	**-2.409**
Ln pesticide expenditures (per ha)	-2.874	**-2.952**	-3.000	**-2.617**
Dummy North	634	**2,970**	6	**4,865**
Dummy West	856	**3,549**	127	**4,313**
Dummy South	7,505	**581**	365	**3,718**
Dummy East	143	95	4	179
Number of observations	9,138	7,195	502	13,075

Table A11(b)

Results from Greedy Matching applying an 'naïve estimator'

(b) Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 - 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.097	0.041	0.056	8.69	(***)
Ln on-farm labour	0.004	-0.009	0.013	2.57	(*)
Ln off-farm labour	-0.005	-0.003	-0.002	-1.06	
Ln area under cultivation	0.086	0.044	0.042	13.70	(***)
Ln share of grassland	-0.042	-0.087	0.045	5.78	(***)
Ln share of rented land	0.025	-0.014	0.039	5.73	(***)
Ln farm sales (per ha)	0.011	-0.003	0.014	2.30	(**)
Ln farm capital (per ha)	-0.019	0.050	-0.069	-9.47	(***)
Ln cattle livestock units	-0.163	-0.197	0.034	2.87	(***)
Ln cattle livestock density	-0.112	-0.078	-0.034	-4.37	(***)
Ln fertilizer expenditures (per ha)	0.118	0.091	0.027	2.98	(***)
Ln pesticide expenditures (per ha)	-0.048	0.026	-0.074	-6.73	(***)
Less Favoured Area Program					
Ln farm sales	0.159	0.052	0.107	5.67	(***)
Ln on-farm labour	0.012	-0.002	0.014	1.19	
Ln off-farm labour	-0.010	-0.002	-0.008	-1.31	
Ln area under cultivation	0.115	0.055	0.060	6.46	(***)
Ln share of grassland	-0.040	-0.073	0.033	1.90	(*)
Ln share of rented land	0.047	-0.006	0.053	2.67	(***)
Ln farm sales (per ha)	0.045	-0.003	0.048	2.61	(***)
Ln farm capital (per ha)	0.004	0.045	-0.041	-1.84	(*)
Ln cattle livestock units	-0.100	-0.220	0.120	3.38	(***)
Ln cattle livestock density	-0.098	-0.090	-0.008	-0.39	
Ln fertilizer expenditures (per ha)	0.151	0.125	0.026	1.05	
Ln pesticide expenditures (per ha)	0.004	-0.006	0.010	0.32	

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5 % level. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level. 'Naïve estimator' means that the difference-in-difference estimator was applied without control for pre-treatment characteristics in year 2000.

Table A12(a)

Results from Greedy Matching (one year of participation)

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.871	**4.777**	4.871	4.816	4.785	4.822
Ln on-farm labour	0.313	**0.267**	0.305	0.335	0.317	0.263
Ln off-farm labour	1.067	1.164	1.145	1.354	1.211	1.221
Ln area under cultivation	4.057	**3.905**	4.057	4.022	**3.928**	4.065
Ln share of grassland	2.829	**2.946**	2.808	2.360	2.307	2.507
Ln share of rented land	3.812	**3.714**	3.797	3.884	**3.706**	3.812
Ln farm sales (per ha)	0.814	**0.871**	0.814	0.793	**0.857**	0.757
Ln farm capital (per ha)	2.314	2.329	2.308	2.424	2.420	2.412
Ln cattle livestock units	2.700	2.762	2.701	2.553	2.520	2.774
Ln cattle livestock density	0.460	0.484	0.458	0.473	0.459	0.451
Ln fertilizer expend. (per ha)	-2.456	-2.433	-2.455	-2.527	**-2.421**	-2.491
Ln pesticide expend. (per ha)	-2.728	**-2.861**	-2.751	-2.660	-2.622	-2.670
Dummy North	519	**3,791**	503	37	**5,518**	47
Dummy West	3	**4,473**	633	73	**4,892**	72
Dummy South	309	**679**	321	192	**4,244**	179
Dummy East	70	**120**	64	4	214	8
Number of observations	1,521	9,063	1,521	306	14,868	306

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5% level.

Table A12(b)

Results from Greedy Matching (one year of participation)

(b) Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.067	0.046	0.021	1.30	
Ln on-farm labour	0.015	0.016	-0.001	-0.12	
Ln off-farm labour	-0.007	-0.005	-0.002	-0.37	
Ln area under cultivation	0.076	0.045	0.031	3.73	(***)
Ln share of grassland	-0.090	-0.059	-0.031	-1.50	
Ln share of rented land	0.006	-0.033	0.039	2.40	(**)
Ln farm sales (per ha)	-0.009	0.001	-0.010	-0.62	
Ln farm capital (per ha)	0.046	0.072	-0.026	-1.39	
Ln cattle livestock units	-0.228	-0.153	-0.075	-2.68	(***)
Ln cattle livestock density	-0.103	-0.048	-0.055	-2.81	(***)
Ln fertilizer expenditures (per ha)	0.104	0.125	-0.021	-0.91	
Ln pesticide expenditures (per ha)	0.007	-0.01	0.017	0.70	
Less Favoured Area Program					
Ln farm sales	0.086	0.089	-0.003	-0.10	
Ln on-farm labour	0.028	0.063	-0.035	-1.06	
Ln off-farm labour	-0.011	0.000	-0.011	-0.82	
Ln area under cultivation	0.096	0.078	0.018	0.97	
Ln share of grassland	-0.050	-0.124	0.074	1.71	(*)
Ln share of rented land	0.024	0.029	-0.005	-0.17	
Ln farm sales (per ha)	-0.009	0.011	-0.020	-0.71	
Ln farm capital (per ha)	-0.051	-0.07	0.019	0.48	
Ln cattle livestock units	-0.290	-0.209	-0.081	-1.20	
Ln cattle livestock density	-0.196	-0.087	-0.109	-2.45	(**)
Ln fertilizer expenditures (per ha)	0.114	0.065	0.049	0.94	
Ln pesticide expenditures (per ha)	-0.016	-0.031	0.015	0.27	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level.

Table A13(a)

Results from Greedy Matching (two years participation)

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.804	4.769	4.798	4.658	**4.798**	4.751
Ln on-farm labour	0.360	**0.288**	0.344	0.332	0.325	0.385
Ln off-farm labour	1.129	1.116	0.963	1.221	1.220	1.232
Ln area under cultivation	4.002	**3.929**	3.992	3.989	3.933	3.949
Ln share of grassland	2.907	2.948	2.954	2.830	**2.322**	2.701
Ln share of rented land	3.780	3.725	3.762	3.820	3.708	3.839
Ln farm sales (per ha)	0.802	0.841	0.806	0.669	**0.863**	**0.801**
Ln farm capital (per ha)	2.378	**2.313**	2.351	2.427	2.415	2.421
Ln cattle livestock units	3.140	3.149	3.168	2.905	**2.560**	2.607
Ln cattle livestock density	0.536	0.544	0.572	0.412	0.471	0.379
Ln fertilizer expend. (per ha)	-2.500	**-2.442**	-2.482	-2.761	**-2.421**	-2.744
Ln pesticide expend. (per ha)	-2.877	**-2.985**	-2.924	-2.805	**-2.615**	-2.82
Dummy North	198	**3,360**	193	22	**5,281**	19
Dummy West	358	**3,827**	368	37	**4,651**	34
Dummy South	250	**582**	246	122	**3,948**	127
Dummy East	31	**109**	30	2	191	3
Number of observations	837	7,878	837	183	14,071	183

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5% level.

Table A13(b)

Results from Greedy Matching (two years participation)

(b) Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.050	0.026	0.024	0.87	
Ln on-farm labour	0.002	0.000	0.002	0.10	
Ln off-farm labour	0.000	-0.003	0.003	0.53	
Ln area under cultivation	0.066	0.040	0.026	2.19	(**)
Ln share of grassland	-0.107	-0.159	0.052	1.83	(*)
Ln share of rented land	0.012	-0.010	0.022	1.08	
Ln farm sales (per ha)	-0.016	-0.013	-0.003	-0.10	
Ln farm capital (per ha)	0.046	0.041	0.005	0.20	
Ln cattle livestock units	-0.255	-0.207	-0.048	-1.14	
Ln cattle livestock density	-0.111	-0.074	-0.037	-1.29	
Ln fertilizer expenditures (per ha)	0.047	0.116	-0.069	-2.32	(**)
Ln pesticide expenditures (per ha)	-0.005	0.073	-0.078	-2.07	(**)
Less Favoured Area Program					
Ln farm sales	0.059	0.032	0.027	0.47	
Ln on-farm labour	-0.024	0.020	-0.044	-1.26	
Ln off-farm labour	0.008	0.003	0.005	0.79	
Ln area under cultivation	0.083	0.071	0.012	0.60	
Ln share of grassland	-0.068	-0.058	-0.010	-0.21	
Ln share of rented land	0.047	0.006	0.041	0.80	
Ln farm sales (per ha)	-0.024	-0.038	0.014	0.27	
Ln farm capital (per ha)	-0.018	0.029	-0.047	-0.73	
Ln cattle livestock units	-0.162	-0.154	-0.008	-0.11	
Ln cattle livestock density	-0.079	-0.004	-0.075	-1.19	
Ln fertilizer expenditures (per ha)	0.165	0.243	-0.078	-1.05	
Ln pesticide expenditures (per ha)	-0.096	-0.024	-0.072	-0.89	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level.

Table A14(a)

Results from Greedy Matching (three years participation)

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in the year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.753	4.769	4.754	4.738	4.805	4.791
Ln on-farm labour	0.347	**0.288**	0.353	0.436	**0.326**	0.458
Ln off-farm labour	1.136	1.117	1.157	0.617	**1.223**	0.679
Ln area under cultivation	3.961	**3.930**	3.934	3.825	**3.941**	3.844
Ln share of grassland	2.982	2.949	2.993	2.934	**2.304**	2.815
Ln share of rented land	3.732	3.727	3.720	3.544	**3.713**	3.540
Ln farm sales (per ha)	0.792	**0.839**	0.820	0.912	0.864	0.947
Ln farm capital (per ha)	2.443	**2.310**	2.424	2.704	**2.411**	2.637
Ln cattle livestock units	3.252	3.150	3.290	3.022	**2.548**	3.025
Ln cattle livestock density	0.573	0.543	0.576	0.578	**0.470**	0.556
Ln fertilizer expend. (per ha)	-2.486	**-2.443**	-2.487	-2.640	**-2.410**	-2.627
Ln pesticide expend. (per ha)	-2.908	**-2.987**	-2.951	-3.046	**-2.617**	-3.011
Dummy North	208	**3,372**	202	7	**5,180**	7
Dummy West	357	**3,831**	350	38	**4,578**	41
Dummy South	415	**582**	425	158	**3,898**	156
Dummy East	26	117	29	3	197	2
Number of observations	1,006	7,902	1,006	206	13,853	206

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5% level.

Table A14(b)

Results from Greedy Matching (three years participation)

(b) Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.022	0.036	-0.014	-0.60	
Ln on-farm labour	0.006	-0.008	0.014	0.85	
Ln off-farm labour	-0.003	-0.006	0.003	0.51	
Ln area under cultivation	0.065	0.038	0.027	2.73	(***)
Ln share of grassland	-0.069	-0.116	0.047	2.01	(**)
Ln share of rented land	-0.016	-0.006	-0.010	-0.48	
Ln farm sales (per ha)	-0.043	-0.003	-0.040	-1.86	(*)
Ln farm capital (per ha)	0.017	0.050	-0.033	-1.67	
Ln cattle livestock units	-0.227	-0.187	-0.040	-1.11	
Ln cattle livestock density	-0.112	-0.059	-0.053	-2.37	(**)
Ln fertilizer expenditures (per ha)	0.023	0.090	-0.067	-2.26	(**)
Ln pesticide expenditures (per ha)	-0.028	0.028	-0.056	-1.68	(*)
Less Favoured Area Program					
Ln farm sales	0.093	0.073	0.020	0.45	
Ln on-farm labour	-0.025	0.001	-0.026	-0.90	
Ln off-farm labour	-0.002	-0.005	0.003	0.53	
Ln area under cultivation	0.109	0.078	0.031	1.29	
Ln share of grassland	-0.036	-0.080	0.044	0.93	
Ln share of rented land	0.038	0.040	-0.002	-0.03	
Ln farm sales (per ha)	-0.016	-0.004	-0.012	-0.28	
Ln farm capital (per ha)	-0.009	-0.026	0.017	0.34	
Ln cattle livestock units	-0.174	-0.173	-0.001	-0.01	
Ln cattle livestock density	-0.136	-0.081	-0.055	-1.25	
Ln fertilizer expenditures (per ha)	0.113	0.143	-0.030	-0.54	
Ln pesticide expenditures (per ha)	0.030	0.091	-0.061	-0.80	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level.

Table A15(a)

Results from Greedy Matching (four years participation)

(a) Mean comparison of selected variables (Frequencies for Dummy Variables) in year 2000

	Agri-Environmental Programs			Less Favoured Area Program		
	(1)	(2)	(3)	(4)	(5)	(6)
Variables	Selected Treatments	Potential Controls	Selected Controls	Selected Treatments	Potential Controls	Selected Controls
Ln farm sales	4.717	**4.725**	4.725	4.773	4.798	4.744
Ln on-farm labour	0.336	**0.369**	0.335	0.374	0.325	0.393
Ln off-farm labour	1.216	1.150	1.114	0.757	**1.221**	0.618
Ln area under cultivation	3.999	**4.014**	3.992	4.098	**3.937**	4.143
Ln share of grassland	2.975	2.962	3.010	2.761	**2.324**	2.601
Ln share of rented land	3.736	**3.800**	3.753	3.889	**3.709**	3.955
Ln farm sales (per ha)	0.718	**0.711**	0.733	0.675	**0.861**	0.600
Ln farm capital (per ha)	2.366	**2.309**	2.376	2.316	2.412	2.317
Ln cattle livestock units	3.186	3.154	3.232	2.848	**2.562**	2.867
Ln cattle livestock density	0.502	0.544	0.518	0.387	**0.471**	0.426
Ln fertilizer expend. (per ha)	-2.531	**-2.442**	-2.527	-2.635	**-2.422**	-2.605
Ln pesticide expend. (per ha)	-2.962	-2.988	-2.990	-2.786	**-2.617**	-2.626
Dummy North	326	**3,365**	339	2	**5,298**	1
Dummy West	472	**3,824**	460	67	**4,651**	56
Dummy South	440	**582**	444	113	**3,956**	124
Dummy East	37	117	32	2	200	3
Number of observations	1,275	7,888	1,275	184	14,105	184

Notes: For variable definition and abbreviations see Table A1. Bold numbers indicate significantly different means between observation from the potential (selected) treatment group and from the potential (selected) control group in a t-test for equality of means at the 5% level.

Table A15(b)

Results from Greedy Matching (four years participation)

(b) Average treatment effect (ATT) of the treated for the AE and LFA programs (2000 – 2005)

	Treatments [1]	Controls [2]	ATT = [1] - [2]	t-value (Significance)	
Agri-Environmental Programs					
Ln farm sales	0.022	0.021	0.001	0.05	
Ln on-farm labour	0.001	0.01	-0.009	0.59	
Ln off-farm labour	0.003	0.002	0.001	0.18	
Ln area under cultivation	0.074	0.033	0.041	4.80	(***)
Ln share of grassland	-0.022	-0.107	0.085	4.07	(***)
Ln share of rented land	0.026	-0.013	0.039	2.16	(**)
Ln farm sales (per ha)	-0.052	-0.012	-0.040	-1.96	(**)
Ln farm capital (per ha)	-0.001	0.047	-0.048	-2.50	(**)
Ln cattle livestock units	-0.224	-0.208	-0.016	-0.51	
Ln cattle livestock density	-0.151	-0.054	-0.097	-4.29	(***)
Ln fertilizer expenditures (per ha)	0.037	0.113	-0.076	-2.75	(***)
Ln pesticide expenditures (per ha)	-0.046	0.001	-0.047	-1.58	
Less Favoured Area Program					
Ln farm sales	0.158	0.073	0.085	1.77	(*)
Ln on-farm labour	0.031	-0.011	0.042	1.49	
Ln off-farm labour	-0.027	0.002	-0.029	-1.83	(*)
Ln area under cultivation	0.109	0.065	0.044	1.84	(*)
Ln share of grassland	-0.027	-0.105	0.078	1.70	(*)
Ln share of rented land	0.017	-0.039	0.056	1.10	
Ln farm sales (per ha)	0.049	0.008	0.041	0.86	
Ln farm capital (per ha)	0.018	0.003	0.015	0.28	
Ln cattle livestock units	-0.025	-0.267	0.242	3.38	(***)
Ln cattle livestock density	-0.032	-0.117	0.085	1.71	(*)
Ln fertilizer expenditures (per ha)	0.184	0.183	0.001	0.02	
Ln pesticide expenditures (per ha)	-0.052	-0.017	-0.035	-0.51	

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 % (***), 5 % (**), or 10 % (*) level.

FigureA1:
Distribution of propensity scores ($p(\boldsymbol{X})$) of potential and selected treatment and controls in the AE and LFA programs

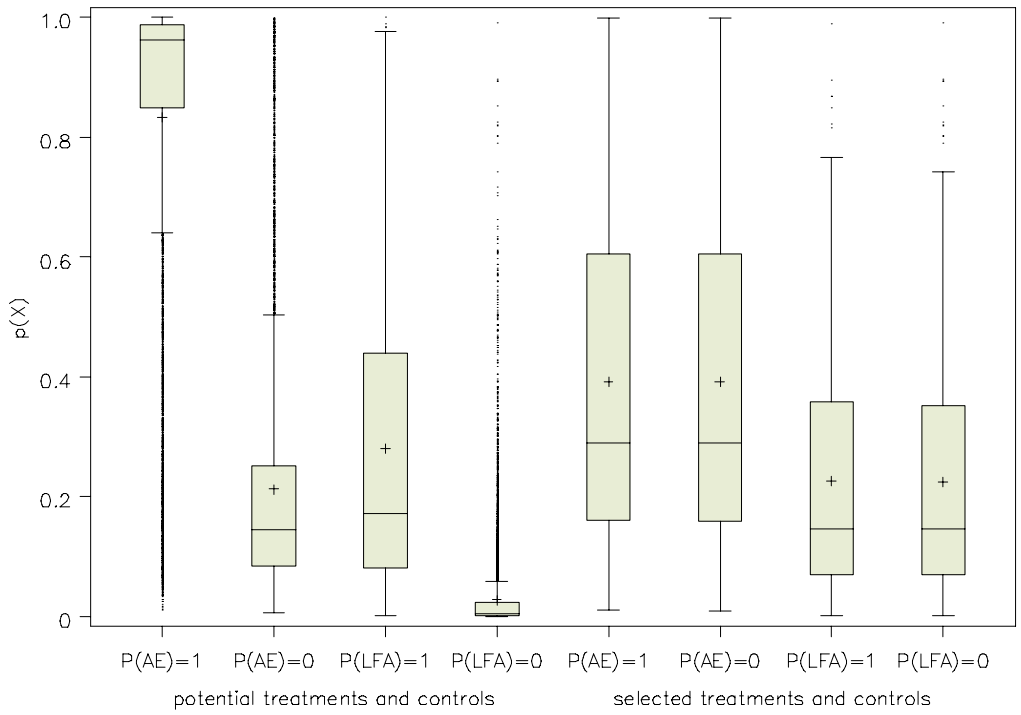
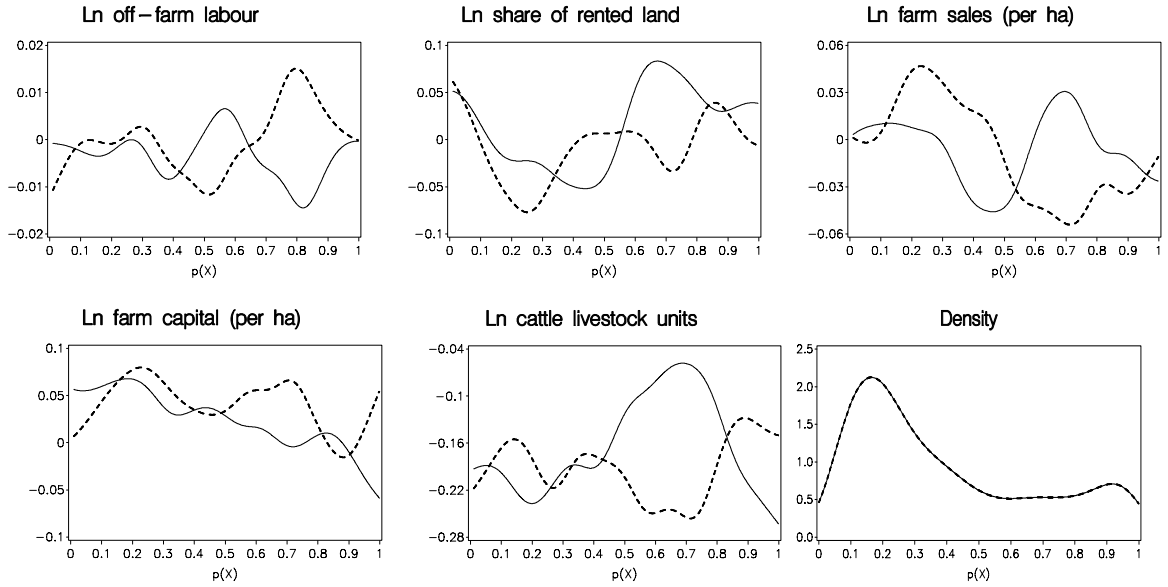


Figure A2:

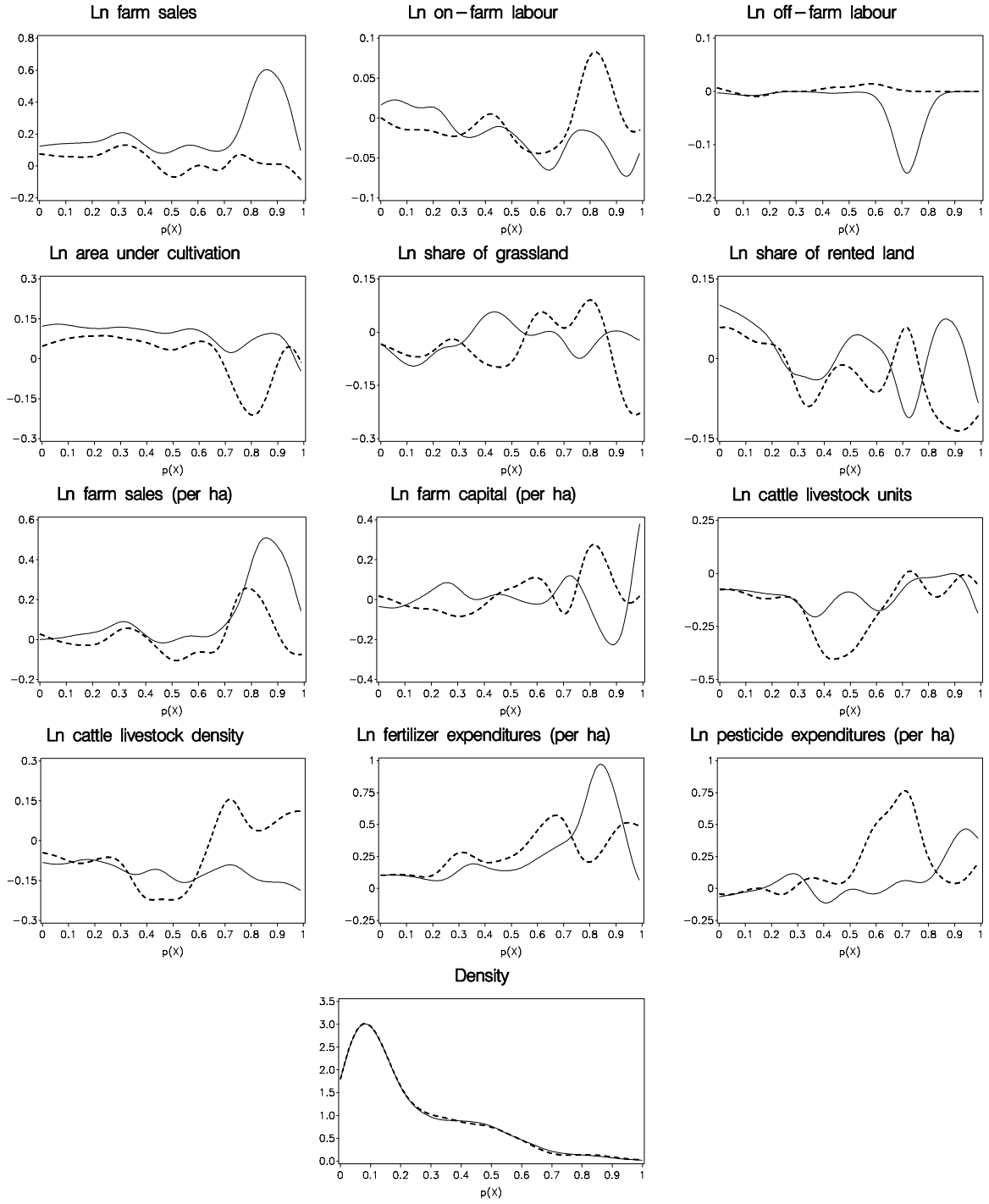
Nonparametric regression of the conditional participation probabilities ($p(\boldsymbol{X})$) on additional outcome variables for the AEP.



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. The solid (dotted) line represents the outcome variable for participants (non-participants) in AE programs. Note that the plots of the densities suggest that there is no substantial problem of non-overlapping support.

Figure A3:

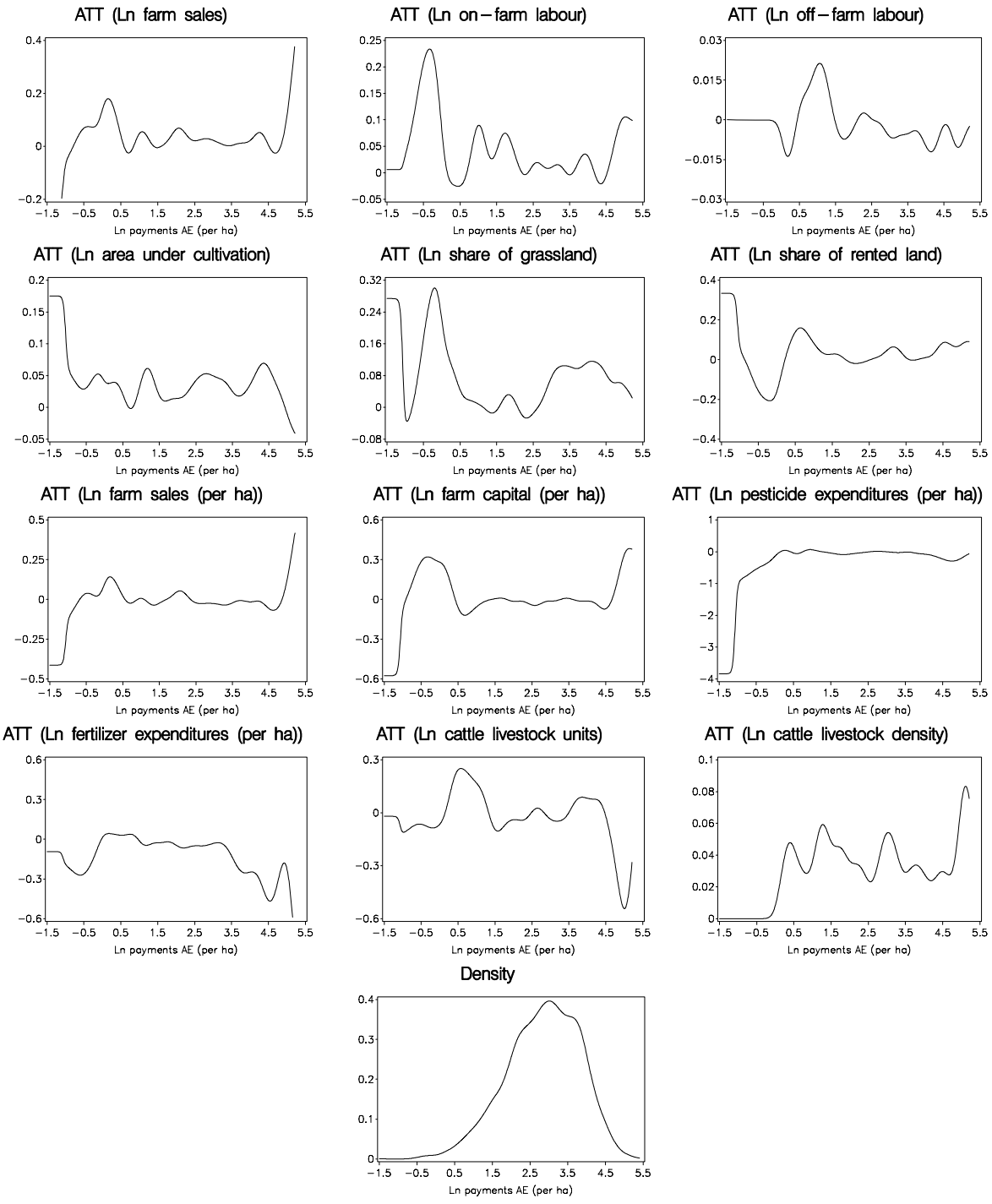
Nonparametric regression of the conditional participation probabilities ($p(\boldsymbol{X})$) on outcome variables for the LFA program.



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. The solid (dotted) line represents the outcome variable for participants (non-participants) in the LFA program. Note that the plots of the densities suggest that there is no substantial problem of non-overlapping support.

Figure A4

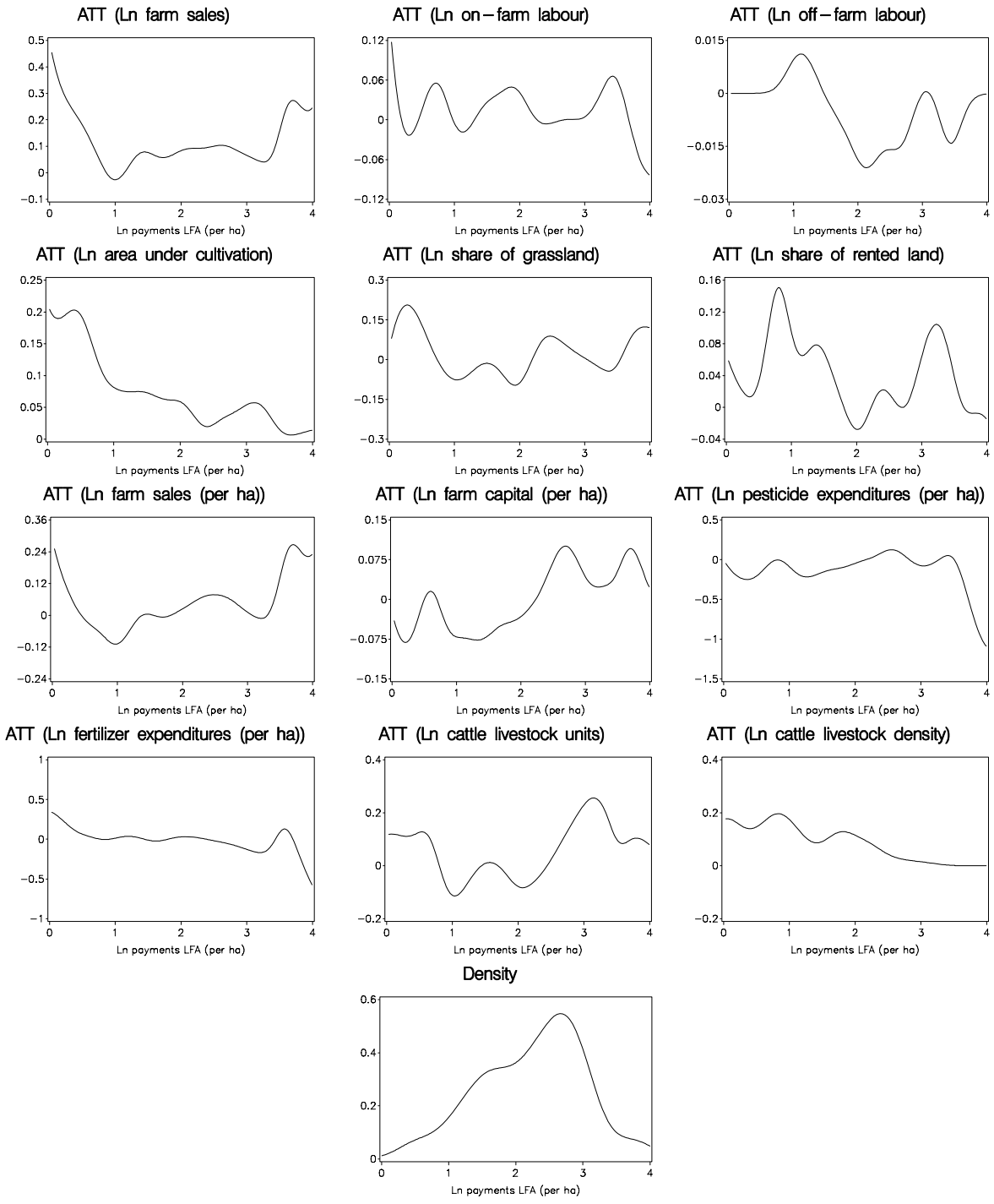
Nonparametric regression of the average (ln) program payments (per ha, 2001 – 2005) on the ATT for the AE programs.



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. Non-participants receive no payment, thus no dotted line is shown here. The solid line represents the outcome variable for participants in AE programs and can be interpreted as the causal effect of the program.

Figure A5

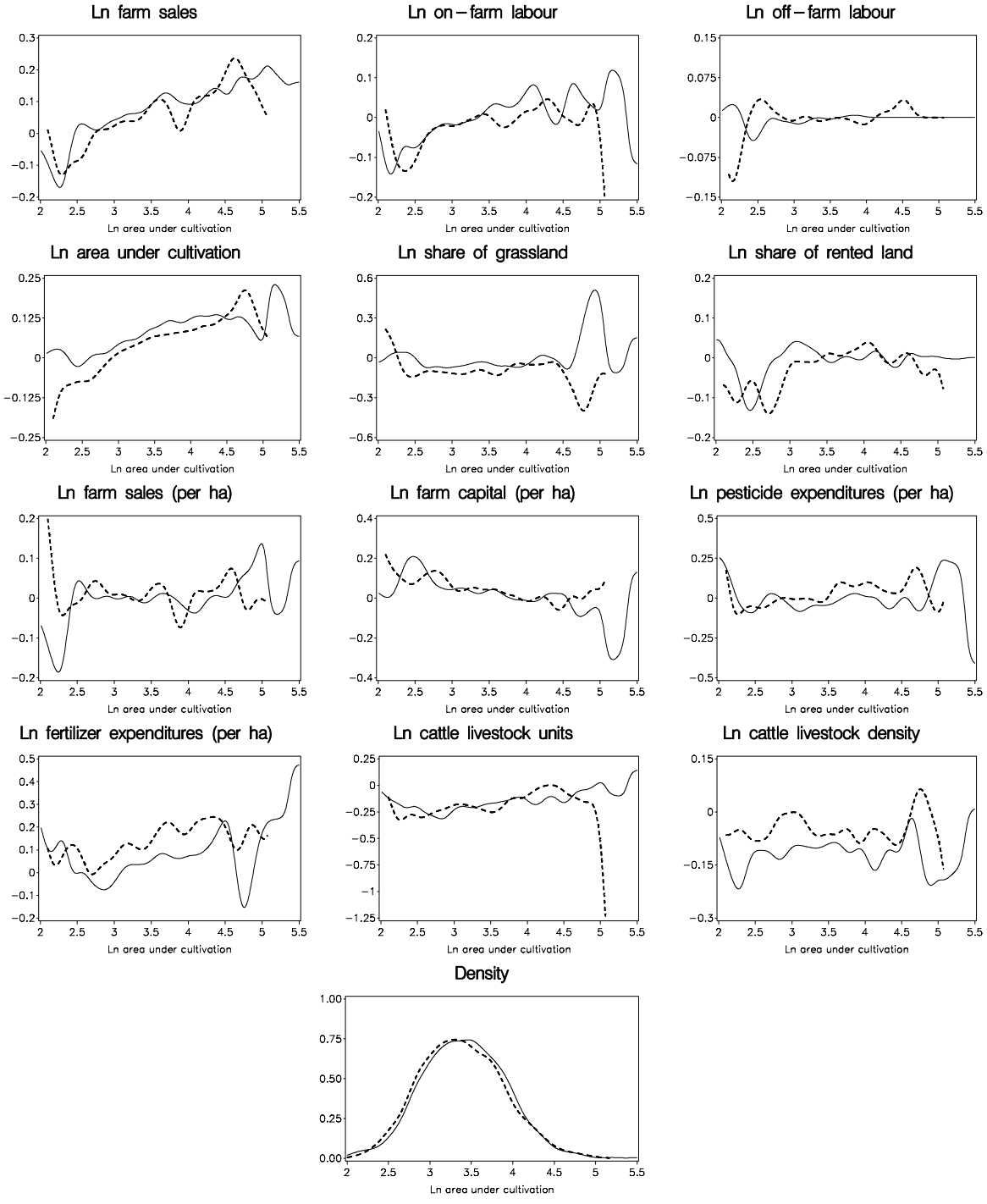
Nonparametric regression of the average (ln) program payments (per ha, 2001 – 2005) on the ATT for the LFA program.



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. Non-participants receive no payment, thus no dotted line is shown here. The solid line represents the outcome variable for participants in AE programs and can be interpreted as the causal effect of the program.

Figure A6

Nonparametric regression of the average (ln) area under cultivation (2001 – 2005) on outcome variables for the AE program.



Remarks: Nadaraya-Watson estimate using a Gaussian kernel and the rule-of-thumb bandwidth. The solid (dotted) line represents the outcome variable for participants (non-participants) in AE programs.

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