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**

I. 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 [1, 2], as well as for different regions [3, 4]. 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 et al. [3, 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. Government programs frequently have different objectives, and each program often uses a large set of diverse instruments to accommodate these goals. Further more, policy measures not only impact individual farmers directly but also can trigger indirect effects through a variety of mechanisms [5]. Given the very complex effects and interactions, economic theory often provides only limited guidance with respect to the ‘correct’ specification of an econometric model.

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. We should not expect to find the response to farm programs to be homogenous across individual farms. 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’). To distinguish between the two effects, an evaluator has to answer the 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 cannot be observed constitutes the ‘classical evaluation problem’.

The present paper applies a non-parametric propensity score matching approach to evaluate the effects of two types of farm programs (agri-environmental programs and the less favoured area scheme) for individual farms in Germany. The matching approach is widely used when evaluating labour market policies [6]. According to our knowledge, Lynch et al. [7] 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) 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 effects 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 policy objective has been realized. Instead, we follow previous studies and assess the effects of policy measures with respect to input use (land, labour, farm chemicals) and farm output (sales).

II. THE AGRI-ENVIRONMENT AND LESS FAVOURED AREA PROGRAM

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. Both measures are directly targeted to farm enterprises.

The average proportion of total farmland classified as LFA is 55 % in the EU-15. 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 zero in The Netherlands and Denmark [8]. Support for naturally less-favoured areas in Germany is available on 50 % of farmland. 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 [9]. The share of granted farmland on total farmland is highest in the southern part of Germany, followed by western and eastern states. LFA support has little relevance in the north of Germany due to superior natural conditions for agricultural production.

The EU's AE programs were introduced as 'Accompanying Measures' of the 1992 Mac Sharry Reform of the CAP. Farmers receive compensation payments for the adoption of environmentally favourable production technologies. Participation in the programs is voluntary and varies significantly between EU member states 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 [10]. 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. Support for reduced inputs on grassland and arable land and organic farming account for the largest share of AE expenditures in Germany [11].

III. 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, 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 [6, 12]. 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,

$$ATT = E\left(Y_i^1 - Y_i^0 \mid P_i = 1\right) = E\left(Y_i^1 \middle| P_i = 1\right) - E\left(Y_i^0 \middle| P_i = 1\right), \quad (1)$$

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 $E(Y_i^1 | P = 1)$ are available from the program participants. An evaluator's 'classic problem' 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.

The solution advanced by Rubin [13] is based on the assumption that given a set of observable covariates X, potential (non-treatment) outcomes are independent of the participation status (conditional independence assumption-CIA): $Y_i^0 \perp P_i \mid \boldsymbol{X}$. 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 et al. [14] 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:

$$ATT = \left(Y_{it}^1 - Y_{it'}^0 \mid P_i = 1, \boldsymbol{X}\right) - E\left(Y_{it}^0 - Y_{it'}^0 \mid P_i = 0, \boldsymbol{X}\right). \quad (2)$$

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 [15].

Instead of conditioning on *X*, Rosenbaum and Rubin [16] 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 $p(\boldsymbol{X}) \equiv \Pr\left(P_i = 1 \mid \boldsymbol{X} = \boldsymbol{x_i}\right)$. 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 calliper pair (1:1) matching without replacement is applied [17].

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.[1] 'LAND-Data' provides information on farm characteristics and on the participation in the AE and LFA program. Roughly one third of the 32,000 observations had to be eliminated due to missing data. To evaluate the effect of programme participation with the conditional d-i-d estimator, we focus only on those farms, which did not participate in the program in the initial time period (2000). The selection of data and the definition of the participation variables are described in Table 1 (for additional information on variable definition and data source see Table A1 in the appendix).

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 the base year 2000. From those farms, 9,138 farms (42.4 %) continually

[1] The sample is not representative for Germany as large-scale and full-time farm enterprises are over represented.

Table 1 Sample Selection Criteria and Program Participation

	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):		
P_{AE}=1 for farms continually participate in an AE program from 2001 until 2005 (for five years)	**9,138**	
P_{LFA}=1 for farms which continually participate in the LFA scheme starting from 2001, 2002 or 2003 until 2005 (for at least for three years)		**502**
Program participation in some years only (excluded from analysis):		
Farms with participation to AE program (for less than five years)	5,223	
Farms with participation to LFA scheme (for less than three years)		637
Continuous non-participation (2001 – 2005):		
P_{AE}=0 for farms with non-participation in AE programs	**7,195**	
P_{LFA}=0 for with non-participation in the LFA scheme between		**13,075**

participate in AE programs during the following five-year period from 2001 until 2005 (P_{AE} = 1). The dummy variable P_{AE} is set to zero for the 7,195 farms (33.4 %) that never participate in AE programs between 2001 and 2005. Those 5,223 farms (24.2 %) that participate in some years only, are excluded from the empirical analysis.

The participation in the LFA program is defined in a similar way. In the initial period 2000, 14,214 farms did not participate in the LFA program. In the case of the LFA program, the number of farms continually participating in the program in all five years (from 2001 until 2005) but not 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. The dummy variable P_{LFA} is set 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 (P_{LFA} = 0). The remaining 637 farms, which participate in a few years only, are eliminated from the empirical analysis.

IV. 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 (LFA scheme) correctly classifies 87.8 % (96.6 %) of all observations. From the parameter estimates of the logit models, the propensity score $x_i^{'}\hat{\beta}$ is calculated for every farm, which is then used for the matching analysis. Matching is considered successful when significant differences of covariates among participants and non-participants are removed. Table 2 reports unadjusted and adjusted mean differences of covariates among participants and non-participants of AE and LFA programs, in the pre-treatment year (2000).

Table 2: Mean comparison of selected variables (Frequencies for Dummies) 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 (1000 Euro)	4.781	**4.783**	4.776	4.742	**4.807**	4.783
Ln on-farm labour (FTE)	0.365	**0.307**	0.363	0.427	**0.326**	0.464
Ln off-farm labour (FTE)	1.080	1.118	1,083	0.723	**1.159**	0.740
Ln area under cultivation (ha)	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 cattle livestock units (LU)	0.728	**0.850**	0.737	0.787	**0.866**	0.812
Ln cattle livestock density (LU)	2.301	**2.349**	2.319	2.521	2.414	2.493
Ln farm sales (1000 Euro per ha)	3.247	**3.135**	3.227	2.995	**2.553**	2.926
Ln farm capital (1000 Euro per ha)	0.489	**0.545**	0.494	0.511	**0.474**	0.501
Ln fertilizer expenditures (1000 Euro per ha)	-2.522	**-2.443**	-2.532	-2.925	**-2.409**	-2.641
Ln pesticide expenditures (1000 Euro per ha)	-2.970	**-2.952**	-2.992	-2.640	**-2.617**	-2.871
Dummy North Germany	593	**2,970**	541	6	**4,865**	5
Dummy West Germany	711	**3,545**	751	108	**4,313**	108
Dummy South Germany	451	**581**	463	334	**3,718**	337
Dummy East Germany	52	**95**	52	4	179	2
Number of observations	1,807	7,195	1,807	452	13,075	452

Notes: Bold numbers indicate significantly different means between potential treatments and potential controls in a t-test for equality of means at the 5 % level.

Prior to the matching analysis, farms participating in AE and LFA programs significantly differ from non-participants with respect to nearly all characteristics shown in Table 2. A comparison between columns (1) and (2) ((4) and (5) respectively) indicates that farms enrolled in AE (LFA) programs are characterized by a higher amount of on-farm labour, for example. These differences in farm characteristics between program participants and non-participants are significantly different from zero.

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:

$$ATT = \frac{1}{N_1}\left(\sum_{i=1}^{N_1} \Delta Y_i^1 - \sum_{i=1}^{N_1} \Delta Y_i^0\right). \quad (3)$$

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).

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, while 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?

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 (1000 Euro)	0.073	0.048	0.025	1.72	(*)
Ln on-farm labour (FTE)	0.007	-0.012	0.019	1.95	(*)
Ln off-farm labour (FTE)	-0.003	-0.001	-0.002	-0.55	
Ln area under cultivation (ha)	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 (LU)	-0.187	-0.187	0.001	0.03	
Ln cattle livestock density (LU)	-0.108	-0.048	-0.060	-3.30	(***)
Ln farm sales (1000 Euro per ha)	-0.004	0.006	-0.010	-0.70	
Ln farm capital (1000 Euro per ha)	0.035	0.047	-0.012	-0.79	
Ln fertilizer expenditures (1000 Euro per ha)	0.037	0.131	-0.094	-4.57	(***)
Ln pesticide expenditures (1000 Euro per ha)	-0.025	0.022	-0.047	-1.97	(**)
Less Favoured Area Program					
Ln farm sales (1000 Euro)	0.144	0.056	0.088	2.96	(***)
Ln on-farm labour (FTE)	0.001	-0.012	0.013	0.83	
Ln off-farm labour (FTE)	-0.008	0.000	-0.008	-1.11	
Ln area under cultivation (ha)	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 (LU)	-0.102	-0.147	0.046	1.09	
Ln cattle livestock density (LU)	-0.095	-0.088	-0.007	-0.26	
Ln farm sales (1000 Euro per ha)	0.030	-0.004	0.034	1.17	
Ln farm capital (1000 Euro per ha)	0.000	-0.011	0.011	0.34	
Ln fertilizer expenditures (1000 Euro per ha)	0.132	0.169	-0.037	-0.91	
Ln pesticide expenditures (1000 Euro per ha)	-0.012	0.037	-0.049	-0.92	

Notes: Asterisks denote statistical significance in a t-test at 1 % (***), 5 % (**), or 10 % (*) level.

Results in Table 3 suggest that the increase in farm sales is paralleled by an increase in the area under cultivation. These results comply with findings of Key et al. [18]. Average growth rates of the area under cultivation differ significantly among program participants and non-participants. 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 farmland 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 these 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 cattle 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 farmland 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 farmland 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.

Table 3 does not suggest a significant treatment effect of AE programs on productivity (sales per hectare). This result corresponds to [1] 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.

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.

Participants in the AE program are required to reduce or abandon the use of 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 differs remarkably between the two programs. 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. No significant treatment effect is observed for the LFA program with respect to expenditures for farm chemicals.

C. Heterogeneity of Effects

It is plausible to expect that the treatment effect increases with the probability of participation in the program; that is, farmers who can generate the largest benefit from the program are most likely to participate. To check these hypotheses, we follow the approach suggested in Lechner [19]. The expectation of the outcome variable conditional on the conditional selection probability *(p(X))* in the pool of participants and non-participants is shown in Figure 1.

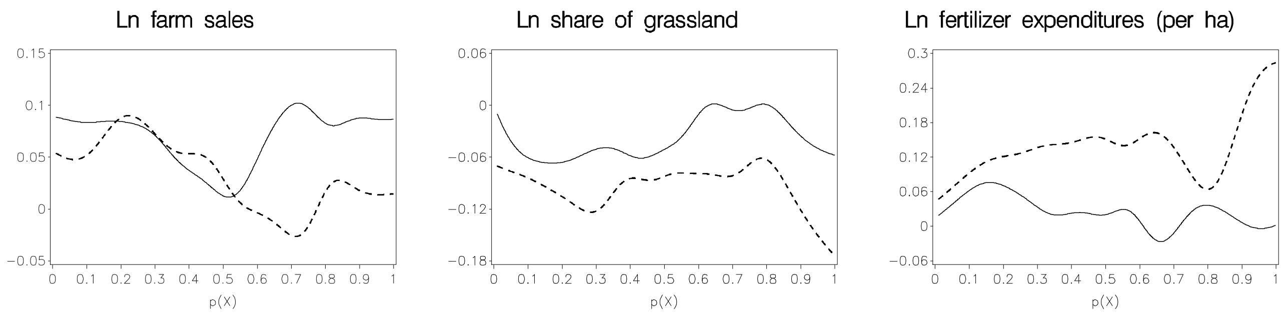

Fig. 1 Nonparametric regression of the conditional participation probabilities (p(X)) on selected outcome variable for the AE programs

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 comparison is based on kernel-smoothed regressions for program participants in AE programs (solid line) versus non-participants (dotted line).

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 are higher for farm sales and the share of grassland; and lower for fertilizer expenditures at (almost) all points, which is consistent with the average treatment effect of AE programs for these variables reported in Table 3. Similar results we observe for the LFA programs [20].

V. CONCLUSIONS

Evaluating the effects of farm programs is a key policy issue. 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; 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). Finally, the response to policies 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). The method turns out to be a useful technique for the empirical evaluation of farm programs. Specifically, we investigate the effects of two farm programs – agri-environment (AE) programs and the less favoured area (LFA) scheme – with respect to input use and farm output in Germany for the period 2000 to 2005.

The analysis reveals a positive and significant treatment effect of the LFA program on farm sales. 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. Compared to non-participation, AE participants significantly reduce expenditures for farm chemicals (fertilizer, pesticides). 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. We observe substantial differences in the treatment effects between farms (heterogeneous treatment effects). Farmers who can generate the largest benefit from the program are most likely to participate.

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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 income, including labour costs	1000 Euro	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
Livestock units (all livestock) (1 LSU = 1 milk cow)	LSU	2000-2005	LAND-Data
Ruminant livestock units (only cattle, goats)	LSU	2000-2005	LAND-Data
Forage area (only grassland, fodder crops)	ha	2000-2005	LAND-Data
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)
Land 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 Germany	0=no, 1=yes	2000-2005	LAND-Data
Dummy West Germany	0=no, 1=yes	2000-2005	LAND-Data
Dummy South Germany	0=no, 1=yes	2000-2005	LAND-Data

Abbreviations and Notes: ha = hectare, sqm = square meter, LU = Labour units, LSU = Livestock units. ‘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 (squared)	-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 ruminant livestock units	-0.106	7.526	(***)	-0.223	20.031	(***)
Ln ruminant livestock units (per ha forage area)	-0.118	2.075				
Ruminant 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 square meter	-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 Germany	-1.885	22.447	(***)			
Dummy West Germany	-1.151	4.281	(**)			
Dummy South Germany	1.326	5.303	(**)			
Ln area under cultivation*Dummy North Germany	0.073	0.686		-3.209	17.032	(***)
Ln area under cultivation*Dummy West Germany	-0.153	1.497		2.918	19.839	(***)
Ln area under cultivation*Dummy South Germany	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 prediction		87.79			96.61	
Non-Participants		90.81			99.54	
Participants		85.41			20.32	

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