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The effect of mandatory agro-environmental policy on farm environmental performance

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Abstract

The EU farmers are subject to mandatory cross-compliance measures requiring them to meet environmental conditions to be eligible for public support. These obligations reinforce incentives for the farmers to change their behaviour towards the environment. We apply quasi-experimental methods to measure the causal relationship between cross-compliance and farm environmental performance. We find that cross-compliance reduced farm fertiliser and pesticide expenditure. This result also holds for farmers who participated in other voluntary agro-environmental schemes. However, the results do not support our expectations that farmers who relied on larger shares of public payments had a stronger motivation to improve their environmental performance.

Keywords: agriculture, Common Agriculture Policy, cross-compliance, environment, EU, farm

1. Introduction

With increased pressure to integrate environmental concerns into agricultural policy, environmental cross-compliance is increasingly being used as a policy tool for improving the environmental quality of farm management. Cross-compliance means to make the receipt of public support payments contingent on compliance with environmental and other requirements.[1] Environmental cross-compliance, first explicitly introduced in the 1985 US Farm Bill, has become a popular measure in the European Union (EU), after the failure of more voluntary approaches (Osterburg et al., 2005). The EU Common Rules Regulation (European Commission, 1999) provides a possibility for introducing cross-compliance measures. However, up to 2005 such measures were optional for EU Member States (MS) but they became mandatory with the 2003 Common Agricultural Policy (CAP) reform for all European farmers applying to all direct payments from 2005 (European Commission, 2003). MS must now set farming standards in relation to EU regulations and directives (Statutory Management Requirements or SMR) and define Good Agricultural and Environmental Conditions (GAEC).

Environmental cross-compliance strategies have considerable support in that they remove some of the inconsistencies of previous agricultural policies. Previously, one agricultural program rewarded a farmer for non-conservation behaviour (e.g. subsidies dependant on production), while another encouraged conservation (e.g. EU Nitrate Directive). Moreover, by shifting from a policy of paying farmers to reduce their pollution to requiring them to comply with environmental standards using the reduction of support payments as an additional sanction, somewhat implements the “polluter pays principle” in the agricultural sector.

The effectiveness of any cross-compliance programme depends on numerous aspects. Winter and May (2001) discuss some of these factors. In principal, regulated farms comply with a given regulation when they conclude that the benefits of compliance (here, received subsidies), exceed the costs of compliance (here, costs of improving environmental

[1] According to Swales et al. (2007), the notion of cross-compliance originated in the US, in the 1970s. It refers to conditions that farmers must meet in order to be eligible for assistance under government support schemes for agriculture. In the US, farmers claiming support under one programme had to comply with both the rules of that programme and certain obligations of other federal programs: thus making a link “across programmes” which gave rise to the term “cross-compliance”. The use of the term has been extended since then, both within the US and elsewhere, to refer to linkages between agricultural and environmental (and other) policies. In the EU, the term “cross-compliance” is fully recognised and utilised by the European Commission. For a comparison of agri-environmental policies in the EU and United States see Baylis et al. (2008).

conditions). A second motivation for compliance comes from regulated farmers' combined sense of moral duty[2] and agreement with the importance of a given regulation. Awareness of what a given regulation is requiring is also a prerequisite for compliance. In the context of the recently introduced European environmental cross-compliance, incentives to comply will be highest for farmers that receive the highest subsidy payments (Bennett et al., 2006). Likewise, the more decoupled the payments are from production, the more responsive farmers are likely to be in their reaction to the cross-compliance requirements (Webster and Williams, 2002). Nevertheless, Juntti (2006) argues that the likelihood of achieving significant environmental improvements in Europe with cross-compliance is low. The reason for this is an apparent mismatch between the aspirations set out by the 2003 CAP reform to simultaneously liberalise the agricultural sector, secure high international competitiveness and at the same time to enhance environmental standards. According to Juntti (2006), these multiple aims limit the capacity of cross-compliance to properly secure environmental objectives.

To date, the overall effect of European environmental cross-compliance on environmental outcomes is not clear. The existing studies on the environmental improvements arising from cross-compliance are few and mainly based on either expert judgement or simulation models rather than direct empirical measurement of environmental outcomes. Several projects have analysed cross-compliance implementation in the EU.[3] They focus have been on a number of aspects of EU-wide post-2005 cross-compliance, such as implementation costs, degree of cross-compliance, effects on competitiveness, environmental effects, among others. Their results on environmental effects are rather similar: cross-compliance is effective (i.e. it improves compliance with environmental regulations); compliance levels are high; and the early evidence (mostly anecdotal) suggests that cross-compliance improved farming practice up to EU standards (Elbersen et al., 2010; Jongeneel and Brouwer, 2006; Swales, 2007; Swales et al., 2007).

Few studies address cross-compliance in the context of the Common Agricultural Policy decoupling. Brady et al. (2009) assess the long-term effects of the 2003 CAP reform on farm structure, landscape mosaic and biodiversity using a spatial agent-based model for a sample of EU regions. They find that GAEC measures did not prove to be a sufficient measure to avoid

[2] See Mzoughi (2011) for more discussion on how moral and social concerns affect farm environmental behaviour.
[3] See the report made by Jongeneel et al. (2007) for the synthesis of the projects on cross-compliance.

all of the environmental consequences of decoupling (their other results show that decoupling would, in some regions, have resulted in land abandonment, resulting in an even greater loss in mosaic and biodiversity values). Also, they show that environmental outcomes greatly depend on the regional characteristics, and this calls for spatially differentiated environmental policy instruments.[4] Mosnier et al. (2009) employ a farm-level bio-economic model to estimate the effect of decoupled payments and cross-compliance measures for two typical arable farms in the Southwest of France. Their results show that if cross-compliance measures are imposed, a small reduction in the cultivated area of irrigated crops is observed and environmental indicators at farm level are improved. In Switzerland (not an EU member), a similar policy (Proof of Ecological Performance) has been shown to be effective in reducing diffuse nitrogen and phosphorus pollution from agriculture although some goals were not reached (Herzog et al., 2008).

To the best of our knowledge, this paper is the first attempt to empirically evaluate the impact of the newly reorganised European agricultural policy on farmers' environmental performance by using econometric techniques. Swales (2006) stresses that cross-compliance does not seek to address all environmental issues in agriculture. Thus, following him, we should judge the environmental effectiveness of cross-compliance only in relation to its objectives and the framework available to meet these objectives. One of the main cross-compliance environmental issues is water pollution, soil quality and the protection of biodiversity features. Thus, in this paper we focus on specific quantitatively measurable and available environmental indicators related to the above mentioned primary cross-compliance environmental issues. The farm's usage of artificial fertilisers and pesticides are our environmental indicators (proxies) for cross-compliance effectiveness.

The effect of the cross-compliance policy on farm environmental performance is identified using difference-in-differences method, where we investigate the response of farms subject to *national* cross-compliance measures introduced *before* the introduction of the *EU-wide* cross-compliance policy in 2005.[5] Our main hypothesis is that cross-compliance should improve environmental performance in the form of fertiliser and pesticide reduction. To sharpen the identification, we take into account farms' dependency on overall subsidies and also

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[4] The major shortcoming of cross-compliance is that it does not take into account differences between farms and the effect of farmers on the environment.
[5] To distinguish between cross-compliance measures introduced before 2005 and after 2005, we define pre-2005 cross-compliance as *national* cross-compliance, and post-2005 cross-compliance as *EU-wide* cross-compliance.

participation in other (voluntary) agro-environmental schemes. We account for observed and unobserved farm-level heterogeneity by controlling for farm productivity changes and other farm and time specific characteristics.

The following Section 2 describes the background on the EU cross-compliance policy. Section 3 outlines the empirical framework we employ. The data and the descriptive statistics of the main variables are presented in Section 4. Section 5 discusses the main results and robustness checks. Section 6 provides our conclusions.

2. Policy background

Cross-compliance has been discussed in the EU since the early 1990s, and various reforms of the CAP have increased the importance of cross-compliance as a policy tool for environmental integration.

To address some of the changes in farming practices which negatively affect the state of the environment, the CAP reform of 1999 (Agenda 2000) introduced for the first time the principle of compliance with environmental requirements. The Horizontal Regulation (Article 3 of Regulation 1259/1999, covering all payments granted directly to farmers) gave an option to Member States to introduce cross-compliance measures, or, as outlined in the regulation, "specific environmental requirements constituting a condition for direct payments", relating to one or more environmental issues (European Commission, 1999).

Nine out of 15 EU Member States introduced some cross-compliance measures following the Horizontal Regulation (see Table 1). As it was up to each MS to decide on a cross-compliance strategy, implementation of this *national* cross-compliance differed across MS. Activities that were subject to some cross-compliance measures include soil management to control surface water run-off, animal waste management, sustainable crop rotation and efficient use of fertiliser and pesticides.[6] However, the implementation of *national* cross-compliance measures was below the expectations of the EU Commission, so that in 2005 cross-compliance became an obligatory element of the new agricultural policy reform.

[6] See Bergschmidt et al. (2003) for a comprehensive discussion on the *national* cross-compliance measures introduced across MS.

From 2005 onwards, farmers in receipt of CAP direct payments are required to respect a set of SMR set out in Annex III of Council Regulation (EC) No. 1782/2003 (European Commission, 2003). They also have to meet minimum requirements of GAEC, to be defined by Member States, on the basis of a Community framework given in Annex IV of the same regulation.

Table 1 Implementation of cross-compliance in Member States of EU15 before 2005

Group	Cross-compliance standards	Countries
THE TREATMENT GROUP	Standards beyond existing legislation	Austria, the Netherlands, Ireland, UK
	Combination of existing legislation and standards beyond	Finland, Greece, Italy, Spain
	Legal standards	France, Denmark (abandoned in 2002)
THE CONTROL GROUP	No cross-compliance	Belgium, Denmark, Germany, Luxembourg, Portugal, Sweden

Source: Adapted from Osterburg et al. (2005).

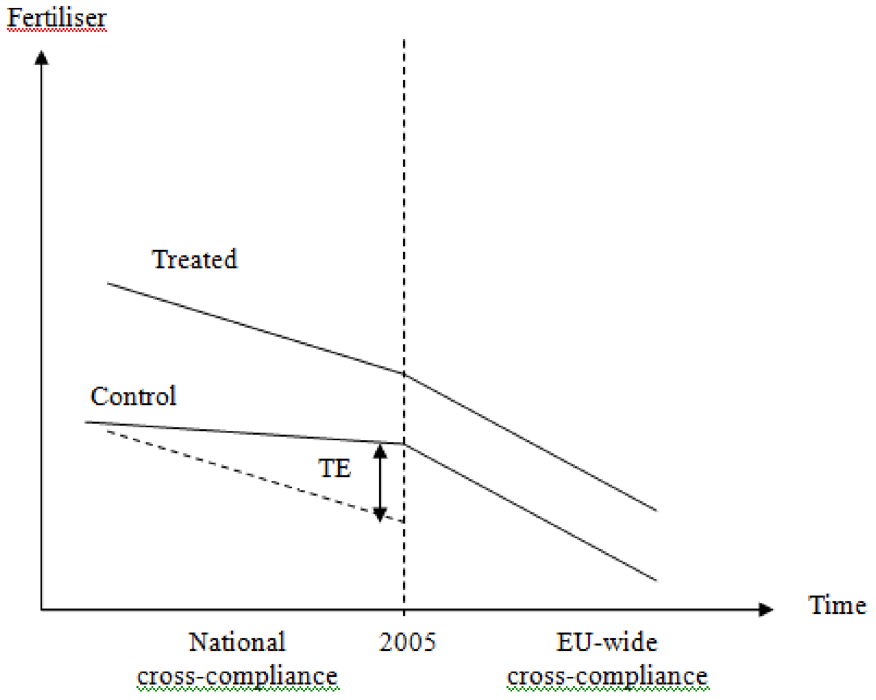
As summarised by Swales (2006), the recital of Regulation 1782/2003 set out three objectives. The first is to integrate basic standards for the environment, food safety, animal health and welfare and good agricultural and environmental condition in the common market organisation by linking direct aid to rules relating to agricultural land, agricultural production and activity. A second objective is to avoid the abandonment of agricultural land and ensure that it is maintained in good agricultural and environmental condition. Land abandonment may, alongside other drivers, arise as a result of decoupling. A third objective is to maintain the existing area of permanent pasture as it is regarded to have a positive environmental effect.

The EU15 Member States are subject to EU-wide cross-compliance since 2005, although the full set of SMRs was not implemented until January 2007. The MS that acceded to the EU in 2004 have been implementing the SMRs from 2009, and later still in Bulgaria and Romania, although standards for GAEC have been introduced.

3. Empirical identification strategy

Differences in the timing and nature of the reform policies implemented across EU Member States are used as a quasi-natural experiment for establishing causal policy relationships.[7] First, Member States are grouped in terms of the timing of the implementation of the cross-compliance policies. Second, treatment and control groups are identified within the sample of countries (see Table 1 for the treatment and the control groups by country; and Figure 1 for a simplified graphical representation of the identification strategy).

Figure 1 The graphical representation of the policy effect identification strategy



We use a difference-in-differences identification strategy that is "backward looking" as opposed to the common approach of "forward looking" difference-in-differences methodologies, where pre-policy time period values are used as the base reference point for the policy effect. In our case, the base reference point is the time period (post-2005) when both the control and treatment groups have implemented the *EU-wide* cross-compliance policies. The difference between the control and the treatment groups in the pre-2005 time period, taking into account the treatment and the control group differences in the post-2005 time period and the common trends, is our *national* cross-compliance policy effect. The

[7] See Greenstone and Gayer (2009) for a comprehensive discussion and examples on quasi-experimental approaches to environmental economics.

choice of our "backward looking" identification strategy is determined by the data availability issue.[8]

The difficulty in modelling farm environmental performance using farm-level data is that we do not observe this performance directly. As such, we consider two proxy variables to capture farms' environmental performance, namely, expenditure on pesticides and fertilisers.

One of the main concerns regarding our identification assumption is that time variant farm specific unobserved productivity may differ systematically across the treatment and control groups. For example, it might be the case that the decoupling policy changed farmers' individual productivity and this in turn led to changes in farmer's behaviour in relation to environmental indicators (Kažukauskas et al., 2011; Kažukauskas et al., 2010). In order to isolate the cross-compliance effect we need to control for unobservable farm productivity changes. In line with Levihnson and Petrin (2003) we use the farm's choice of intermediate inputs to control for unobserved farm individual productivity (ω_{it}). We assume that the demand for intermediate inputs is given by $m_{it} = f(\omega_{it}, k_{it}, a_{it})$, where m_{it} are intermediate inputs (such as energy or fuel), k_{it} is capital and a_{it} is land, and that intermediate input demand is monotonic in ω_{it}. Inverting this function will give us an expression for $\omega_{it} = f^{-1}(m_{it}, k_{it}, a_{it})$ that can be used to control for productivity in our difference-in-differences models in a non-parametric way.

As our outcome variables (pesticide and fertiliser use) are also farm production inputs that may affect farm productivity we use a lagged productivity term (ω_{it-1}) in our empirical models to avoid endogeneity problems which may arise.

As indicated, differences in the timing and nature of the reform policies implemented across the EU15 countries are used as a natural experiment for establishing causal policy relationships. As discussed in detail in Section 2, the Member States are grouped in terms of the timing of the implementation of the cross-compliance measures. Countries that are subject to the cross-compliance measures only from 2005 represent the *control* group, and countries

[8] As learning-by-doing effect might confound our main policy treatment effects using the "backward looking" difference-in-differences approach, we do a robustness check (see Section 5) using the common "forward looking" difference-in-differences method for our limited available data. The robustness check confirms our main results.

that have had the national cross-compliance instruments earlier than 2005 represent the *treatment* group.

It is important to note that even though the cross-compliance measures were exogenous for individual farmers, the potential country self-selection into implementing national cross-compliance might cause a bias in our estimates if the particular countries' decisions were based on farm fertiliser or pesticide use. We argue that the national cross-compliance measures were very broad and that the primary policy goals were very diverse, thus, the use of fertiliser and pesticide expenditures as partial indicators for measuring policy effectiveness is not likely to be correlated with the cross-compliance policy implementation decisions. The decisions on implementing the national cross-compliance regulations were more related to political climate in the particular countries[9], agricultural authorities' incentives, environmental and farm lobby groups influence powers (Jones, 2006).

Furthermore, to reduce the potential country specific bias, the heterogeneity across countries is controlled by the country specific dummies and the country specific time trends. This allows treatment and control countries to follow different trends thus further strengthening our identification (Angrist and Pischke, 2009). The motivation for including these variables comes from the fact that countries have slightly varying national agricultural policies, different socio-economic conditions and climates which may affect the trends in our variables of interest across EU Member States. A similar motivation exists for the inclusion of farm sector time trends given that the EU cross-compliance policies affect farms in different ways depending on their farm sector. This is incorporated into the difference-in-differences model in the following way:

$$environ\_indicator_{it} = \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1 T_i + \theta_2 Y_t + \theta_3 (Y_t * T_i) + \mathbf{z}_i \boldsymbol{\beta} + \mathbf{x}_{it} \boldsymbol{\gamma} + \alpha \quad (1)$$

Where γ_{0c} are country specific intercepts; γ_{1ct} are country specific time trends; ϱ_{0s} are farm sector[10] specific intercepts; and ϱ_{1st} are farm sector specific time trends; T_i is a binary treatment indicator of cross-compliance for countries which implemented the *national* cross-

[9] For example, in Denmark, in April 2002, cross-compliance was abandoned for political reasons by the new liberal-conservative government (Kristensen and Primdahl, 2006).
[10] Farm sector dummies are based on FADN Type of Farms (TF) clustering methodology.

compliance policy pre-2005; Y_t is a time dummy for the year of the *national* cross-compliance policy implementation; and λ_t are time dummies by year; $\mathbf{z}_i$ are farm specific time invariant variables; $\mathbf{x}_{it}$ are farm specific time variant variables, including the polynomial to control for productivity; α is a constant. We are interested in the sign and significance of the θ_3 coefficient which will measure the cross-compliance policy effect.

Farmers in different countries might have a greater reliance on subsidies than others. This might suggest that farmers might be less responsive to policy changes if farm incomes are not significantly dependent on farm direct payments. Our farm direct payment dependency rate variable (dpr_{it}) is denominated by total farm output, so it takes into account the extent to which farms are dependent on farm subsidies:

$$dpr_{it} = \left[\frac{total\ farm\ direct\ payments_{it}}{total\ farm\ output_{it}}\right] \quad (2)$$

The inclusion of this variable in our triple difference-in-differences analysis therefore controls for the fact that the environmental friendly behaviour of farms may depend on the extent to which they rely on farm direct payments:

$$\begin{aligned} environ\_indicator_{it} &= \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1 T_i + \theta_2 Y_t + \theta_3 (Y_t * T_i) + \delta_0 dpr_{it} \\ &+ \delta_1 (Y_t * dpr_{it}) + \delta_2 (T_i * dpr_{it}) + \delta_3 (Y_t * T_i * dpr_{it}) + \mathbf{z}_i \boldsymbol{\beta} + \mathbf{x}_{it} \boldsymbol{\gamma} + \alpha \end{aligned} \quad (3)$$

In this model we check for whether the direct payment dependency rate has an effect on farm environmental performance given the national-wide cross-compliance policy introduction. This effect will be determined by the δ_3 coefficient.

The farm's environmental performance may also be affected by its participation in agro-environmental schemes.[11] To control for this we also consider the following model:

[11] For example, Pufahl and Weiss (2009) find that agri-environmental schemes significantly reduced the purchase of fertiliser and pesticide of individual farms in Germany.

$$environ\_indicator_{it} = \gamma_{0c} + \gamma_{1ct} + \varrho_{0s} + \varrho_{1st} + \lambda_t + \theta_1 T_i + \theta_2 Y_t + \theta_3 (Y_t * T_i) + \tau_0 ENV_{it} + \tau_1 (Y_t * ENV_{it}) + \tau_2 (T_i * ENV_{it}) + \tau_3 (Y_t * T_i * ENV_{it}) + \mathbf{z}_i \boldsymbol{\beta} + \mathbf{x}_{it} \boldsymbol{\gamma} + \alpha \quad (4)$$

ENV_{it} is a dummy variable for whether the farm participates in agro-environmental schemes. All other variables and coefficients have the same meaning as in the previous equations. In this model, the effect of cross-compliance on farm environmental performance, given farm participation in agro-environmental schemes, will be determined by the τ_3 coefficient.

As a robustness check for possible endogeneity problems we use the lagged dpr_{it} and ENV_{it} in the respective models presented above. The results are in line with the results of the original models presented below.[12]

4. Data sources and description

For the purpose of this analysis we use the Farm Accountancy Data Network (FADN) farm level data for the EU15 countries for the 2001-2007 time period. The FADN dataset is created by the European Union as an instrument for evaluating the income of agricultural holdings and the impacts of the CAP. Derived from annual national surveys, the FADN data is based on the same bookkeeping principles across all EU countries. Farm holdings for the national surveys are selected to get farm population representative samples at country/region level.

Our dependent variables are fertiliser and crop protection expenditures which are deflated using country specific and the farm production input specific deflators from Eurostat. Table A1 in the appendix presents the descriptive statistics for these two variables across all EU Member States for the pre-2005 and post-2005 time periods. The set of control variables and the dependent variables are summarised for the full sample and the balanced sample in Table 2. Farm dependency on farm direct payments (subsidies and decoupled payments) is measured by our constructed farm subsidy dependency ratio variable (*dpr*). Participation in the agro-environmental schemes is measured by a dummy variable (*ENV*), and all monetary variables (farm capital, intermediate inputs, farm direct payments) are measured in Euros.

[12] The full set of results is available from the authors upon request.

Table 2 Descriptive statistics of variables for the EU15 MS separated by the treatment/control groups and by full/balanced samples, 2001-2007

The control group

	Full sample			Balanced sample		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev
Pesticide, EUR	295,318	4,065	12,655	92,534	4,417	10,649
Fertiliser, EUR	295,318	4,186	9,011	92,534	4,782	7,895
dpr	295,301	0.278	0.291	92,534	0.319	0.297
Capital, EUR	295,318	127,083	246,943	92,534	122,736	187,523
Intermediate inputs, EUR	295,318	59,984	155,543	92,534	60,590	121,558
Land, ha	295,318	55	116	92,534	64	102
ENV	295,318	0.215	0.411	92,534	0.272	0.445
Farm direct payments, EUR	295,318	18,962	39,460	92,534	21,716	28,118

The treatment group

	Full sample			Balanced sample		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev
Pesticide, EUR	90,356	9,578	28,296	34,411	8,469	24,774
Fertiliser, EUR	90,356	8,744	23,368	34,411	7,979	19,722
dpr	90,350	0.239	0.240	34,411	0.247	0.229
Capital, EUR	90,356	336,230	654,813	34,411	231,233	399,693
Intermediate, EUR	90,356	150,468	344,983	34,411	122,197	258,963
Land, ha	90,356	117	288	34,411	111	255
ENV	90,356	0.501	0.500	34,411	0.587	0.492
Farm direct payments, EUR	90,356	43,798	112,014	34,411	40,925	97,544

Notes: Farm holdings from Belgium are not included in the balanced sample due to the changes in Belgian sample selection strategy and the new identification numbers for Belgian farms. All monetary variables are deflated by their country specific deflators from Eurostat.

Table 2 presents the descriptive statistics on the main variables included in the empirical analysis, separated by the treatment and the control groups. Of particular note is the fact that farms in the treatment and the control groups are different in terms of size. On average, the farms in the treatment group are at least twice as big as the farms in the control group in terms of their capital and farming land. Thus, it is important to control for farm heterogeneity differences in our empirical analysis.

Figure A1 in the appendix depicts fertiliser and pesticide expenditure per hectare for the EU15 MS during 1999-2007, separated by the treatment and the control groups. We observe somewhat similar trends in the fertiliser and pesticide expenditure for both groups. Also, there is some evidence that, during 2000-2004, the treatment group decreased their fertiliser and crop protection expenditure relative to the control group. However, there are substantial differences between the both groups. Controlling for these factors is essential before we can make any conclusions regarding the effects of cross-compliance.

5. Cross-compliance effects

From the data description presented in the previous section, it is not clear whether on average farmers in the treated group reduced their fertiliser and pesticide use in the last years due to cross-compliance. However, the dynamics of fertiliser and pesticide use might depend on many other factors which should be taken into account when measuring policy effects. The results of our difference-in-differences model given in Equation (2), which attempts to identify these effects, are presented in Table 3. Columns (1) to (4) summarise the estimates of ordinary least squares (OLS) and panel fixed effects (FE) models for the unbalanced EU15 sample. It is evident that farmers subject to *national* cross-compliance before 2005 (our treatment group) reduced their fertiliser use by between EUR 420 (FE) and EUR 454 (OLS), and pesticide use by between EUR 496 (FE) and EUR 611 (OLS) relative to our control group in the same time period. This is between 4.8 and 5.2 percent of the average annual fertiliser expenditure and between 5.2 and 6.4 percent of the average annual pesticide expenditure of the treated farms. The results are very similar when the balanced sample is used (see columns (5) to (8)).

It must be noted that our *control* period (post-2005) coincides with the introduction of the farm subsidy decoupling policy. This policy itself might have changed farm production behaviour (e.g. see Sckokai and Moro (2009), Kažukauskas et al. (2010) and Kažukauskas et al. (2011)). We try to control for this by controlling for farm productivity changes with the inclusion of a polynomial function of the set of farm inputs. Another issue with using 2005-2007 as the control period is that farmers may anticipate the introduction of cross-compliance thus biasing the estimated effect of cross-compliance by altering the behaviour of the control group in the treatment period. We perform a robustness check for whether the introduction of the decoupling policy in 2005 and our “backward looking” quasi-experimental approach presented in Table 3 are validated by a common "forward looking" quasi-experimental difference-in-differences identification strategy for the introduction of *national* cross-compliance policy measures by comparing our treatment and control groups between 1999[13] (pre-treatment year) and 2001 (post-treatment year). The robustness check partially confirms our main results in Table 3 but the policy effects are smaller and, in the case of fertiliser use, they are insignificant (see Table A5 in the appendix).

As discussed, incentives to comply with environmental standards might be highest for the farmers that receive the highest subsidy payments. To see whether this is the case we estimate the difference-in-differences-in-differences econometric model which contains the interaction between the farm subsidies to total farm output ratio, the binary treatment indicator and the year dummy variable (see Equation (3)). We focus on the coefficient on this interaction term as it represents the impact of the introduction of national cross-compliance given the farm subsidy dependency level.

Table 4 highlights that there are no significant differences between treated and control farms across different levels of subsidy dependence. The estimates are insignificant across all models for both the balanced and unbalanced samples. Furthermore, the coefficient on the interaction term for the treatment variable and year ($Y*T$) remains negative and statistically significant across most of the models. These results do not support the argument that farmers who rely on larger shares of subsidies in total output have stronger incentives to comply with the cross-compliance measures. This result might reflect the nature of this policy in that all farmers, irrespective of the level of subsidy payments they receive, are subject to the same set of environmental requirements. Our reasons for expecting higher levels of farm subsidy dependency to significantly affect farm compliance is that farmers may lose relatively more of their income in the form of fines in the event of non-compliance. The insignificant effect observed here might reflect a low probability of policy enforcement, being checked and punished under this regulation and a relatively low non-compliance fine.

[13] Due to data availability issue for the pre-treatment time period we use just one available year (1999).

Table 3 Cross-compliance effect on fertiliser and pesticide use

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE	OLS	FE	OLS	FE
*Y*T*	-454.2**	-419.9***	-611.2**	-496.4**	-561.7***	-476.4***	-541.6*	-389.2*
	(201.5)	(147.1)	(268.7)	(191.2)	(177.5)	(159.9)	(275.9)	(197.8)
Y	omitted	omitted	omitted	omitted	omitted	omitted	omitted	Omitted
T	132.0	-69.3	749.0*	51.4	531.4*	212.8	7463.6***	5840.5***
	(312.7)	(216.1)	(398.6)	(249.7)	(278.5)	(380.8)	(598.3)	(399.7)
ENV	-840.3***	-1.8	-941.5***	-29.8	-1030.7***	380.9	-1157.4***	-45.6
	(183.8)	(74.3)	(201.6)	(51.4)	(198.9)	(104.0)	(283.2)	(77.3)
Constant	47840.1	177497.3**	-1348838***	-196553.2	-2244717***	100366.6	-6306594***	-516804.6***
	(419459)	(82340.5)	(350902.5)	(164142.8)	(416549.1)	(95062.2)	(608683.9)	(135762.4)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	yes	yes	no	yes	no	yes
Country*time trend	yes	yes	yes	yes	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6809	0.0205	0.6637	0.0271	0.7411	0.0326	0.7286	0.0533
No. of observations	306949	306949	306949	306949	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation; *ENV* is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes. Belgium drops from the balanced sample. *** p<0.01, ** p<0.05, * p<0.1.

Table 4 Cross-compliance effect on fertiliser and pesticide use when taking into account farm subsidy dependency

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE	OLS	FE	OLS	FE
*dpr*Y*T*	-221.6	-26.2	-505.3	163.9	-760.4	-125.8	70.4	439.4
	(653.1)	(240.9)	(791.0)	(323.3)	(549.3)	(307.7)	(688.2)	(411.2)
*dpr*Y*	408.1	155.8	1037.0	416.1	714.8	152.3	416.7	148.0
	(615.8)	(207.7)	(777.5)	(262.8)	(501.0)	(269.7)	(683.6)	(343.9)
*dpr*T*	72.8	1579.7**	-157.3	1611.1**	722.5	1961.1**	-198.3	1325.8
	(365.8)	(607.9)	(1226.3)	(743.8)	(1365.7)	(828.1)	(1596.0)	(856.8)
*Y*T*	-420.3*	-419.4**	-526.4*	-563.8**	-414.5	-455.8**	-676.2**	-562.2**
	(227.3)	(169.2)	(268.5)	(226.1)	(250.7)	(203.0)	(281.4)	(280.8)
dpr	-1899.1	-2100.0***	-2740.7**	-2485.5***	-2915.2*	-2479.6***	-3086.2*	-2250.8**
	(1164.3)	(614.9)	(1349.6)	(748.2)	(1570.8)	(836.3)	(1818.4)	(865.6)
Y	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
T	71.7	-360.9	688.7*	-223.8	386.1	-229.1	7629.4***	5606.7***
	(365.8)	(227.1)	(398.8)	(191.3)	(442.7)	(393.0)	(698.2)	(288.2)
ENV	-653.8***	45.7	-668.3***	28.8	-805.8***	99.9	-864.3***	10.4
	(172.2)	(76.7)	(197.1)	(53.8)	(167.8)	(108.0)	(268.0)	(80.6)
Constant	90889.0	181526.0**	-1334216***	-244192.5	-2331990***	119820.7	-6395192***	-534372.2***
	(442674.6)	(86218.7)	(370762.3)	(159359.4)	(440922.8)	(95164.8)	(663957.9)	(139029.8)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes	no	yes	no	yes
Country*trend	yes	yes	yes	yes	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes	yes	yes	yes	yes
Sector*trend	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6816	0.0214	0.6646	0.0281	0.7422	0.0341	0.7299	0.055
No. of observations	306934	306934	306934	306934	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. *dpr* is a ratio of farm direct payments by total farm output; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation; *ENV* is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes. Belgium drops from the balanced sample. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Some farmers participate in other voluntary agro-environmental schemes. We might expect that for these farmers it is easier to conform to cross-compliance requirements due to learning-by-doing effects and also due to a higher probability of being selected for inspection. To see whether this is the case we measure the difference-in-differences-in-differences econometric model which contains the interaction between the environmental subsidy dummy (our proxy for participation in other agro-environmental programmes), the treatment variable and the year dummy (see Equation (4)). The coefficient on this term represents the impact of compulsory cross-compliance for farms that are subject to other agro-environmental requirements.

Table 5 reveals a negative coefficient on the triple interaction term almost across all models. This finding indicates that farmers in the treated group that participate in other environmental programmes reduce their polluting chemical use by more than those farmers who are not in an environmental programme. The negative coefficient on this interaction term is statistically significant in the four models for fertiliser use only. This finding might suggest that farmers, who participate in additional agro-environmental schemes, have more incentives and knowledge on how to comply with certain environmental standards. Likewise, if we assume that farmers, who are subject to other agro-environmental measures, face more sensitive environmental issues (such as being in Natura 2000 areas, for example), this result might hint at the possibility that the cross-compliance regulation helps to convince farmers to comply with the additional agro-environmental regulations. Thus we might conclude that cross-compliance reinforces other policies aimed at reducing the impact of farming activities on the environment at least in cases related to fertiliser.

The above models are estimated for the EU15 Member States. To see whether cross-compliance has similar effects when we consider the EU27 MS, we estimate the same models for the extended full sample for the period 2001-2007 that include the MS that joined the EU in 2004 and 2007. The results of all three models are summarised in the tables A2-A4 in the appendix. They show that the estimates across all models are similar to the estimates for the EU15 sample.

Table 5 Cross-compliance effect on fertiliser and pesticide use when taking into account farmer's participation in other agro-environmental schemes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE	OLS	FE	OLS	FE
*ENV*Y*T*	-1074.1*	-369.0**	-530.5	11.1	-823.0**	-492.7**	-61.1	-168.6
	(584.0)	(162.8)	(666.0)	(223.8)	(342.2)	(204.5)	(583.5)	(219.5)
*ENV*Y*	907.9	161.5	337.6	-57.6	315.3	277.5	-368.1	124.1
	(575.2)	(154.5)	(646.7)	(207.7)	(311.6)	(194.2)	(530.0)	(200.2)
*ENV*T*	734.4	54.9	126.8	-161.3	364.0	-56.4	-480.0	-164.4
	(723.6)	(201.3)	(731.2)	(198.1)	(567.2)	(283.2)	(561.2)	(257.0)
*Y*T*	77.6	-276.2	-373.1	-511.0*	-223.9	-231.6	-614.8	-288.4
	(344.4)	(180.2)	(416.2)	(261.2)	(326.5)	(220.0)	(558.5)	(280.5)
ENV	-1424.3**	-11.5	-1020.6	93.5	-1164.6**	71.6	-671.7	30.4
	(680.9)	(189.6)	(665.0)	(188.9)	(510.3)	(261.9)	(407.2)	(241.7)
Y	omitted	omitted	omitted	omitted	omitted	omitted	omitted	omitted
T	-474.5	-210.0	501.7	78.5	537.0	342.1	8057.3***	5960.7***
	(466.1)	(262.6)	(515.2)	(326.3)	(474.3)	(545.3)	(595.9)	(543.2)
Constant	-77819.6	145227.1	-1379706***	-189472.8	-2284791***	37356.8	-6295443***	-547619***
	(470040.2)	100544.2	(407836.3)	(171350.3)	(427719.2)	(118344.4)	(622395.3)	(138697.4)
Year effects	yes	yes	yes	yes	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes	no	yes	no	yes
Country*trend	yes	yes	yes	yes	yes	yes	yes	yes
Sector*trend	yes	yes	yes	yes	yes	yes	yes	yes
polynomial	yes	yes	yes	yes	yes	yes	yes	yes
R-squared	0.6810	0.0206	0.6637	0.0271	0.7411	0.0330	0.7287	0.1185
No. of observations	306949	306949	306949	306949	123276	123276	123276	123276
No. of countries	15	15	15	15	14	14	14	14
Panel	unbalanced	unbalanced	unbalanced	unbalanced	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the regional level are reported in parentheses. *ENV* is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes; *T* is the binary treatment indicator of cross-compliance; *Y* is the time dummy for the year of the cross-compliance policy implementation. Belgium drops from the balanced sample. *** p<0.01, ** p<0.05, * p<0.1.

6. Conclusion

To date, the overall effect of the CAP reform and newly introduced environmental cross-compliance measures is not clear. The existing studies on environmental benefits arising from cross-compliance are few and mainly based on either expert judgement or simulation models rather than direct measurement of environmental outcomes. To the best of our knowledge, this paper is the first attempt to empirically evaluate the impacts of the newly reorganised European agriculture policy on farmers' environmental performance. Our identification strategy is to use a differences-in-differences approach, where we investigate the differential environmental response of farms subject to the cross-compliance policy implementation relative to the performance of farms that were not subject to the cross-compliance measures. We consider two proxy variables to capture farm environmental performance: expenditure on pesticides and fertilisers. To sharpen the identification of the cross-compliance policy effect, we take into account farms' dependency on overall subsidies and also their participation in other agro-environmental schemes. We also account for observed and unobserved farm-level heterogeneity by controlling for farm unobserved productivity changes, farm fixed effects, etc.

We find evidence that farmers subject to the national pre-2005 cross-compliance policy improved their environmental performance by significantly reducing their fertiliser and pesticide use. This effect is approximately 5 percent of the average annual fertiliser expenditure and 6 percent of the average annual pesticide expenditure of the treated farms.

We find no significant differences between treated and control farms when we take into account farm subsidy dependency levels. This might reflect a low probability of being checked and punished under this regulation and a relatively low non-compliance fine. When we take into account farms that participate in other agro-environmental programmes we find evidence that the cross-compliance policy effect is mostly negative and significant for fertiliser allowing us to conclude that the cross-compliance reinforces other policies directed to reduce the impact of farming activities on the environment.

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Appendix

Table A1 Descriptive statistics of pesticide and fertiliser expenditure by country (EU25)

Country	Pesticide expenditure, EUR				Fertiliser expenditure, EUR			
	Pre-2005		Post-2005		Pre-2005		Post-2005	
	Mean	Obs.	Mean	Obs.	Mean	Obs.	Mean	Obs.
BEL	5555	4655	7264	3375	6630	4655	7812	3375
CYP	1684	432	1024	1146	2909	432	1600	1146
CZE	41784	1287	42513	3781	36902	1287	42991	3781
DAN	8337	7554	10310	5350	9860	7554	12282	5350
DEU	11498	26132	14870	21527	11780	26132	17699	21527
ELL	1151	16530	1258	11707	1490	16530	1726	11707
ESP	1677	31643	1710	24456	2867	31643	2966	24456
EST	3427	482	4464	1461	7635	482	11552	1461
FRA	9363	29613	9554	21687	9568	29613	10393	21687
HUN	15884	1841	13679	5549	15962	1841	15166	5549
IRE	1358	4885	886	3585	5541	4885	5300	3585
ITA	2651	59316	3442	42445	2717	59316	3658	42445
LTU	5714	1027	6036	3335	11209	1027	13975	3335
LUX	3675	1830	4585	1338	7095	1830	8011	1338
LVA	6520	779	5972	2869	11062	779	13448	2869
MLT	1180	240	1360	813	1511	240	1776	813
NED	10280	4963	12321	4056	6926	4963	7723	4056
OST	1337	7561	1444	5998	1787	7561	2099	5998
POL	1450	11722	2504	35520	3036	11722	4699	35520
POR	1192	7853	1211	6042	2006	7853	1938	6042
SUO	1587	3045	1635	2559	4967	3045	5894	2559
SVE	2721	3679	3072	2872	6834	3679	8257	2872
SVK	44699	592	46659	1710	37020	592	41713	1710
SVN	605	494	703	2128	1386	494	1508	2128
UKI	9397	11088	9376	8330	12969	11088	13919	8330
Total	5180	239243	6435	225532	5941	239243	8038	225532

Figure A1 Fertiliser and pesticide expenditure per ha dynamics for EU15, 1999-2007

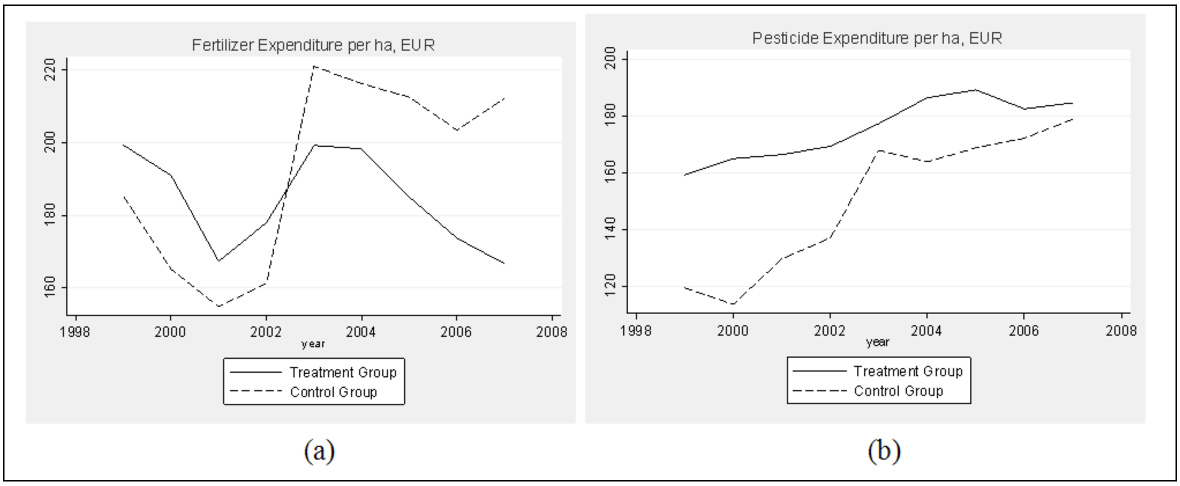

Table A2 Cross-compliance effect on fertiliser and pesticide use, EU27

	(1)	(2)	(3)	(4)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE
*Y*T*	-485.5**	-428.1***	-564.7**	-491.4***
	(203.1)	(145.8)	(244.4)	(188.7)
Y	omitted	omitted	omitted	omitted
T	175.2	-52.7	669.5*	31.5
	(312.1)	(208.6)	(359.9)	(244.2)
ENV	-1035.7***	-60.6	-1198.0***	-45.2
	(234.7)	(85.5)	(263.2)	(67.5)
Constant	-325153.6	9160.4	-1327927***	-334597.2**
	(473435.5)	(84300.1)	(361014.4)	(150845.2)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7017	0.0287	0.6900	0.0300
No. of observations	356082	356082	356082	356082
No. of countries	27	27	27	27
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation; ENV is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table A3 Cross-compliance effect on fertiliser and pesticide use when taking into account farm subsidy dependency, EU27

	(1)	(2)	(3)	(4)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE
*dpr*Y*T*	-1056.5	9.8	-775.3	437.5
	(908.2)	(315.6)	(1230.7)	(0.268)
*dpr*Y*	1427.7	149.1	1192.6	131.2
	(997.4)	(270.8)	(1329.8)	(322.5)
*dpr*T*	913.4	1510.8***	-229.0	1003.9**
	(994.7)	(420.8)	(1307.6)	(431.0)
*Y*T*	-237.2	-435.7**	-404.2	-630.1**
	(294.7)	(187.4)	(380.5)	(256.1)
dpr	-3034.2***	-2028.1***	-2760.7**	-1861.6***
	(1088.1)	(416.6)	(1366.5)	(419.4)
Y	omitted	omitted	omitted	omitted
T	-155.3	-335.5	583.1	-105.2
	(400.5)	(217.4)	(488.5)	(232.4)
ENV	-790.9***	0.8	-900.4***	18.8
	(209.7)	(85.2)	(237.5)	(68.7)
Constant	-323667.3	11272.1	-1260221***	-355404.7**
	(518627.1)	(85319.6)	(418440.2)	(144637.6)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7023	0.0297	0.6907	0.0308
No. of observations	356067	356067	356067	356067
No. of countries	27	27	27	27
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. dpr is a ratio of farm direct payments by total farm output; T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation; ENV is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes. *** p<0.01, ** p<0.05, * p<0.1.

Table A4 Cross-compliance effect on fertiliser and pesticide use when taking into account farm participation in other agri-environmental schemes, EU27

	(1)	(2)	(3)	(4)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE
*ENV*Y*T*	-1603.9**	-482.0***	-1539.8*	-58.8
	(745.0)	(182.5)	(922.6)	(218.1)
*ENV*Y*	13911.0**	267.6	1332.5	2.9
	(717.3)	(172.1)	(873.6)	(199.7)
*ENV*T*	1250.5	219.6	1158.2	-63.7
	(773.5)	(206.0)	(925.3)	(203.3)
*Y*T*	322.5	-226.6	211.9	-473.4*
	(433.9)	(170.0)	(564.1)	(247.2)
ENV	-1913.0***	-176.4	-2015.0**	2.4
	(727.9)	(196.0)	(845.4)	(193.9)
Y	omitted	omitted	omitted	omitted
T	-770.6	-264.6	-236.3	20.4
	(550.4)	(245.3)	(699.4)	(310.8)
Constant	-510151.3	-42491.7	-1502316***	-336136.2**
	(541875.3)	(96442.2)	(437363.9)	158551.8)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	no	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.7018	0.0288	0.6901	0.0300
No. of observations	356082	356082	356082	356082
No. of countries	27	27	27	27
Panel	unbalanced	unbalanced	unbalanced	unbalanced

Notes: Standard errors corrected for clustering at the regional level are reported in parentheses. ENV is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes; T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation. *** p<0.01, ** p<0.05, * p<0.1.

Table A5 National cross-compliance effect on fertiliser and pesticide use between 1999 and 2001

	(1)	(2)	(3)	(4)
Outcome variable	Fertiliser	Fertiliser	Pesticide	Pesticide
Model	OLS	FE	OLS	FE
*Y*T*	-192.4	-178.8	-366.0**	-301.3***
	(123.4)	(128.2)	(144.5)	(104.8)
Y	-237.8***	-267.5***	394.2***	343.5***
	(60.9)	(59.8)	(143.2)	(100.8)
T	-842.4***	175.5	-1490.2***	-706.6***
	(251.2)	(258.7)	(97.6)	(130.5)
ENV	-757.9***	-172.4**	-876.6***	2.9
	(158.6)	(68.9)	(227.4)	(68.9)
Constant	201481.3	-359150.1	107983	-66563.9**
	(240038.7)	(250061.2)	(94101.3)	(34942.4)
Year effects	yes	yes	yes	yes
Farm fixed-effects	no	yes	yes	yes
Country*time trend	yes	yes	yes	yes
Sector*time trend	yes	yes	yes	yes
Polynomial	yes	yes	yes	yes
R-squared	0.6787	0.0466	0.7478	0.0962
No. of observations	77263	77263	77263	77263
No. of countries	15	15	15	15
Panel	balanced	balanced	balanced	balanced

Notes: Standard errors corrected for clustering at the region level are reported in parentheses. T is the binary treatment indicator of cross-compliance; Y is the time dummy for the year of the cross-compliance policy implementation; ENV is a dummy variable for farms receiving compensations for their participation in other agro-environmental schemes. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

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