111 EAAE-IAAE Seminar 'Small Farms: decline or persistence'

University of Kent, Canterbury, UK

26th-27th June 2009

Farm Structure and the Effects of Agri-Environmental Programs: Results from a Matching Analysis for European Countries

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Abstract : This paper extends previous research (Pufahl and Weiss, 2009) and applies a semi-parametric propensity score matching approach to evaluate the effects of agri-environment (AE) programs on input use and farm output of individual farms in eight Member States of the European Union. We find substantial differences in treatment effects between countries. The analysis reveals significant effects of AE participation on production (Germany, France) and farm profits (France, Ireland, United Kingdom). AE participation sporadically reduces the intensity of land use as measured by the purchase of farm chemicals (fertilizer, pesticide) and grazing livestock densities. We also find differences in the treatment effect among farms with different farm size (heterogeneous treatment effects).

Keywords: evaluation, agri-environment programs, propensity score matching, Germany, Italy, Spain, France, Portugal, United Kingdom, The Netherlands, EU-15

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1. INTRODUCTION

Evaluating the effects of farm programs on farm output is a key policy issue. This determines whether programs are condemned as trade distorting or can be classified as 'decoupled' and conform with WTO regulations. Further, changes in the focus of EU agricultural policy (towards more environmental types of support, for example) will have implications for farm structure and structural change. Depending (among other things) on the participation decisions of individual farmers, the impact of farm programs will differ between regions and individual Member States.

An empirical evaluation of the effects of farm programs however faces a number of challenges: First, farms self-select into program participation and participants and non-participants thus differ significantly in important characteristics (selection bias). Second, 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 in combination with a difference-in-difference estimator.[2] The key advantage of matching (over standard regression methods) is that it is less demanding with respect to the modelling assumptions. 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. Specifically, we aim at investigating the effects of agri-environment programs (AE programs) 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 for the period 2000 to 2005. We extend previous research (Pufahl and Weiss, 2009) by using FADN data for farms in Germany, Spain, France, Ireland, Italy, The Netherlands, Portugal and the United Kingdom. To evaluate and compare the effects of AE programs between EU Member States, the propensity score analysis will be carried out separately for each of the above mentioned countries. In addition, we investigate heterogeneous treatment effects within Member States.

The following Section 2 briefly describes AE programs and their implementation in EU-15. 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 draws some conclusions.

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[2] According to our knowledge, the first applications of these methods for individual farms are Lynch et al. (2007) and Pufahl and Weiss (2009).

2. AGRI-ENVIRONMENT PROGRAMS IN THE EU-15

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 per cent) of CAP expenditures, a minor but increasing part of the CAP budget (22 per cent) is allocated to rural development policies (EU Commission, 2006). Among them, AE programs account for 37 per cent of EU rural development expenditures (Agrar CEAS Consulting, 2005). These figures illustrate that AE programs became a core instrument of the rural development policies within the EU and are no longer of marginal importance within the CAP framework.

The EU's AE programs were introduced as 'Accompanying Measures' of the 1992 Mac Sharry Reform of the CAP. Since the 2000 CAP reform (EC Regulation No. 1257/1999), AE programs are categorized as 'second pillar' policies. Farmers receive compensation payments for the adoption of environmentally friendly production technologies. Agri-environment payments are calculated on an acreage base and are meant to cover the income foregone plus additional costs for compliance. Participation in AE programs is voluntary, restricted to farm enterprises and usually bound to renewable five year contracts. Program participation requires farm enterprises to meet pre-defined eligibility criteria that go beyond the level of 'good farming practise'. With few exceptions, program eligibility does not depend on the actual change of management practices. This enables farms that already comply with program eligibility criteria to enter AE programs.

The type of AE programs (AE schemes) offered and their acceptance among farmers varies significantly between EU member states as well as between different regions within member states. While more than eighty per cent of the total agricultural area is covered by at least one AE program in Austria, Finland, Sweden, and Luxemburg, the average share is around 26 per cent in the EU-15 (see Table 1). The varying share of AE programs in the EU-15 reflects the political relevance placed upon them, the financial capability of the Member States, as well as their opportunity costs of the adoption of AE programs (Glebe and Salhofer, 2007). The importance of AE programs tends to be high in countries with less favourable natural conditions for agricultural production and small scale farming structures as encountered in Scandinavia and Austria. On the contrary, AE programs are of minor importance in Denmark, The Netherlands and Belgium, where agriculture is dominated by large scale intensive livestock, milk and arable production.

The EU budget allotted to AE programs was 2.012 million Euros in 2003. The total spending on AE programs was about twice as much, as Member States co-finance EU expenditures with up to 50 %. The average EU expenditure per hectare farmland enrolled in AE programs is 60 Euro and 120 Euro when doubled by national co-finance (EEA, 2005). Theoretically, we should expect high AE payments in Member States with high opportunity costs of AE participation (e. g. The Netherlands) and/or high social benefits of AE programs (e. g. Austria and Ireland). Given the large variability of available AE schemes, natural conditions within Member States and the varying political power of the farming lobby in the Member States, country-specific observed AE payments per hectare do not always meet these theoretical expectations. In the empirical analysis, country-specific effects and natural conditions can be controlled to some extent, but we can not distinguish among different AE schemes. Organic farms are identified by a specific code but are too few in numbers to permit a separate analysis.

Table 1. Share of the agricultural land enrolled in AE programs and EU expenditures per area enrolled

	Share of farmland under AE programs (2002) *per cent*	EU expenditures to AE programs (2003)/contracted farmland (2002) *Euro/ha*
GRE	3.2	60.9
NED	3.2	140.5
ESP	8.9	54.1
DEN	11.1	62.0
BEL	11.7	83.8
UK	16.0	26.3
ITA	17.2	149.9
POR	17.5	99.5
GER	24.5	91.8
IRE	28.1	105.1
FRA	30.7	26.6
AUT	82.3	111.7
SWE	87.9	51.8
FIN	98.5	75.9
LUX	100.4	45.9
EU-15	26.4	60.2

Source: EEA (2005).

Predominant objectives of AE programs are the reduction of inputs (40 per cent of the supported area in the EU-15) and the maintenance of cultural landscapes (30 per cent of the supported area) (EEA, 2005). The choice of variables analysed in the present paper reflects AE objectives related to land use (area under cultivation, grassland), input reduction (cattle livestock density, pesticides and fertilizer purchase) and the maintenance of labour intensive traditional farm practices (on-farm labour). Of further interest is, whether AE programs have trade distortive production effects (farm sales) or create substantial windfall profits (farm net value added).

3. ESTIMATION METHOD AND DATA

Matching is a widely-used non-experimental method of evaluation that can be used to estimate the average effect of a particular program.[3] 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 distinguished by participation status P = 0/1, where 1 (0) indicates farms that did (not) participate in a program. Denote by Y^1 the outcome conditional on participation (P = 1) and by Y^0 the outcome conditional on non-participation (P = 0).

The most common evaluation parameter of interest is the 'average treatment effect on the treated' (ATT) defined as $ATT = E\left(Y^1 - Y^0 \mid P = 1\right) = E\left[Y^1 \mid P = 1\right] - E\left[Y^0 \mid P = 1\right]$, 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 $E(Y^1 | P = 1)$ are available from the program participants. An evaluator's 'classic problem'

3 A detailed discussion of the matching approach as well as a survey on its applications in labour-market evaluation studies is available in Caliendo and Kopeinig (2008).

is to find $E(Y^0 | P = 1)$, since data on non-participants enables one to identify $E(Y^0 | P = 0)$ only. So the difference between $E(Y^1 | P = 1)$ and $E(Y^0 | P = 1)$ 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 ***X***, potential (non-treatment) outcomes are independent of the participation status (conditional independence assumption-CIA): $Y^0 \perp P \mid \boldsymbol{X}$. Hence, after adjusting for observable differences, the mean of the potential outcome is the same for $P = 1$ and $P = 0$ ($E(Y^0 | P = 1, \boldsymbol{X}) = E(Y^0 | P = 0, \boldsymbol{X})$).

To improve the results of this estimator, Heckman et al. (1997) 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: $E\left(Y_t^1 - Y_{t'}^0 \mid P = 1, \boldsymbol{X}\right) - E\left(Y_t^0 - Y_{t'}^0 \mid P = 0, \boldsymbol{X}\right)$.

Instead of conditioning on ***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 $p(\boldsymbol{X}) \equiv \Pr(P = 1 \mid \boldsymbol{X} = \boldsymbol{x}_i)$. The propensity scores are derived from a logit model were participation in the AE program serves as the endogenous variable. The estimated propensity scores are then used to construct the comparison groups.

The empirical analysis is based on a balanced FADN panel from eight EU Member States (Germany, Spain, France, Ireland, Italy, The Netherlands, Portugal and United Kingdom) for which continuous records are available for the period 2001 to 2004. The analysed sample comprises 16,337 farms, which represent 1.8 million farm enterprises in the selected Member States. In the empirical analysis we weight each farm equally because farm-specific weights would not make the sample representative with respect to AE participation. FADN provides information on farm characteristics (area under cultivation, sales, on- and off farm labour, capital endowment and purchase for farm chemicals ...) and also includes information on the participation in AE programs. To evaluate the effect of program 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 (2001). The selection of data and the definition of program participation are described in Table 2 (for additional information on variable definitions and data sources see Table A1 in the appendix).

The basis for the empirical analysis (propensity score difference-in-difference matching) of AE programs are those 11,581 farms that did not participate in AE programs in the base year 2001. Participation is defined as receiving a positive amount of program payments. From those farms, 1,150 farms (9.9 per cent) participated in AE programs from 2002 or 2003 until 2004 (the dummy variable P_{AE} is set equal to one). The dummy variable is set equal to zero for the 8,854 farms (80.4 per cent) which never participate in AE programs between 2001 and

2004. Note that 1,577 farms (9.7 per cent) participate in some years only. These farms will not be used for the empirical analysis.[4]

Table 2. Sample Selection Criteria and Program Participation

	All	GER	ESP	FRA	IRE	ITA	NED	POR	UK
Total number of farms with records from 2001 to 2004*	16,337	4,063	3,785	4,071	873	679	633	817	1,416
Program participation in base year (2001)	4,756	2,528	170	913	255	266	144	150	330
Non-participation in base year (2001)	11,581	1,535	3,615	3,158	618	413	489	667	1,086
Program participation starts in 2002 or 2003 until 2004:									
Dummy variable (P_{AE}) is set equal to 1 for farms which participate in agri-environment programs from 2002 or 2003 until 2004 (for two or three years)	**1,150**	**304**	**74**	**438**	**55**	**26**	**23**	**140**	**90**
Program participation in 2003 or 2004 only (these farms are excluded from the empirical analysis):	1,577	544	244	377	33	59	43	104	173
Continuous non-participation (2001 – 2004):									
Dummy variable (P_{AE}) is set equal to 0 for farms which never participated in agri-environment programs between 2001 and 2004	**8,854**	**687**	**3,297**	**2,343**	**530**	**328**	**423**	**423**	**823**

Notes: * Excluding farms of the farm type ‘Horticulture’, ‘Wine’ and ‘Other permanent crops’.

4. EMPIRICAL RESULTS

4.1 Propensity Scores and Matching

Conditional probabilities for participation in AE programs are computed by estimating a logit model. Table A2 in the appendix reports the parameter estimates for the model, the results are only briefly discussed here. The estimated model is statistically significant at the 1 per cent level or better, as measured by the likelihood ratio test. The empirical model for AE programs correctly classifies 88.74 per cent of all observations, but only 0.57 per cent of participants. From the parameter estimates of the logit model, the bounded propensity scores are calculated for every farm which are then used for the matching analysis. The results when using the unbounded propensity scores are very similar.

The parameters included in the logit model mainly comprise pre-treatment outcomes in the reference year 2001. Since the decision of program participation is closely related to the objective of AE programs, these pre-treatment outcomes are important factors explaining the decision to participate in AE programs. Assuming a profit-maximising behaviour of farm enterprises, fixed AE payments per hectare and the predominance of input reducing AE schemes, farms with relatively low land use intensity (fertiliser expenditures, grazing

[4] An interesting extension of the present analysis would be to consider treatment effects in a dynamic framework. Lechner (2006) addresses some practical issues that come with the non- or semi-parametric estimation of models with sequential interventions.

livestock density) and unfavourable natural conditions (altitude zone) are most likely to participate to AE programs. The respective coefficients show the expected signs (Table A2). Member State differences between AE programs and factors influencing program participation (agricultural structure, management types) are captured by respective dummy variables.

Matching is considered successful when significant differences of covariates among participants and non-participants are removed. Table 3 reports unadjusted and adjusted means of covariates among participants and non-participants of AE programs for the pre-treatment year (2000).[5]

Table 3. Unadjusted and adjusted means of selected variables (frequencies for dummy variables) in the pre-treatment year 2001, all countries

	(1)	**(2)**	**(3)**	**(4)**
Variable	**Potential Treatments**	**Potential Controls**	**Selected Treatments**	**Selected Controls**
Farm sales	11.310	11.096 *	11.307	11.295
Farm sales (per ha)	7.153	7.266 *	7.166	7.165
Area under cultivation	4.160	3.835 *	4.143	4.152
Permanent pasture	2.051	1.471 *	2.028	2.041
Rented land	3.213	2.355 *	3.187	3.179
On-farm labour	8.264	8.099 *	8.242	8.248
On-farm labour (per 100 ha)	-0.501	-0.341 *	-0.506	-0.509
Farm net value added	67,529	48,684 *	59,843	58,211
Farm capital (per ha)	7.994	8.053 *	7.997	7.996
Grazing livestock units	3.078	2.322 *	3.046	3.085
Grazing livestock density	0.232	0.284 *	0.236	0.228
Pesticide expenditures (per ha)	3.115	2.945 *	3.141	3.141
Fertilizer expenditures (per ha)	3.981	4.120 *	4.029	4.007
Dummy variable ‘Arable farm’	346	3,916 *	340	347
Dummy variable ‘Dairy farm’	254	2092	252	253
Dummy variable ‘Livestock farm’	264	1410 *	250	240
Dummy variable ‘Pig & poultry farm’	22	266 *	22	21
Dummy variable ‘Mixed farm’	264	1,170 *	255	358
Dummy variable ‘Germany’	304	687 *	288	300
Dummy variable ‘Spain’	74	3,243 *	74	78
Dummy variable ‘France’	438	2,343 *	434	422
Dummy variable ‘Ireland’	55	530	55	60
Dummy variable ‘Italy’	26	328 *	26	22
Dummy variable ‘Portugal’	140	423 *	129	129
Dummy variable ‘United Kingdom’	90	823	90	76
Dummy variable ‘The Netherlands’	23	423 *	23	32
Number of observations	1,150	8,854	1,119	1,119

Notes: For variable definition and abbreviations see Table A1. * indicate significantly different means between observations from the potential (selected) treatment group and from the potential (selected) control group in a ttest for equality of means at the 5 per cent level.

Prior to the matching analysis, farms participating in AE programs significantly differ from non-participants with respect to nearly all characteristics shown in Table 3. A comparison between column (1) and (2) indicates that farms enrolled in AE programs are characterized by

[5] Additional test statistics for these variables (such as the ‘standardized bias’ (Baser, 2006)) are available from the authors upon request.

a larger area under cultivation and a higher on-farm labour input, for example. These differences in farm characteristics between program participants and non-participants are significantly different from zero.

Columns (3) and (4) report the adjusted means of the selected variables for the treatment and control group after the matching procedure has been applied. From the 1,150 farms with participation in AE programs, 1,119 were matched to farms with no participation but similar propensity scores. The differences between treatments and controls are now much smaller and in no case significantly different from zero at the 5 per cent level. We can thus conclude that all observable differences in means between treatments and controls have been removed through matching in the initial period 2001 (before program participation).

4.2 Treatment Effects

The average effect of the participation in AE programs is estimated by comparing the changes in individual outcomes between participants ($\Delta Y^1 = Y^1_{2004} - Y^1_{2001}$) and their matched counterparts ($\Delta Y^0 = Y^0_{2004} - Y^0_{2001}$) between 2001 and 2004 (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:

$ATT = \frac{1}{N_1}\left(\sum_{i=1}^{N_1} \Delta Y_i^1 - \sum_{i=1}^{N_1} \Delta Y_i^0\right)$, where N_1 is the number of matches.

A positive (negative) value of ATT suggests that farms with participation in AE programs have higher (lower) growth rates of outcome variable *Y* than non-participants. Table 4 displays the growth rates (log differences) of outcome variables for the treatment and control group as well as the difference between both (the ATT).

Table 4. Average treatment effect on the treated (ATT) for AE programs from 2001 to 2004 (in log differences), all countries

Outcome	Treatments [1]	Controls [2]	ATT = [1] - [2]	Std. Error	t-value (Significance)
Farm sales	0.028	0.057	-0.029	0.031	-0.96
Farm sales (per ha)	-0.029	0.021	-0.050	0.024	-2.12 (**)
Area under cultivation	0.058	0.023	0.035	0.011	3.37 (***)
Permanent pasture	0.007	-0.041	0.048	0.028	1.67 (*)
Rented land	0.073	-0.011	0.084	0.026	3.25 (***)
On-farm labour	-0.121	-0.156	0.035	0.012	2.81 (***)
On-farm labour (per 100 ha)	-0.179	-0.179	0.000	0.016	-0.06
Farm net value added	4,024	2,982	1,041	1,705	0.61
Farm capital (per ha)	0.001	-0.027	0.028	0.015	1.87 (*)
Grazing livestock units	-0.045	-0.067	0.022	0.020	1.08
Grazing livestock density	-0.041	-0.021	-0.020	0.019	-1.03
Pesticide expenditures (per ha)	0.001	0.016	-0.015	0.035	-0.45
Fertilizer expenditures (per ha)	-0.066	-0.008	-0.058	0.034	-1.71 (*)

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 per cent (***), 5 per cent (**) or 10 per cent (*) level. Log differences are reported for all variables. Results are based on a Greedy algorithm with calliper pair matching without replacement.

Results of the d-i-d estimator suggest a positive and significant causal impact of program participation on the area under cultivation. Between 2001 until 2004 farms with participation to AE programs increased their area of cultivation by 5.8 per cent, while non-participants report a positive growth rate of 2.3 per cent on average. The difference (ATT = 3.5 per cent) is different from zero at the 1 per cent level of significance.

The positive effect of AE programs on the area under cultivation confirms the results of Osterburg (2004) and Pufahl and Weiss (2009) for Germany. Higher farm land growth rates of program participants can be explained by acreage related AE payments and the adjust process of farms induced by program eligibility criteria. The increase of the area under cultivation seems to be a strategy to maintain farm income under AE programs: Economic farm growth is realised by increasing the area under cultivation instead of increasing the land use intensity per hectare. Farm growth is mainly achieved by renting in additional land. The area of rented land increases for the treatment group (+7.3 per cent) and decreases in the control group (-1.1 per cent). The ATT with 8.4 per cent is significantly different from zero.

While there is a highly significant increase in the area under cultivation, the effect of AE programs on the reduction of inputs is less clear cut: During the period of analysis, program participants reduced fertilizer expenditures per hectare by 6.6 per cent, while non-participants show a slight decrease of 0.8 per cent. The ATT of -6.8 per cent indicates that farms participating in AE significantly reduced the purchase of farm chemicals compared to the control group but is significant at the 10 per cent level only. No significant effects of AE programs are observed with respect to the reduction of pesticide expenditures per hectare and the grazing livestock densities. This might be explained by the lack of AE scheme focusing on the reduction of pesticide use (mainly relevant in cash crop and permanent crop production) and livestock densities.

Table 4 further suggest a significant, negative productivity effect of AE programs: Farms sales per hectare decrease in participating farms (-2.9 per cent) and increase in farms with non-participation (2.1 per cent). The ATT of -5.0 per cent is significant at the 5 per cent level. This result contradicts findings of Salhofer and Streicher (2005) and Pufahl and Weiss (2009), who observe an insignificant productivity effect of AE programs in Austria and Germany, respectively. The effect of AE programs on total farm sales is insignificant.

Farm-household models suggest a positive effect of coupled payments on on-farm labour (El-Osta *et al.*, 2004). Government payments contribute to farm income and enhance the remuneration of farm factors used. Shaik and Helmers (2006), Lambert and Griffin (2004) and Pufahl and Weiss (2009) provide empirical evidence for a positive effect of government payments on on-farm labour, while the effect was insignificant in the study of El-Osta *et al.* (2004). The results in Table 4 support the idea that adjustments with respect to farm labour are slowed down under AE participation. AE participants show a decreasing on-farm labour endowment (-12.1 per cent), which is exceeded by an even steeper decrease in non-participating farms (-15.6 per cent). The respective ATT of +3.5 % is significant different from zero at the one per cent level and suggests a positive effect of AE programs on on-farm labour.

Although farm land growth rates of AE programme participants are about double of those of non-participants, AE participants maintain a constant capital endowment per hectare. On the contrary, non-participants show a substantial decrease in farm capital per hectare. The ATT with respect to farm capital per hectare is 2.8 per cent. This might suggest that AE program payments enhance farm liquidity (Ciaian and Swinnen, 2006) and are not used for non-farm purposes. No significant treatment effect of AE programs is observed with respect to farm profit (farm net value added).

An important objective of AE policies in the EU-15 is the maintenance of permanent pastures. We find that AE support resulted in an increase of permanent pastures in farms with program participation. The size of permanent pastures remains stable in farms participating in AE programs (+0.7 per cent) while it decreases in those with non-participation (-4.1 per cent). The ATT of 4.8 per cent is significantly different from zero at the 10 per cent level only. The extra permanent pastures in farms with AE participation might come from exiting, shrinking and/or intensifying farms. Unfortunately, more detailed (plot specific) information on the adjustment of land allocation as a consequence of AE programs is not available.

4.3 Heterogeneity of Effects and Robustness of Results

The effect of AE programs will differ between individual observations (heterogeneity of treatment effects) for various reasons: First, there is a wide variability of AE schemes available in EU Member States.[6] Second, the magnitude of treatment effects might depend on certain farm characteristics of which the farm size is of special interest here.

To extend the empirical analysis along the two lines, we carry out additional estimation experiments: (a) The heterogeneity of the effects of AE programs across Member States is analysed by stratifying the sample and performing separate analyses for each country. (b) Whether the effect of AE programs differs between farms with different farm size is estimated by using parametric regressions.

The causal effects of AE programs in different Member States are shown in Table 5. Estimates for countries with a small number of observations (Italy, The Netherlands) however turn out not to be significantly different from zero. Results in Table 5 suggest a positive and significant causal impact of program participation on farm sales in Germany and France. The growth rate of farm sales of participants exceeded those of non-participants by 4.9 per cent (Germany) and 3.8 per cent (France), respectively. Both effects are significant on the 5 per cent level. These results confirm those of Pufahl and Weiss (2009) for Germany. The significant increase in farm sales is paralleled by a significant increase in the area under cultivation. The respective ATT is significant in Germany (+3.8 per cent) and France (+2.3 per cent).

The positive effect of AE programs on the area under cultivation seems to be common in all countries and is often paralleled by a positive effect on-farm labour input (although the effects are statistically significant in some countries only). Significant effects of AE programs on the reduction of land use intensity (grazing livestock density, pesticides and fertilizer expenditures per hectare) are evident for Germany, Spain and France. If farm land growth is not followed by a substantial decrease of the land use intensity, the overall production effect of AE programs will be positive.

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6 The data do not allow to distinguish among different AE schemes within or between EU Member States, nor are there information about the area enrolled into AE programs or the AE premia per hectare.

Table 5. Average treatment effect on the treated (ATT) for AE programs from 2001 to 2004 (in log differences) by country

Outcome	**GER** ATT (Sign.)	**ESP** ATT (Sign.)	**FRA** ATT (Sign.)	**IRE** ATT (Sign.)	**ITA** ATT (Sign.)	**NED** ATT (Sign.)	**POR** ATT (Sign.)	**UK** ATT (Sign.)
Farm sales	0.049 (**)	-0.186	0.038 (**)	-0.171	0.103	0.136	-0.029	0.014
Farm sales (per ha)	0.011	-0.333 (*)	0.017	-0.141	0.035	0.019	-0.087	-0.019
Area under cultivation	0.038 (***)	0.171	0.023 (**)	0.049	0.068	0.118	0.058	0.033
Permanent pasture	0.067	0.265 (*)	0.065	0.134	-0.208	-0.108	0.050	-0.084
Rented land	0.131 (**)	0.270 (*)	0.033 (**)	0.149 (*)	0.346	0.014	0.009	0.097
On-farm labour	0.032	0.102 (**)	0.077 (***)	0.018	-0.040	0.150	0.031	0.034
On-farm labour (per 100 ha)	-0.007	-0.070	0.054 (***)	-0.032	-0.108	0.032	-0.027	0.001
Farm net value added	2,996	-3,452	6,601 (***)	5,805 (***)	-7,226	20,855	-159	9,534 (*)
Farm capital (per ha)	0.031	-0.011	0.037 (**)	-0.036	0.101	-0.005	0.019	-0.053
Grazing livestock units	0.081 (*)	-0.021	0.031	0.021	0.107	0.143	0.031	-0.073
Grazing livestock density	0.027	-0.208 (*)	-0.042 (*)	-0.035	0.058	0.051	0.029	-0.065
Pesticide expenditures (per ha)	0.132 (**)	0.041	-0.091 (**)	-0.340	-0.310	0.218	0.126	-0.136
Fertilizer expenditures (per ha)	-0.139 (**)	-0.380 (**)	0.032	-0.206	-0.148	-0.522	0.061	0.004
Number of treatments/controls	280/280	74/74	422/422	54/54	25/25	20/20	106/106	88/88

Notes: For variable definition and abbreviations see Table A1. Asterisks denote statistical significance in a t-test for equality of means at 1 per cent (***), 5 per cent (**) or 10 per cent (*) level. Log differrences are reported for all variables. Results are based on a Greedy algorithm with calliper pair matching without replacement.

Table 6. Parameter estimates of linear regression models of farm size (area under cultivation) on the average treatment effect on the treated (ATT) for AE programs from 2001 to 2004 by country and outcome variable

Outcome	**ESP**		**FRA**		**IRE**		**ITA**		**NED**		**POR**		**UK**	
	ATT	**(Sign.)**	**ATT**	**(Sign.)**	**ATT**	**(Sign.)**	**ATT**	**(Sign.)**	**ATT**	**(Sign.)**	**ATT**	**(Sign.)**	**ATT**	**(Sign.)**
Farm sales	0.236		0.006		-0.556	(*)	-0.350	(*)	0.133		0.085		0.023	
Farm sales (per ha)	0.339		0.115	(**)	-0.242		-0.136		0.11		0.090		0.053	
Area under cultivation	-0.113		-0.109	(***)	-0.204	(***)	-0.214	(**)	0.023		0.000		-0.031	
Permanent pasture	-0.323		-0.197	(*)	-0.197		-1.186	(***)	-0.187		0.078		-0.115	
Rented land	-0.019		-0.089	(*)	0.089		-0.170		-0.362	(**)	-0.188		0.265	
On-farm labour	-0.014		0.087	(**)	0.029		-0.142		-0.089		0.050		0.079	
On-farm labour (per 100 ha)	0.099		0.196	(***)	0.233	(**)	0.072		-0.112		0.050		0.11	
Farm net value added	7.308		5.448		-894		7.180		12.077		4.272	(*)	3.062	
Farm capital	-0.090		0.070	(*)	0.115		0.251		0.074		0.077		0.105	
Grazing livestock units	-0.029		-0.060		-0.066		0.278		-0.283		0.080		0.014	
Grazing livestock density	0.215		0.110	(**)	0.116		0.111		-0.126		0.039		0.111	
Pesticide expenditures (per ha)	-0.167		0.196	(**)	-0.081		-0.101		0.607		0.216		-0.400	
Fertilizer expenditures (per ha)	0.002		0.084		-0.418		-0.417		1.664	(*)	-0.008		-0.021	

Notes: For variable definition and abbreviations see Table A1. Control variables in each regression model include: farm size of participants, farm size of non-participants, dummy variables for the type of farming and dummy variables for Nuts 3 regions. Asterisks denote statistical significance in a t-test for equality of means at 1 per cent (***), 5 per cent (**) or 10 per cent (*) level. No estimates are computed for Germany, because the farm size of selected treatments is significantly higher as the farm size of non-selected treatments that are off common support. The estimated effect of farm size on the ATT would be biased.

For three countries, we observe a significant and positive income effect of AE programs. The annual farm net value added of AE participants is about 6,601 Euro (France), 5,805 Euro (Ireland) and 9,534 Euro (United Kingdom) higher then those of the control group.

The regression estimates in Table 6 reflect the influence of farm size (area under cultivation) on country-specific effects of AE programs (the ATT). The results support the idea that the magnitude of treatment effects is influenced by farm size. In the case of France and Ireland, for example, the ATT with respect to the area under cultivation is negatively correlated with farm size, suggesting that smaller farms growth faster under AE program participation than larger farms. A positive correlation is observed between the ATT with respect to on-farm labour per 100 hectare and farm size: The positive effect of AE programs on labour input per 100 hectare is highest in large farms.

To assess the robustness of our results, we carried out a number of additional country-specific estimation experiments with different matching estimators. Specifically, we tested calliper matching with replacement (1:1, 1:5) and kernel matching. Matching with replacement and kernel matching did remove the observed differences of covariates among participants and non-participants. The treatment effects would be biased (results are available from the authors upon request).

5. CONCLUSIONS AND EXTENSIONS

The present paper uses a semi-parametric propensity score matching estimator combined with a difference-in-difference approach to evaluate agri-environment (AE) programs with respect to their effects on farm size (area under cultivation), labour supply, farm output (sales), farm profits (farm net value added), productivity (sales per hectare), expenditures for farm chemicals (pesticides, fertilizers), and livestock densities. The analysis is carried out for Germany, Spain, France, Ireland, Italy, The Netherlands, Portugal and United Kingdom.

We observe a significant positive effect of the AE program on the area under cultivation. This complies with findings of earlier studies (Key *et al*., 2005; Osterburg, 2004; Shaik and Helmers, 2006; Pufahl and Weiss, 2009). Higher farm land growth rates of program participants can be explained by acreage related AE program payments and the adjust process of farms induced by program eligibility criteria. The increase of the area under cultivation seems to be a strategy to maintain farm income under AE programs: farm growth is realised by increasing the area under cultivation instead of increasing the land use intensity per hectare. This hypothesis is supported by a decrease of fertilizer purchase per hectare and farm sales per hectare under AE programs.

Results of the country specific analysis reveal significant differences in the effects of AE programs on input reduction, production and farm income across Member States. AE programs in Germany and France significantly increase farm sales, suggesting a positive production effect of AE programs. The increase in farm sales in Germany and France is parallel by an increase in the area under cultivation. If the expansion of farm land is not followed by a substantial decrease of the land use intensity, the overall production effect of AE programs will be positive. In various countries, on-farm labour supply increases under AE programs. This may suggest that AE programs help to maintain ‘desirable’ labour-intensive traditional farming practices (e. g. maintaining hedgerows and stone walls). Further, we observe positive income effects (farm net value added) of AE programs for France, Ireland and United Kingdom.

The country-specific propensity score matching analysis also reveals differences in the treatment effects among farms of different farm sizes (heterogeneous treatment effects), suggesting that AE programs are not scale neutral. Smaller farms seem to growth faster under AE program participation than larger farms, for example. Heterogeneous 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, since distributional issues (i. e. the distribution of the impacts of farm programs among different farm households) are intensively debated in agricultural policy.

The present analysis also underlines some difficulties in empirically evaluating the effects of farm programs. First, the specific form and implementation of the programs differ substantially between the countries analysed. The treatment effects obtained on the basis of a cross-country analysis thus have to be interpreted very carefully and a more detailed country-specific evaluation of program effects seems warranted. This brings us to the second difficulty of the present study. A precondition for the application of matching procedures is the availability of a large number of observations. „Propensity score matching is ‚data hungry' not only in terms of the number of variables required to estimate participation and outcomes, but also in the number of participants and non-participants entering the matching process" (Bryson, Dorsett und Purdon, 2002, S. 14). Unfortunately, the small number of observations available for some countries reduces the reliability of the treatment effects reported.

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Appendix

Table A1. Variable definition and data sources

Variable	**Definition**	**Unit**
Farm sales	log Farm sales	ha
Farm sales (per ha)	log Farm sales (per ha)	ha
Area under cultivation	log Area under cultivation	ha
Permanent pasture	log Permanent pasture incl. rough grazing	ha
Rented land	log Rented land	ha
On-farm labour	log On-farm labour	Hours/year
On-farm labour (per 100 ha)	log On-farm labour (per 100 ha)	Hours/year
Farm net value added	Farm net value added	1000 Euro
Farm capital (per ha)	log Farm capital (per ha)	Euro
Grazing livestock units	log Grazing livestock units	LSU
Grazing livestock density	log Grazing livestock per forage area	LSU
Pesticide expenditures (per ha)	log Pesticide expenditures (per ha)	Euro
Fertilizer expenditures (per ha)	log Fertilizer expenditures (per ha)	Euro
Total subsidies	log Total subsidies excluding on interest	Euro
Altitude zone	Altitude zone	4 zones
Dummy variables		
'Arable farm'	Type of farming: Fieldcrops	0=no, 1=yes
'Dairy farm'	Type of farming: Milk	0=no, 1=yes
'Livestock farm'	Type of farming: Other grazing livestock	0=no, 1=yes
'Pig & poultry farm'	Type of farming: Granivores	0=no, 1=yes
'Mixed farm'	Type of farming: Mixed	0=no, 1=yes
'Germany'	Germany (GER)	0=no, 1=yes
'Spain'	Spain (ESP)	0=no, 1=yes
'France'	France (FRA)	0=no, 1=yes
'Ireland'	Ireland (IRE)	0=no, 1=yes
'Italy'	Italy (ITA)	0=no, 1=yes
'Portugal'	Portugal (POR)	0=no, 1=yes
'United Kingdom'	United Kingdom (UK)	0=no, 1=yes
'The Netherlands'	The Netherlands (NED)	0=no, 1=yes
'Nuts 3 regions'		

Abbreviations: LSU = Livestock units. ha = Hektare
Source: Farm Accountancy Data Network (2001-2004).

Table A2. Parameter estimates of logit models explaining AE program participation (all countries)

Variable	**Estimate**	**Std. Error**	**Wald Chi^2**	**(Sign.)**
Intercept (P_{AE}=1, Mixed farm, The Netherlands)	-5.091	0.713	50.959	(***)
Area under cultivation	-0.206	0.079	6.824	(***)
Rented land	0.085	0.029	8.508	(***)
Permanent pasture	0.036	0.030	1.470	
Grazing livestock units	0.068	0.036	3.670	(*)
Grazing livestock density	-0.157	0.069	5.206	(**)
On-farm labour	0.211	0.084	6.275	(*)
Farm sales	-0.224	0.061	13.748	(***)
Farm capital (per ha)	0.280	0.075	13.848	(***)
Pesticide expenditures (per ha)	0.020	0.033	0.348	
Fertilizer expenditures (per ha)	-0.234	0.036	42.934	(***)
Total subsidies	0.128	0.034	14.105	(***)
Altitude zone	0.397	0.063	40.050	(***)
Dummy variables				
'Arable farm'	0.147	0.108	1.856	
'Dairy farm'	-0.180	0.096	3.514	(*)
'Livestock farm'	0.158	0.103	2.364	
'Pig & poultry farm'	-0.360	0.221	2.663	
'Germany'	1.495	0.091	267.863	(***)
'Spain'	-1.994	0.134	221.776	(***)
'France'	0.525	0.090	33.929	(***)
'Ireland'	0.077	0.149	0.265	
'Italy'	-0.654	0.198	10.902	(***)
'Portugal'	0.937	0.129	52.610	(***)
'United Kingdom'	0.041	0.127	0.103	
Number of observations	10.004			
LR chi-squared	1,127.163			(***)
Pseudo R^2 rescaled	0.209			
% Correct predictions	88.74			
Non-Participants	88.17			
Participants	0.57			

Notes: For variable definition see Table A1. Asterisks denote statistical significance at 1 per cent (***), 5 per cent (**) or 10 per cent (*) level.