Agri-Environment Advisory Activities Effects on Best Management Practices Adoption: A Nonparametric Analysis

Tamini, Lota D.

Institut de recherche et de développement en agroenvironnement

August 2009

Agri-environmental Extension Activities and Best Management Practices Adoption[†]

Lota D. Tamini
Senior Research Fellow,
Institut de recherche et de développement en agroenvironnement,
Adjunct Professor, Department of Agricultural Economics
and Consumer Studies, Laval University

(April 2010)

Abstract: This study investigates the factors that determine producers' participation in agri-environmental advisory activities and their adoption of best management practices (BMPs) in Quebec (Canada). Data were collected from farmers in telephone interviews and the impacts of agri-environmental extension activities were analysed using *average treatment effect* and *local average treatment effect*, estimated with non-parametric approaches. The average effects of agri-environmental extension activities are statistically significant for the majority of BMPs. We also find a statistically significant formal diffusion effect of producer's membership in an agri-environmental advisory club. The informal diffusion effect is statistically significant for BMPs that need specific knowledge.

Key words: best management practices, producers' behaviour, agri-environmental extension, treatment effects.

J.E.L. Classification: Q12, Q16, Q58.

[†] Address of correspondence: 2700 Einstein Street, Québec (QC), G1P 3W8, Canada. Email: lota.tamini@eac.ulaval.ca. Financial support from the *Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec* (MAPAQ) and the *Conseil pour le développement de l'agriculture du Québec* (CDAQ) is gratefully acknowledged. The views expressed in the paper should not be attributed in any way to these funding agencies or to the Institut de recherche et de développement en agroenvironnement (Research and Development Institute for the Agri-Environment (IRDA)). The usual caveat about remaining errors applies.

Agri-environmental Advisory Activities and Best Management Practices Adoption

1. Introduction

Concerns about climate change, biodiversity and water pollution have heightened interest in mitigating the environmental consequences of agriculture through best management practices (BMPs). However, given the voluntary nature of the adoption of most conservation practices, farmers need to decide whether to adopt BMPs or not. Agri-environmental extension activities attracted considerable interest because of their ability to improve the performance of producers in the delivery of ecological goods and services (EGS) through BMPs. The farms' response to agri-environmental extension activities is thus a critical factor in determining the relative merits of alternative policies, together with key factors that govern BMP adoption, and ultimately, the supply of EGS.

There is a large body of literature regarding the determinants of adoption of BMPs in agriculture. Prokopy *et al.* (2008) provide a detailed survey with a focus on the United States. They review 25 years of literature to examine general trends in the categories of capacity, awareness, attitudes and farm characteristics. They conclude "*…the results are clearly inconclusive on what factors consistently determine BMP adoption*" (p. 308).

Rogers (2003) asserts that social systems can be characterized as *heterophilous* or *homophilous*. *Heterophilous* social systems tend to encourage interactions between people from different backgrounds, in a vertical and formal linkage system. In *homophilous* social systems, most interactions are between people from similar backgrounds in a horizontal system. People and ideas that differ from the norm thus appear strange and undesirable. In a BMP adoption setting, that effect contains important policy information for public policy planning (Case, 1992). Darr and Pretzsch (2006) and Knowler and Bradshaw (2007) find that formal and informal groups are important even if they do not know whether it is the access to information provided through social networks or the influence of social networks on subjective norms that affects adoption behaviour.

A major methodological problem that has not been addressed sufficiently by many of the previous studies on BMP adoption is the bias related to potential participation in formal and informal groups' activities. The correlation between participation in activities and BMP adoption could be due to a positive effect caused by participation in activities. There could also be a *self-selection* effect if farmers that already have more positive environmental attitudes than their peers participate more eagerly in such activities (see Salhofer and Streicher, 2005). To resolve this selectivity problem, one could use an instrumental variables (IV) approach, which uses an instrument that is correlated with participation in activities but is uncorrelated with BMP adoption.[1] However, identification and estimation is more complicated when the partial effect depends on unobserved heterogeneity. Indeed, farmers have different attitudes towards new technologies, risk and uncertainty, all of which might influence their adoption decision. Therefore, adopters and non-adopters may differ significantly in unobserved variables, which might lead to bias when analysing BMP adoption (Strauss *et al.*, 1991; Owens, Hoddinott and Kinsey, 2003; Feder, Murgai and Quizon, 2004). The focus is typically on estimating the *average partial effect,* that is the partial effect averaged across the population distribution of the unobserved heterogeneity.[2] When the endogenous variable is binary, for example, participation in a program, the

[1] In the first step, one would estimate an equation describing the participation in advisory activities and use this to calculate the inverse Mills ratio and include it in the adoption equation as an additional explanatory variable (Heckman, 1979). The coefficient of the Mills ratio can be seen as the value added to the extension activities through the BMPs' adoption. The study by Rejesus *et al.* (2009) is a recent application of this method. Crost *et al.* (2007) use fixed effects to control for the selectivity problem. This approach cannot be used in situations where only cross-sectional data are available.

[2] A popular model where the endogenous explanatory variable interacts with unobserved heterogeneity is the *switching regression model* (e.g., Maddala, 1983), which has received considerable attention recently in the program evaluation literature.

average partial effect is called the *average treatment effect*. This concept, introduced by Rosenbaum and Rubin (1983), is based on the fact that only one of the potential outcomes is ever observed for each producer. In the setting of a voluntary program where those not enrolled will never be required to participate in the program, the *average treatment effect on treated* (ATT) is the *estimand* of most interest (Imbens and Wooldridge, 2009).

The aim of the paper is to identify how agri-environmental extension activities in the province of Quebec (Canada) affect the adoption of BMPs by a farmer compared with what he would have experienced had he not participated. We use the concept of ATT to evaluate the effect of extension activities on the adoption of BMPs. The estimated ATT is the expected effect on BMP adoption of extension activities on a farm randomly drawn from the subpopulation of farms that participate in extension activities (Wooldridge, 2002). In addition, we quantify the potential vertical (i.e. formal) and horizontal (i.e. informal) diffusion effects on BMP adoption of the agri-environmental advisory clubs. We do so using the concept of *local average treatment effect* (LATE) suggested by Imbens and Angrist (1994). The LATE measures the average treatment effect among producers who decide to participate in agri-environmental activities because of the activities of the advisory clubs.

Our estimations show that for most of the studied BMPs, both extension activities and the advisory clubs have a positive statistically significant impact on the probability of BMPs adoption. Nevertheless, the advisory clubs network has a lesser effect on the probability of establishing and maintaining a riparian buffer zone, and on the immediate incorporation of manure. In addition, we found an informal relationship, i.e. the possible horizontal diffusion effect of the advisory clubs for the BMPs that require most advanced knowledge.

The remainder of the paper is structured as follows. Section 2 describes agri-environmental extension activities in the province of Quebec while Section 3 presents our empirical approach. Section 4 outlines aspects of our data and Section five presents and discusses the results of the estimations. The last section concludes the paper.

2. Institutional background: agri-environmental extension activities in Quebec

In June 2002, the Québec government adopted the *Regulation Respecting Agricultural Operations* to address the non-point source pollution problem (Éditeur officiel du Québec, 2002). Its provisions took immediate effect for new facilities and for the expansion of existing ones. Other farms were given until 2010 to fully comply. In November 2002, the Quebec government adopted the *Quebec Water Policy* to ensure a better framework for water management and to guarantee the sustainability of the resource (MENV, 2002). Because agricultural activities may have a major impact on natural resources, the farming sector is expected to play a significant role in compliance with water quality standards. The water policy also sets forth commitments to intensifying agricultural clean-up efforts complementary to the *Regulation respecting agricultural operations*. In addition, in 2003, the government of Quebec adopted a directive on odours caused by manure from agricultural activities and a code on pesticide management. The latter introduces standards to regulate the use, sale and storage of pesticides with the objective of reducing human exposure.

To help farmers adapt to all these regulations, in 2004, the Quebec Department of Agriculture (*Ministère de l'agriculture des pêcheries et de l'alimentation du Québec*) launched a "farm-by-farm" agri-environmental strategy based on a comprehensive environmental tool called the agri-environmental support plan. It is the provincial equivalent of the federal environmental farm plan. The support plan involves obtaining a comprehensive portrait of a farm's agri-environmental situation, formulating an action plan and implementing the solutions described in the support plan. The disposal capacity of fertilizers, whether a farm's agri-environmental practices comply with regulatory requirements; and other farming practices that involve the environment (e.g., erosion control, odour reduction and optimization of pesticide use) are evaluated. During the process, the priorities identified by the farm and its particular business features are taken into account (MAPAQ, 2003). It is a voluntary process done either with or without the assistance of an advisor from an agri-environmental advisory club.

The creation of advisory clubs in 1993 was inspired by various agri-environmental initiatives by Quebec farmers. Consultations conducted in 1996 showed that the advisory clubs successfully educated and engaged farmers in sustainable agriculture. The Quebec Department of Agriculture and the farmers' union (*Union des producteurs agricoles,* UPA hereafter) were eager to make agri-environmental advisory activities accessible to more farmers. In 2008, the advisory club network had more than 8,300 members grouped into 83 clubs, served by more than 300 advisors.[3] Activities of advisory clubs relate to guidance for management of fertilizer, reducing pesticide use, including methods of integrated pest management, cultural practices for conservation, management and protection of watercourses. The approach used combines activities oriented toward individual producers

[3] A partnership agreement between the Quebec Department of Agriculture and UPA on advisory services for sustainable development of farms, whose general objective is to develop and offer advisory services, came into effect on April 1, 2009 and will end on March 31, 2013 (see http://www.clubsconseils.org/accueil/affichage.asp?B=745, accessed on February 8, 2010). The *Prime-Vert* program provides financial assistance for the agri-environment advisory services. It also targets the purchase of odour-reduction equipment and non-point source pollution by providing financial assistance to encourage specific management practices such as soil conservation, windbreaks, winter cover crops,… A portion of the *Prime-Vert* funding is provided by the federal government of Canada through its strategic agricultural framework (Boutin, 2005).

and group activities. They include individual support for developing plans (fertilization plans, rotation plans, management plans for riparian buffers), advisories to achieve balance (phosphorus and nutrient balance) and soil sampling. Groups' activities may include training, demonstration and information, and visits to leading farms. These activities allow farmers to share their knowledge and aim to clarify agri-environmental issues farms are facing.

Since 2004, the advisors in the advisory clubs have used the support plan in their daily work. The February 2008 Report by the *Commission sur l'avenir de l'agriculture et de l'agroalimentaire du Québec* indicates that the progress of Quebec farmers in protecting the environment is largely due to the fact that they have been able to rely on the advice of experts who understand their needs and who helped them formulate and implement agri-environmental support plans (CAAAQ, 2008). There are two dimensions to consider when trying to evaluate the impacts of advisory activities on the adoption of BMPs in Quebec: the relevance of agri-environmental support plans as a tool to improve farmers' environmental practices and the efficacy of the advisory clubs as a way to persuade producers to adopt a support plan, and ultimately, to improve their environmental practices.

3. Estimation methods

The dominance of family businesses is an important characteristic of the farm sector in Quebec (CAAAQ, 2008). It complicates the theoretical and empirical analysis of the impact of agri-environmental extension activities. Decisions relating to production, consumption, and leisure for family members must be made simultaneously. Moreover, the reduction of pollutants following the adoption of BMP affects the welfare of producers through both their production function and their health. Costs and benefits ought to differ between individuals depending on specific characteristics of the farm and depending on the characteristics of the farmer, some of which, however, may not be fully observed (unobserved heterogeneity). We should not expect to find responses to extension activities to be homogenous across individual farms. Participation in extension activities is typically voluntary, introducing another potential unobserved heterogeneity. Therefore, we estimate the treatment effect averaged across the population distribution of unobserved heterogeneity using non-parametric approaches.[4,5] These approaches avoid delicate assumptions about functional form and independence. In addition, the endogeneity of regressors that are not of main interest may not affect the estimated relationship between the regressor of interest and the outcome (Frölich, 2006). We rely on the non-parametric instrumental variables (IV) estimation of *local average treatment effect* with covariates proposed by Frölich (2007) to estimate the potential vertical. i.e. *heterophilous*, diffusion effect of the advisory clubs. Applying Frölich's (2007) approach, we allow for confounding factors, that is, factors that influence the potential probability of adopting a given BMP and the decision to adopt a support plan and the decision to be a member of an advisory club. We then try to mitigate some of the difficulties of improper instrumental variables resulting from inadequate covariates. As Oréopoulos (2006: p. 152) notes, "*…when responses to treatment vary, different instruments measure different effects…*" We exploit this fact and use "vicinity" as an instrumental variable for the informal, i.e. *homophilous*, diffusion impact of the advisory clubs.

---

[4] Most models assume additive separability in the error term; hence, they assume a constant treatment effect for individual farms with the same value of covariates (e.g. Rejesus *et al.*, 2009). Additively separable models thus rule out unobserved heterogeneity and are not appropriate given the issues of the study at hand.

[5] Non-parametric empirical applications of treatment effect models when evaluating policies in the agricultural context are limited. Examples are Godtland *et al.* (2004), Lynch, Gray and Geoghegan (2007), Lynch and Liu (2007) and Pufahl and Weiss (2009).

Measuring the impact of agri-environmental extension activities on BMP adoption

Participation in agri-environmental extension activities is modeled as a discrete choice taking the value of 1 if the producer has a support plan and 0 otherwise. The estimated *average treatment effect* is the expected effect on the outcome (adoption of the BMP) that producers have gained because of their participation in extension activities (treatment). However, given the voluntary nature of participation in extension activities, the estimated *average treatment effect on the treated* is of greatest interest (see Imbens and Wooldridge, 2009). The ATT is the expected effect that participants in extension activities have experienced because of their participation:

(1) $$ATT = E\left(\lambda^1 \mid \mathbf{x}, s=1\right) - E\left(\lambda^0 \mid \mathbf{x}, s=1\right)$$

where $\lambda \in \{0,1\}$ is the adoption variable taking the value of λ^1 when the BMP is adopted and λ^0 when it is not; $\mathbf{x}$ the vector of farms' and farmers' characteristics; $s \in \{0,1\}$ shows whether the producer has a support plan $\left(s^1\right)$ or not $\left(s^0\right)$ and is assumed to be endogenous. The treatment effect is estimated non-parametrically using propensity-score matching estimators (Frölich, 2006).

Measuring the impact of the agri-environmental advisory clubs on BMP adoption

Producers can be distinguished into four types according to their reaction at an external intervention, i.e. an instrument (see Imbens and Ingrist, 1994): *never-participant*, *complier*, *defier* and *always-participant* (Table 1). The *compliers* are farmers who adopted a support plan because of an external intervention. Consistent with Imbens and Ingrist's (1994) definition, the estimated LATE measures the expected effect of participation in extension activities (treatment) on the probability of adopting a BMP (the outcome) because of external intervention. The LATE is:

(2) $$LATE = \frac{E\left[\lambda \mid \mathbf{x}, z=1\right] - E\left[\lambda \mid \mathbf{x}, z=0\right]}{E\left[s \mid \mathbf{x}, z=1\right] - E\left[s \mid \mathbf{x}, z=0\right]}$$

where $z = \{0,1\}$ is the instrumental variable taking the value of 1 or 0; the other variables have been defined above. The LATE is estimated using a propensity score matching estimator (Frölich, 2007; Frölich and Lechner, 2010).[6] Aside from the estimated LATE, the fractions of *compliers* (c) and *never-participants* (n) are *estimands* of interest for public policy planning. They are given, respectively, by equations (3) and (4):

(3) $$\Pr\left(\varpi = c \mid \mathbf{x}\right) = E\left[s \mid \mathbf{x}, z=1\right] - E\left[s \mid \mathbf{x}, z=0\right]$$

(4) $$\Pr\left(\varpi = n \mid \mathbf{x}\right) = E\left[1 - s \mid \mathbf{x}, z=1\right]$$

where ϖ represents producers' types according to their reaction to the instrument. IV does not identify the expected average treatment effects for the *always-participants* (a) and the *never-participants*. Nevertheless, using the results of Frölich and Lechner (2010), we can identify the expected treatment outcome for the *always-participants* by

(5) $$E\left[\lambda^1 \mid \varpi = a\right] = \frac{E\left[\lambda \cdot s \mid \mathbf{x}, z=0\right]}{E\left[s \mid \mathbf{x}, z=0\right]}$$

and the control outcome of the *never-participants* by

(6) $$E\left[\lambda^0 \mid \varpi = n\right] = \frac{E\left[\lambda \cdot (1-s) \mid \mathbf{x}, z=1\right]}{E\left[(1-s) \mid \mathbf{x}, z=1\right]}$$

[6] The ATT and the LATE are estimated using the Gauss codes of Frölich available at http://froelich.vwl.uni-mannheim.de/1357.0.html?&L=1. Accessed March 3, 2009.

Measuring vertical diffusion effects

The vertical, i.e. *heterophilous*, linkage that can increase access to information and BMP adoption is studied using membership in an advisory club as instrument. Using membership as an instrument for participation in extension activities, assuming that membership is exogenous from adoption, will return the effect of extension activities for farms whose adoption is highly affected by membership. These farms are likely to respond more significantly to a change in participation status than the average farm.

Measuring horizontal diffusion effects

The horizontal, i.e. *homophilous*, diffusion effects of the agri-environmental advisory clubs network is estimated using the "vicinity" as the instrumental variable. To construct this variable, producers who are not members of an advisory club had to answer the following survey question: "*Do you know a producer, friend or neighbour who is a member of an agri-environmental advisory club?*" Nevertheless, regardless of whether living close to or far from a member of an advisory club is an active choice, that choice might be related to characteristics that affect the decision to adopt a given BMP or not. The estimated LATE measures the expected impact in adoption caused by the participation in extension activities because of the "neighbourhood effect."[7]

Implementation procedure

Our implementation procedure follows Frölich (2004, 2007) and is described in Frölich and Lechner (2010). The propensity score is derived from a Probit model. Bandwidth values are

---

[7] In Case (1992) and Holloway, Shankar and Rahman (2002) the term "neighbours" refers to all farmers living in the same district. Halloway *et al.* (2002). The authors use spatial econometrics to estimate "neighborhood effects" in high-yielding variety adoption among Bangladeshi rice producers.

selected by leave-one-out least squares cross-validation for the nonparametric regression. With the selected bandwidth, treatment effects are estimated non-parametrically using *ridge matching*. Usually, *ridge matching* was the best estimator (lower mean square error) particularly in small samples (Frölich, 2004).

In line with Viet (2008), Frölich and Lechner (2010) and Behrman, Cheng and Todd (2004), confidence intervals (CI) of the treatment effects are simulated using bootstrapping methods. The bootstrap consisted of drawing with replacement from the original sample and repeating 999 times the entire estimation process (see Brownstone and Valleta, 2001; Wooldridge, 2002).[8]

4. Data description

Data are from a survey and the coordinates of the farms were provided by *Ministère de l'agriculture, des pêcheries et de l'alimentation du Québec* (MAPAQ) upon authorization from the *Commission on Access to Information*. Data are from a survey implemented between February and March 2009. The year of reference was 2008 and the dataset consists of 200 observations. The survey targeted agricultural enterprises (i) registered in the MAPAQ farms dataset and (ii) deriving their main revenue from milk production, beef cattle, hogs, poultry, sheep, crops, vegetables, potatoes, apples, berries and tobacco. We use a stratified random plan as the sampling method. The main production of the farm forms the different strata. The portrait of Quebec producers formed the basis of the sampling strategy. Table A1 defines the variables used and their corresponding summary statistics.

[8] See Politis, Wolf and Romano (1999) and Imbens and Wooldridge (2009) for a proof of the validity of this subsampling approach.

The support plan is modelled as a discrete choice taking the value of one when the producer has a support plan and zero otherwise. 47.37% of producers have a support plan and 36% are members of an advisory club. In addition, 40.34% of producers that are not members of an advisory club claimed to have a neighbour or a friend that is a member. In that case, the variable *vicinity* takes the value of 1 and 0 otherwise. As a covariate, producers and farm attributes are taken into account as well as some external characteristics.

Six BMPs are analysed and are all introduced through binary variables that take the value of 1 if the BMP is adopted and 0 otherwise. The BMP studied first is related to compliance with the regulatory norms concerning manure analyses; it is supposed to be in effect in 2010. The BMP takes the value of 1 if the analysis was done in the last 12 months for manure and 5 years for soil. Producer adoption decisions regarding conservation tillage are studied. Consistent with Davey and Furtan (2008), we define conservation tillage as tillage that retains most of the previous crop residue on the soil surface, including zero tillage. The BMP associated with the management of manure takes the value of 1 when the manure is injected into the soil within 24 hours of the initial spreading and 0 otherwise. The establishment and maintenance of a riparian buffer zone takes a value of 1 when a riparian buffer zone larger than one metre is established and maintained and 0 otherwise. The BMP related to the use of mineral fertilizers is studied. It takes the value of 1 if the producers do not use mineral fertilizers. Otherwise, the value is zero. Finally, investment in the construction of run-off control structures (hydraulic infrastructures) is studied.

Table 2 presents a preliminary analysis of the BMPs. For the studied BMPs, it compares proportions of adopters between the subpopulations of producers with and without a support plan. Table 2 shows that the differences in proportion of adopters are significant, at a level of 5%.

4. Empirical results

4.1. Factors affecting participation in agri-environmental extension activities

Factors affecting the decision to participate in agri-environmental extension activities, proxied by the adoption of a support plan, are estimated using a Probit. Table A2 presents the results. Results show that age has a negative impact for one class while that effect is statistically non-significant for the other classes. Farmers aged between 45 and 55 are found to have a 44.1% lower probability of participating in extension activities compared with farmers age 45 and under. Farmers that have completed secondary school have a higher probability of participating, as are farmers who have more experience with farm management. When a farmer possesses environmental awareness, this increases the probability of deciding to have a support plan by 27.4%. Kaiser, Wolfing and Fuhrer (1999) indicate that awareness of environmental concerns usually precedes the adoption of a desirable attitude toward the issue of interest. However, Kaiser *et al.* (1999) do not find a strong relationship between behaviour and awareness. In the context of developing countries, Ecobichon (2001) and Heong *et al*. (2002) also report a general awareness of chemical inputs' secondary effects, but this does not necessarily influence farmers' production behaviour. Tucker and Napier (2001) find that even if some Midwestern US farmers were aware of the potentially negative consequences of chemical input use, this awareness does not necessarily influence farmers' production behaviour.

Only the smallest farms, i.e., with TGR below $50,000, have a lower probability of adopting a support plan. They are 30.4% less likely to use a support plan than the median class. For the other classes of TGR, the differences are statistically non-significant. It is also the case for bovine, milk, hog and cereal production. However, there is a difference for the other animal and crop production, with respective probabilities of participating in extension activities 39.8% and 37% lower, compared with hog production, the base production. As expected, having observed soil degradation has a positive marginal effect; it increases the probability of having a support plan by 23.5%. Finally, the degradation of rivers and the geographical location of the farm have a statistically non-significant effect on the probability of having a support plan.

Evidence of heterogeneity of participation in extension activities

Figure 1 presents a histogram of the propensity scores for adopters and non-adopters of the selected BMPs. For most of the selected BMPs, it clearly supports the idea of heterogeneous treatment effects of the adoption of a support plan; high propensity scores are associated with adoption, as are low propensity scores. The same is observed for non-adoption.

Balancing test

A "balancing test" reveals whether the comparison groups created with the propensity score sufficiently resemble the treatment groups. We follow Godtland *et al.* (2004) and perform a balancing test by dividing each comparison and treatment group into two strata, ordered by propensity scores. Within each stratum, a *t*-test of equality of means in the two samples of participants and non-participants was conducted for each control variable. The results of these tests are reported in Table 3. The null was not rejected for the majority of variables. These results indicate no systematic differences between the "treated" farmers, i.e. farmers with a support plan, and the comparison group in their observed characteristics.

4.2. Average effect of agri-environmental extension activities

For each studied BMP, the estimated average treatment effect on treated measures the impact of agri-environmental extension activities on the expected probability of adopting for the subgroup of producers who have a support plan. A positive ATT value suggests that the subgroup of producers with a support plan have a greater probability of adopting because of it. Table 4 reports ATT and their corresponding bootstrapped 95% confidence intervals.

The average positive impact is higher for the immediate incorporation of manure. The value of 0.093 indicates that participating in extension activities increases the probability of adopting the BMP by 9.3%. A possible explanation is that extension activities can show that adopting immediate incorporation of manure can generate private gains (specifically material and energy savings) as well as environmental gains (reduction of pollutants, e.g., phosphorus and nitrogen, and of manure odours). In addition, as reported by Deaton *et al.* (2005) diligence in environmental protection has become a major consideration for farmers because of growth in rural residential. Producers face less understandings vis-à-vis production practice with visible environmental impact, which is the case of manure spreading. The average positive impact on the adoption of the non-use of mineral fertilizers is also notable at 5.9% respectively. This result corresponds to Pufahl and Weiss (2009), who observe a 9.4% reduction in fertilizer expenditures when studying the impact of agri-environmental programs in Germany. Participation in extension activities increase the probability to establishment and maintain a riparian buffer zone by 2% even if, from an individual landowner's perspective, benefits may not clearly outweigh costs when establishing and maintaining such a zone (see Brethour *et al.*, 2007). But, as mentioned by footnote #3, producers receive financial support when implementing riparian buffers. For conservation tillage, although statistically significant, the positive impact of extension activities is lower at 1.3%. This could be due to the mixed results of studies of the impact of this BMP on the profitability of farms. Smith *et al.* (1996) indicates that conservation tillage is not economically competitive, while Mooney and Williams (2007) show that, under some circumstances, it is. The average impact on the adoption of manure analyses is the low at 1%. This is an unexpected result because this BMP is related to compliance with the incoming regulatory norms. Finally, participation in extension activities has no statistically significant impact on the probability to construct hydraulic infrastructures to control soil erosion.

Overall, our results show that, for most of the studied BMPs, the support plan reached its objective, i.e., to help producers enhance their environmental performance.

4.3. Average effects of agri-environmental advisory clubs

Average heterophilous effect of agri-environmental advisory clubs

The estimated fraction of *never-participants* is 0.283 with a bootstrapped 95% CI of [0.156; 0.429]. It indicates that 28.3% of farmers who do not participate in agri-environmental extension activities will not change their status even if they join an agri-environmental advisory club. *Compliers* are farmers who use a support plan because they belong to an advisory club. In a cost-benefit analysis of the advisory clubs network, this *estimand* is important. Their estimated fraction is 0.344 with a bootstrapped 95% CI of [0.185; 0.484]. This result indicates that over one-third of producers in the database react to membership in an advisory club by adopting a support plan. The *always-participants* comprise slightly more than one-third of producers.

Table 5 reports the results of the estimated LATEs of *compliers* with their corresponding 95% confidence intervals. The estimated LATEs are positive and statistically significant for all the studied BMPs, indicating a vertical linkage that increases access to information, spread of ideas and the adoption of BMPs. The values of the ATT (see Table 4) and the LATE (see Table 5) are different, indicating that adherence to an advisory club has a non-homogenous impact on participation in extension activities. Although the advisory clubs have adopted the support plan as a working tool, the estimated LATEs provide only a measure of the effectiveness of the network.[9]

Manure analysis realization is the BMP with the greatest average impact of membership in an advisory club. The result of 47.8% (LATE=0.478) is the expected mean effect on the probability of adoption of manure analyses for farmers that decide to use a support plan because they belong to an advisory club. The probability of adoption is, on average, augmented by 47.8%. This is quite a large effect but it is expected because this BMP is related to compliance with regulatory norms that will be in place in 2010. In a report on the evaluation of the agri-environmental advisory clubs activities, Sogémap (2007) indicates that adherence is largely due to regulatory reasons, at 67%. The estimated LATE of the adoption of conservation tillage, the non-use of mineral fertilizers and the construction of hydraulic infrastructures are also important, indicating a statistically significant effect of the advisory clubs activities on the level of adoption. These results are consistent with Sobels, Curtis and Lokie (2001), who find that increases in social capital play a role in the success of the Landcare program in Australia. Estimates indicate lower effects for the injection of manure into the soil within 24 hours of the initial spreading and riparian buffer zone

[9] As mentioned by Heckman (1997: p 456), the LATE assumes that the external intervention has no effect on non-switchers.

establishment and maintenance: 25.2% and 6.7% respectively. The latter effect is lower than the result of Ghazalian, Larue and West (2009) who report that belonging to a club augments the probability of establishing and maintaining a riparian buffer by 16%.[10] Nevertheless, Prokopy *et al.* (2008) report an inconclusive relationship between networking and the decision to adopt some of the BMPs related to livestock management, landscape management and soil management.

Table A4 shows that, for all the studied BMPs, *compliers* benefit more from the activities of the advisory clubs. For example, for manure analyses, the treatment outcome for the *always-participants* is 0.763, while it is 0.821 for the *compliers*. Interestingly, the control outcome for the *never-participants* is 0.476 while it is 0.342 for the *compliers*. This result indicates that the *never-participants* group consists of producers who are more likely to implement manure analyses without advisors assistance. Excepted the riparian buffer zone establishment and maintenance, the results presented in Table A4 are similar for the other studied BMPs. From policy-makers' perspective, these findings suggest that the agreement between Quebec Department of Agriculture and UPA on advisory services for sustainable development of farms is probably cost effective for the subgroup of *compliers*.

Average homophilous effect of agri-environmental advisory clubs

The estimated fraction of *never-participants* is 0.460 with a bootstrapped 95% CI of [0.393; 0.524]. It indicates that 46% of farmers who do not participate in extension activities will not change their status even if they share "vicinity" with a member of an advisory club. The estimated fraction of *compliers* is 0.220 with a bootstrapped 95% CI of [0.044; 0.38], lower

[10] Ghazalian *et al.* (2009) use Bayesian estimation methods and do not address the potential endogeneity and self-selection issues in their study.

than for those who have a membership in an advisory club. 22% of farmers in the database react to "vicinity" by adopting a support plan.

Table 6 reports the horizontal diffusion impact of the advisory clubs. For the entire population of producers, we try to identify the gain from knowing at least one member of an advisory club. Positive impacts are found for the manure analyses, the construction of hydraulic infrastructures and the non-use of mineral fertilizers at 2.1%, 10.5% and 13.1% respectively. For these BMPs, neighbourhood effect results to a higher probability to adopt.[11] Interestingly, the implementation of these 3 BMPs needs specific knowledge. The non-significant impact for riparian buffer implementation is expected, given the results of the formal diffusion effects. Our results show a negative impact of "vicinity" on the conservation tillage. We had no expectations about the direction of the impact of "vicinity" because of the mixed results of the economic studies on the profitability of conservation tillage. "Vicinity" has a non-significant impact on the implementation of manure incorporation. We expected a positive impact because of the ability of the visible environmental gain (e.g. reduction of manure odours) of this BMP.

5. Conclusion

This study investigated the factors determining producers' participation in agri-environmental extension services and its impact on the adoption of various best management practices (BMPs). The participation in agri-environmental extension activities

[11] Halloway *et al.* (2002) found a "neighborhood effect" significantly different from zero. Defrancesco *et al.* (2007) also suggest that local behavioural influences have to be taken into account when designing and communicating agri-environmental measures. They define *conditional non-adopters* as farmers who participate because of easier-to-fit measures and higher payments. The local community and more particularly by neighbouring farmers negatively influence *conditional non-adopters* while positively influencing *actives participants* (for both financial and environmental protection reasons). Our results show that, as expected, "neighborhood effects" is also BMP specific.

is proxied by Quebec farmers' adoption of an agri-environmental support plan. Data were collected from farmers through telephone interviews conducted in February and March 2009. Collected data include producer and farm characteristics, along with external features that can affect participation in agri-environmental extension activities. We analyse the link between participation in agri-environmental extension activities and the adoption of six BMPs, as well as the link between BMP adoption and the agri-environmental advisory clubs network.

The average impacts of the agri-environmental extension activities on BMP adoption are estimated using *average treatment effect on treated*. In most of the BMPs, extension activities have a positive statistically significant impact on the probability of adopting, with a higher effect for the immediate incorporation of manure within 24 hours of initial spreading. The agri-environmental advisory clubs' impact on the probability of adopting BMPs is estimated using the concepts of *local average treatment effect*. Membership in an advisory club is used as instrumental variable when studying the vertical linkage (*heterophilous*, i.e., people with dissimilar characteristics) that increases adoption. The advisory clubs were found to have a statistically significant positive effect for most of the studied BMPs. Nevertheless, it has no effect on the probability of establishing and maintaining a riparian buffer zone, nor on the immediate incorporation of manure. In addition, the informal relationship, i.e. the possible horizontal diffusion effect of the advisory clubs is studied using "vicinity" as an instrumental variable. In doing so, we use the fact that, in the *local average treatment effect*, different instruments measure different effects. We found a positive significant diffusion effect for only 3 of the studied BMPs.

The number of observations used in the present study limits the extent to which the results can be generalized but, clearly, our results suggest that agri-environmental extension activities and advisory clubs play an important role in disseminating information, raising awareness of BMP adoption and ultimately on the supply of ecological goods and services. The results also confirm that, like most of the other factors affecting BMP adoption, the treatment effects are “BMP-specific.” Even if the non-parametric approach used in the present study is based on the assumption of appropriate control variables and instruments, we consider it a useful technique for empirical evaluation of extension activities or institutions. It provides an adequate way of dealing with the potential endogeneity and treatment heterogeneity issues of the extension and advisory activities when analysing their impact on the supply of EGS. Our results suggest that governmental policies that invest in social capital may help create a sufficiently enabling environment for the adoption of BMPs.

References

Behrman, J.R., Cheng, Y. and Todd, P.E. (2004). Evaluating Preschool Programs when Length of Exposure to the Program Varies: A Nonparametric Approach. *The Review of Economics and Statistics* 86: 108–132.

Boutin, D. 2005. The Challenge of Reconciling Water and Agricultural Policies - The Role of Public Hearings. Presented at the OCDE Workshop on Agriculture and Water: Sustainability, Market and Policies. Adelaide (Australia), 14-18 November 2005.

Brethour, C., Sparling, B., Cortus, B., Klimas, M. and Moore, T. (2007), *An Economic Evaluation of Beneficial Management Practices for Crop Nutrients in Canadian Agriculture.* Final Report. Prepared for: Crop Nutrients Council. Agriculture and Agri-Food Canada.

Brownstone, D. and Valletta, R. (2001). The Bootstrap and Multiple Imputations: Harnessing Increased Computing Power for Improved Statistical Tests. *Journal of Economic Perspectives* 15: 129–141.

CAAAQ [Commission sur l'avenir de l'agriculture et de l'agroalimentaire au Québec]. (2008). *Agriculture and Agrifood: Securing and Building the Future Proposals for sustainable and healthy agriculture.* Report.

Case, A. (1992). Neighbourhood influence and technological change. *Regional Science and Urban Economics* 22: 491–508.

Crost, B., Shankar, B., Bennet, R. and Morse, S. (2007). Bias from Farmer Self-Selection in Genetically Modified Crop Productivity Estimates: Evidence from Indian Data. *Journal of Agricultural Economics* 58: 24-36.

Darr, D. and Pretzsch, J. (2006). The Spread of Innovations within Formal and Informal Farmers Groups: Evidence from Rural Communities of Semi-Arid Eastern Africa. Conference on International Agricultural Research for Development, Tropentag, University of Bonn, October 11-13 2006.

Davey, K.A. and Furtan, H. (2008). Factors that Affect the Adoption Decision of Conservation Tillage in the Prairie Region of Canada. *Canadian Journal of Agricultural Economics* 56:257-276.

Deaton, B., Jayasinghe-Mudalige, U., Ramirez, D., Trant, M. and Weeksink, A. (2005). Effect of Urbanization on the Adoption of Environmental Management Systems in Canadian Agriculture. Selected paper presented at the American Agricultural Economics Association annual meeting, Providence, Rhode Island, July 24-27.

Defrancesco, E., Gatto, P, Runge, F and Trestini, S. (2007). Factors Affecting Farmers' Participation in Agri-environmental Measures: A Northern Italian Perspective. *Journal of Agricultural Economics* 59: 114-131.

Ecobichon, D (2001). Pesticide use in Developing Countries. *Toxicology* 160:27-33.

Éditeur officiel du Québec (2002). Règlement sur les exploitations agricoles. *Gazette officielle du Québec, 14 juin 2002, 134^{e} année, no 24A.* Pp 3525-3539.

Feder, G., Murgai, R. and Quizon, J. (2004). Sending Farmers Back to School: The Impact of Farmer Field Schools in Indonesia. *Review of Agricultural Economics* 26: 45-62.

Frölich, M. (2004). Finite Sample Properties of Propensity-Score Matching and Weighting Estimators. *The Review of Economics and Statistics* 86: 77-90.

Frölich, M. (2006). A Note on Parametric and Nonparametric Regression in the Presence of Endogenous Control Variables. IZA Discussion Paper 2126. Institute for the Study of Labor.

Frölich, M. (2007). Nonparametric IV Estimation of Local Average Treatment Effects with Covariates. *Journal of Econometrics* 139: 35-75.

Frölich, M. and Lechner, M. (2010). Exploiting Regional Treatment Intensity for the Evaluation of Labour Market Policies. Forthcoming in *Journal of American Statistical Association*.

Ghazalian, P. L., Larue, B., and Gale, E.W. (2009). Best Management Practices to Enhance Water Quality: Who is Adopting Them? *Journal of Agricultural and Applied Economics* 41: 663-682.

Godtland, E. M., Sadoulet, E., de Janvry, A., Murgai, R. and Ortiz, O. (2004). The Impact of Farmer Field Schools on Knowledge and Productivity: a Study of Potato Farmers in the Peruvian Andes. *Economic Development and Cultural Change* 53: 63–92.

Halloway, G., Shankar, B. and Rahman, S. (2002). Bayesian Spatial Probit Estimation: a Primer and an Application to HYV Rice Adoption. *Agricultural Economics* 27: 382-402.

Heckman, J. (1979). Sample Selection Bias as a Specification Error. *Econometrica* 47: 153–61

Heckman, J. (1997). Instrumental Variables. A Study of Implicit Behavioral Assumptions Used in Making Program Evaluations. *Journal of Human Resources* 32: 441-462.

Heong, K., Escalada, M., Sengsoulivong, V. and Schiller, J. (2001). Insect Management Beliefs and Practices of Rice Farmers in Laos. *Agriculture, Ecosystems and Environment* 92:137-145.

Imbens, G. and Angrist, J.D. (1994). Identification and Estimation of Local Average Treatment Effects. *Econometrica* 62: 467-475.

Imbens, G. and Wooldridge, J.M. (2009). Recent Developments in the Econometrics of Program Evaluation. *Journal of Economic Literature* 47(1): 5-86.

Kaiser, F.G., Wolfing, S. and Fuhrer, U. (1999). Environmental Attitude and Ecological Behavior. *Journal of Environmental Psychology* 19: 1-19.

Knowler, D. and Bradshaw, B. (2007). Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Recent Research. *Food Policy* 32: 25-48.

Lynch, L., Gray, W. and Geoghegan, J. (2007). Are Farmland Preservation Program Easement Restrictions Capitalized into Farmland Prices? What can a Propensity Score Matching Analysis tell us? *Review of Agricultural Economics* 29: 502–509.

Lynch, L. and Liu, X. (2007). Impact of Designated Preservation Areas on Rate of Preservation and Rate of Conversion: Preliminary Evidence. *American Journal of Agricultural Economics* 89: 1205–1210.

Maddala, G.S. (1983). *Limited-Dependent and Qualitative Variables in Econometrics*. Econometric Society Monographs in Quantitative Economics. Cambridge, Cambridge University Press.

MAPAQ [Ministère de l'Agriculture, des Pêcheries et de l'Alimentation]. (2003). Plan d'Accompagnement Agroenvironnemental (PAA). http://www.mapaq.gouv.qc.ca/Fr/ Productions/md/Formulaires/plan+accompagnement.htm. Accessed April 8, 2009.

MENV [Ministère de l'Environnement, Québec] (2002). *Water. Our Life. Our Future. Québec Water Policy*. *Highlights*. Quebec City: Ministère de l'Environnement. 24 p. http://www.mddep.gouv.qc.ca/eau/politique/index-en.htm

Mooney, S. and Williams, J. (2007). Private and Public Values of Soil Carbon Management. In *Soil Carbon Management: Economic Environmental and Societal Benefits*, edited by J. Kimble, C. Rice, D. Reed, S. Mooney, R. Follet and R. Lal. Chapter 4, pp. 67–98. Boca Raton, Florida: CRC Press, Taylor and Francis Group, LLC.

Oreopoulos, P. (2006). Estimating Average and Local Average Treatment effects of Education when Compulsory Schooling Laws Really Matter. *American Economic Review* 96: 152-175.

Owens, T., Hoddinott, J. and Kinsey, B. (2003). The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe. *Economic Development and Cultural Change* 51: 337-357.

Politis, D., Romano, J. and Wolff, M. (1999), *Subsampling*. Springer Verlag.

Prokopy, L.S., Flores, K., Klotthor-Weinkauf, D. and Baumgart-Getz, A. (2008). Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature. *Journal of Soil and Water Conservation* 63: 300-311.

Pufahl, A. and Weiss, C.R. (2009). Evaluating the Effects of Farm Programmes: Results from Propensity Score Matching. *European Review of Agricultural Economics* 36: 79-101.

Rejesus, R.M., Palis, F.G., Lapitan, A.V., Chi, T.T.N. and Hossain, M. (2009). The Impact of Integrated Pest Management Information Dissemination Methods on Insecticide Use and Efficiency: Evidence from Rice Producers in South Vietnam. *Review of Agricultural Economics* 31: 814-833.

Rogers, E.M. (2003). *Diffusion of Innovations*. 5 ed. New York. The Free Press.

Rosenbaum, P.R. and Rubin, D.R. (1983). The Central Role of the Propensity Score in Observational Studies of Causal effects. *Biometrika* 70: 41-55.

Salhofer, K. and Streicher, G. (2005). Self-selection as a Problem in Evaluation Agri-Environmental Programs. In: K. M. Ortner (ed.), *Assessing Rural Development Policies of the Common Agricultural Policies.* Selection of papers from the 87th EAAE Seminar. Kiel: Vauk, 203–213.

Smith E. G., Peters, T.L., Blackshaw, R.E., Lindwall, C.W. and Larney, F.J. (1996). Economics of Reduced Tillage Fallow-crop Systems in the Dark Brown Soil Zone of Alberta. *Canadian Journal of Soil Science* 76: 411–16.

Sobels, J., Curtis, A., Lockie, S. (2001). The Role of Landcare in Rural Australia: Exploring the Contribution of Social Capital. *Journal of Rural Studies* 17: 265–276.

Sogémap. 2007. Évaluation de l'Entente pour le financement des clubs-conseils en agroenvironnement et la planification agroenvironnementale à la ferme. Rapport d'évaluation (version finale). Présenté au Comité de gestion responsable de l'Entente.

Strauss, J., Barbosa, M., Teixeira, S., Thomas, D. and Gomez, R. (1991). Role of Education and Extension in the Adoption of Technology: a Study of Upland Rice and Soybean Farmers in Central-west Brazil. *Agricultural Economics* 5: 341-359.

Tucker, M and Napier, T. (2001). Determinants of Perceived Agricultural Chemical Risk in Three Watersheds in the Midwestern United States. *Journal of Rural Studies* 17: 219-233.

Viet, C.N. (2008). A Note on Estimation of the Average Treatment Effect and Average Partial Effect in Nonlinear Models. *Economics Bulletin* 15: 1-13.

Wooldridge, J.M. (2002). *Econometric Analysis of Cross Section and Panel Data*. The MIT Press, Cambridge, Massachusetts.

Table 1. Type of farmer *i* according to reaction to an external intervention $\boldsymbol{\tau}$

$\varpi_i = n$	if $Participation_{i,\boldsymbol{\tau}=0} = 0$ and $Participation_{i,\boldsymbol{\tau}=1} = 0$	*Never-participant*
$\varpi_i = c$	if $Participation_{i,\boldsymbol{\tau}=0} = 0$ and $Participation_{i,\boldsymbol{\tau}=1} = 1$	*Complier*
$\varpi_i = d$	if $Participation_{i,\boldsymbol{\tau}=0} = 1$ and $Participation_{i,\boldsymbol{\tau}=1} = 0$	*Defier*
$\varpi_i = a$	if $Participation_{i,\boldsymbol{\tau}=0} = 1$ and $Participation_{i,\boldsymbol{\tau}=1} = 1$	*Always-participant*

Table 2. Results for z-tests (two-side) of equal proportions of BMP adopters

	Proportion of adopters		
BMPs	Control group (Std. err.)	Treatment group (Having a support plan) (Std. err.)	z statistic (Prob. (|z| <|z|))
Manure analyses	0.393 (0.065)	0.786 (0.049)	-4.495 (0.000)
Conservation tillage	0.506 (0.055)	0.683 (0.051)	-2.299 (0.022)
Immediate incorporation	0.420 (0.059)	0.547 (0.057)	-1.516 (0.130)
Riparian buffer	0.705 (0.052)	0.605 (0.054)	1.328 (0.184)
Non-use of mineral fertilizers	0.590 (0.049)	0.756 (0.045)	-2.420 (0.016)
Hydraulic infrastructures	0.654 (0.053)	0.854 (0.039)	-2.957 (0.003)

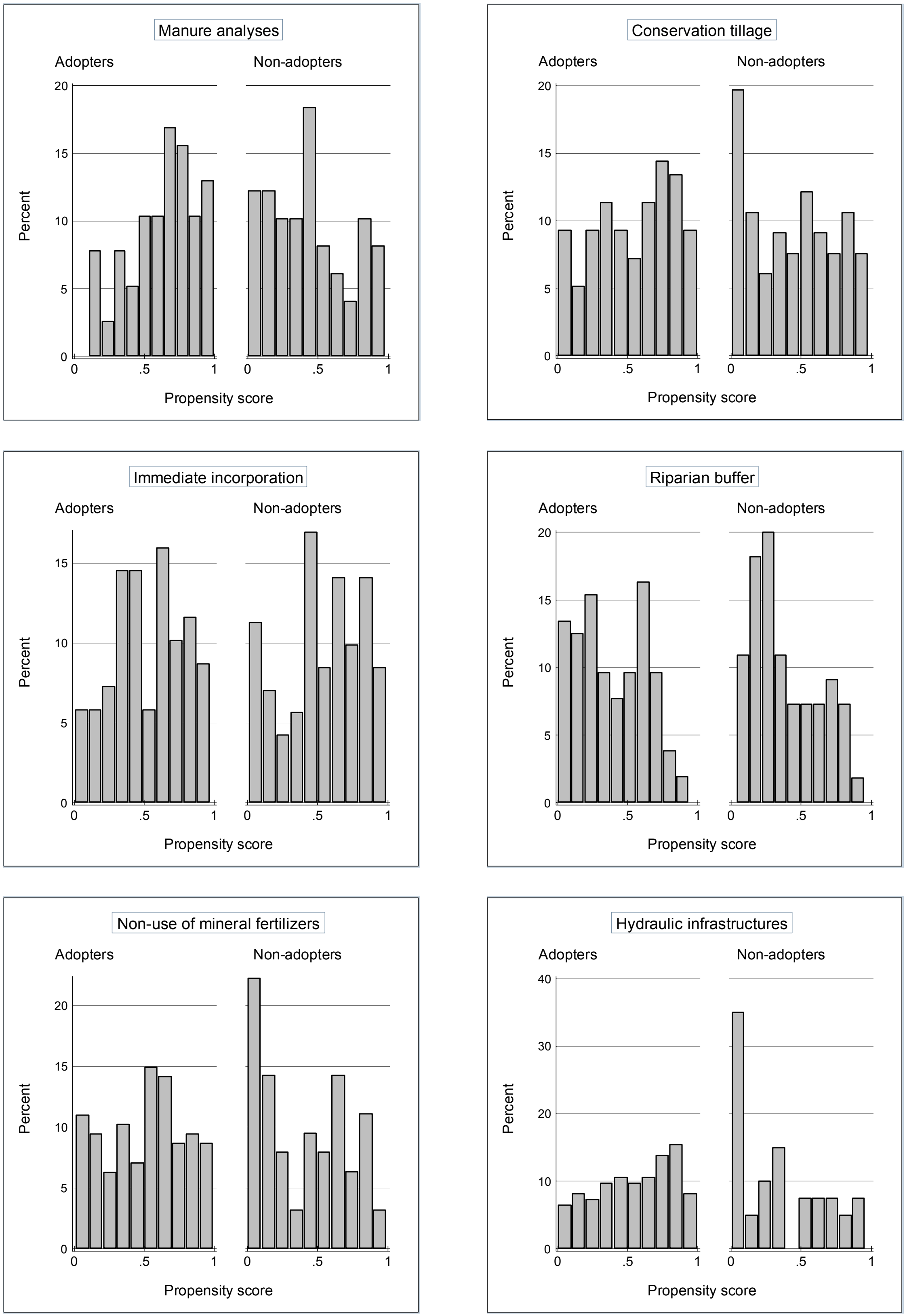

Figure 1. Histogram of propensity scores for adopters and non-adopters of the selected BMPs

Table 3. Balancing test of control variables using the propensity score

Variables	***p*-values for equality of means in the participant and control groups**	
	Strata 1 Pr(|T| > |t|)	Strata 2 Pr(|T| > |t|)
Producer attributes		
Age		
(0; 35[	0.855	0.806
[35; 45[	0.421	0.723
[45; 55[	0.358	0.189
[55; 65[	0.207	0.319
[65;)	0.306	0.227
Gender (Female=1)	0.160	0.097
Management experience (years)	0.013	0.024
Education (> primary=1)	0.099	0.610
Place of *Residence* (Farm=1)	0.160	0.255
Environmental sensitivity (participation in biodiversity project or observation of decrease in biodiversity =1)	0.617	0.031
Information (Use of information provided by the phytosanitary alert network=1)	0.765	0.224
External characteristics		
Production losses (losses due to animals/plants =1)	0.665	0.224
River quality (sand accumulation signs =1)	0.221	0.560
Region	0.677	0.559
Farm attributes		
Total gross revenue (TGR) in $1,000		
[0; 50[	0.000	0.122
[50; 100[	0.953	0.029
[100; 250[	0.315	0.925
[250; 500[	0.001	0.767
[500;)	0.015	0.031
Main production		
Animal productions (=1)	0.120	0.523
Share of the main production in the TGR	0.799	0.401
Land quality (degradation signs=1)	0.208	0.236
Ownership type (Individually owned=1)	0.052	0.723
Share of *rented land*	0.118	0.604

Table 4. Agri-environmental support plan average treatment effect on treated (ATT)

BMPs	Average impact (Standard deviation)	95% confidence interval of the average impact
Manure analyses	0.010 (0.072)	[0.005 ; 0.014]
Conservation tillage	0.013 (0.091)	[0.003 ; 0.024]
Immediate incorporation	0.093 (0.069)	[0.073 ; 0.112]
Riparian buffer	0.020 (0.069)	[0.013 ; 0.027]
Non-use of mineral fertilizers	0.059 (0.033)	[0.055 ; 0.063]
Hydraulic infrastructures	-0.002 (0.077)	[-0.017 ; 0.014]

Confidence intervals (CI) are simulated using bootstrapping methods.

Table 5. Agri-environmental advisory clubs network vertical diffusion effect

BMPs	Average impact (Standard deviation)	95% confidence interval of the average impact
Manure analysis	0.478 (0.571)	[0.426 ; 0.531]
Conservation tillage	0.352 (0.189)	[0.333 ; 0.370]
Immediate incorporation	0.252 (1.300)	[0.133 ; 0.371]
Riparian buffer	0.067 (0.089)	[0.058 ; 0.076]
Non-use of mineral fertilizers	0.415 (0.209)	[0.392 ; 0.439]
Hydraulic infrastructures	0.306 (0.161)	[0.291 ; 0.321]

Confidence intervals (CI) are simulated using bootstrapping methods.

Table 6. Agri-environmental advisory clubs network horizontal diffusion effects

BMPs	Average impact (Standard deviation)	95% confidence interval of the average impact
Manure analyses	0.021 (0.157)	[0.008 ; 0.035]
Conservation tillage	-0.028 (0.224)	[-0.047 ; -0.008]
Immediate incorporation	-0.021 (0.459)	[-0.056 ; 0.027]
Riparian buffer	0.027 (0.384)	[-0.007 ; 0.060]
Non-use of mineral fertilizers	0.131 (0.314)	[0.100 ; 0.162]
Hydraulic infrastructures	0.105 (0.268)	[0.082 ; 0.129]

Confidence intervals (CI) are simulated using bootstrapping methods.

Appendix

Table A1 Summary statistics of controls variables used in the analysis

Variables (unity)	Full sample (N=190)		Treatment group (with support plan (N=101))		Control group (Without support plan (N=89))	
	Mean	Sd. E. (mean)	Mean	Sd. E. (mean)	Mean	Sd. E. (mean)
Producer attributes						
Age						
(0; 35[	0.084	0.020	0.078	0.028	0.090	0.029
[35; 45[	0.205	0.029	0.211	0.043	0.200	0.040
[45; 55[**(b)**	0.379	0.035	0.322	0.050	0.430	0.050
[55; 65[**(b)**	0.247	0.031	0.300	0.049	0.200	0.040
[65;)	0.084	0.020	0.089	0.030	0.080	0.027
Gender (Female=1) **(a)**	0.100	0.022	0.056	0.024	0.140	0.035
Management experience (years) **(a)**	22.453	0.870	25.378	1.245	19.820	1.160
Education (> primary=1)	0.889	0.023	0.911	0.030	0.870	0.034
Place of *Residence* (Farm=1)	0.858	0.025	0.867	0.036	0.850	0.036
Environmental sensitivity (participation in biodiversity project or observation of decrease in biodiversity =1) **(a)**	0.195	0.029	0.256	0.046	0.140	0.035
Information (Use of information provided by the phytosanitary alert network=1)	0.463	0.036	0.422	0.052	0.500	0.050
External characteristics						
Production losses (losses due to animals or plants =1)	0.500	0.036	0.544	0.053	0.460	0.050
River quality (sand accumulation signs =1)	0.321	0.034	0.367	0.051	0.280	0.045
Region	11.058	0.420	10.744	0.646	11.340	0.547
Farm attributes						
Total gross revenue (TGR) in $1000						
[0; 50[**(a)**	0.232	0.031	0.089	0.030	0.360	0.048
[50; 100[	0.105	0.022	0.078	0.028	0.130	0.034
[100; 250[**(a)**	0.253	0.032	0.278	0.047	0.230	0.042
[250; 500[**(a)**	0.247	0.031	0.311	0.049	0.190	0.039
[500;) **(a)**	0.163	0.027	0.244	0.046	0.090	0.029
Main production						
Animal production (=1) **(a)**	0.701	0.033	0.756	0.046	0.650	0.048
Share of the main production in the TGR	0.858	0.013	0.862	0.017	0.854	0.019
Land quality (degradation signs=1) **(a)**	0.511	0.036	0.444	0.053	0.570	0.050
Ownership type (Individually owned=1) **(a)**	0.395	0.036	0.333	0.050	0.450	0.050
Share of rented land **(b)**	0.267	0.027	0.222	0.033	0.307	0.041

Note: **(a)** [**(b)**] Significantly different means between observations from the treatment group and the control group in a *t*-test for equality of means at the 5 [10] percent level.

Table A2. Probit estimation of factors affecting the adoption of a support plan

Variables	Coefficient	Marginal effect	Standard error	Prob.>chi-square
Age				
(0; 35[	-	-	-	-
[35; 45[	-0.672	-0.247	0.479	0.160
[45; 55[[(a)]	-1.227	-0.441	0.489	0.012
[55; 65[	-0.852	-0.308	0.600	0.156
[65;)	-1.181	-0.367	0.843	0.161
Gender (Female=1)	-0.120	-0.047	0.425	0.777
Education (>primary=1) [(a)]	0.961	0.323	0.464	0.038
Management experience (years) [(a)]	0.047	0.018	0.017	0.008
Place of *Residence* (Farm=1)	-0.456	-0.180	0.362	0.208
Information (Use RAP=1) [(b)]	-0.412	-0.161	0.238	0.083
Environmental sensitivity (=1) [(a)]	0.701	0.274	0.302	0.020
Total gross revenue (TGR) in $1,000				
[0; 50[[(a)]	-0.843	-0.304	0.394	0.033
[50; 100[	-0.468	-0.174	0.439	0.286
[100; 250[	-	-	-	-
[250; 500[	-0.108	-0.042	0.329	0.744
[500;)	0.554	0.218	0.385	0.150
Share of main production in TGR	-0.146	-0.057	0.700	0.835
Ownership type (sole = 1)	0.444	0.174	0.283	0.117
Share of *rented land* (%)	0.138	0.054	0.388	0.722
Main production				
Animal productions (=1) [(a)]	-1.389	-0.398	0.623	0.026
Land quality (Degradation=1) [(a)]	0.606	0.235	0.254	0.017
River quality (Degradation=1)	0.061	0.024	0.248	0.804
Region	-0.013	-0.005	0.020	0.508
Production losses (losses=1)	0.043	0.017	0.246	0.862
Pseudo R^2	0.235			

Note: **(a)** [**(b)**] denote significance at 5% [10%] levels (two-tailed test). The marginal effect is calculated at the discrete change of binary variables from zero to one.

Table A3. Probit estimation of factors affecting adherence in an agri-environmental advisory club

Variables	Coefficient	Marginal effect	Standard error	Prob.>chi-square
Age				
(0; 35[	-	-	-	-
[35; 45[[(a)]	-1.467	-0.367	0.080	0.003
[45; 55[[(a)]	-1.395	-0.420	0.120	0.005
[55; 65[[(a)]	-1.679	-0.420	0.102	0.009
[65;) [(a)]	-2.567	-0.378	0.051	0.005
Gender (Female=1)	0.079	0.028	0.155	0.854
Education (>primary=1)	-0.346	-0.128	0.167	0.426
Management experience [(a)]	0.038	0.013	0.006	0.026
Place of *Residence* (Farm=1)	0.521	0.161	0.099	0.165
Information (Use PAN=1)	-0.209	-0.073	0.083	0.387
Environmental sensitivity (=1)	0.454	0.167	0.118	0.140
Total gross revenue (TGR) in $1,000				
[0; 50[[(b)]	-0.793	-0.239	0.103	0.057
[50; 100[	-0.002	-0.001	0.151	0.997
[100; 250[				
[250; 500[	-0.225	-0.076	0.112	0.513
[500;)	0.434	0.160	0.142	0.240
Share of main production in TGR	0.393	0.137	0.251	0.586
Ownership type (sole = 1)	0.040	0.014	0.098	0.887
Share of *rented land* (%)	0.230	0.080	0.136	0.558
Main production				
Animal productions (=1) [(a)]	-1.803	-0.328	0.051	0.026
Land quality (Degradation=1)	-0.284	-0.099	0.086	0.254
River quality (Degradation=1)	0.221	0.078	0.090	0.378
Region [(a)]	-0.054	-0.019	0.007	0.008
Production losses (losses=1) [(a)]	0.753	0.258	0.084	0.003
Pseudo R^2	0.213			

Notes: **(a)** [**(b)**] denote significance at 5% [10%] levels (two-tailed test). The marginal effect is calculated at the discrete change of binary variables from zero to one.

Table A4. Agri-environmental advisory clubs network vertical diffusion effect

BMPs	Average impact (Std. dev.)	95% Confidence interval of average impact
Manure analysis		
Treatment outcome of *compliers*	0.821 (0.201)	[0.801 ; 0.841]
Control outcome of *compliers*	0.342 (0.530)	[0.276 ; 0.408]
Treatment outcome of *always-participants*	0.763 (0.073)	[0.755 ; 0.772]
Control outcome of *never-participants*	0.476 (0.008)	[0.461 ; 0.491]
Conservation tillage		
Treatment outcome of *compliers*	0.943 (0.100)	[0.933 ; 0.952]
Control outcome of *compliers*	0.591 (0.163)	[0.574 ; 0.608]
Treatment outcome of *always-participants*	0.486 (0.004)	[0.479 ; 0.493]
Control outcome of *never-participants*	0.440 (0.007)	[0.427 ; 0.453]
Immediate incorporation		
Treatment outcome of *compliers*	0.634 (0.208)	[0.614 ; 0.655]
Control outcome of *compliers*	0.382 (1.316)	[0.223 ; 0.541]
Treatment outcome of *always-participants*	0.577 (0.004)	[0.569 ; 0.585]
Control outcome of *never-participants*	0.402 (0.006)	[0.391 ; 0.414]
Riparian buffer		
Treatment outcome of *compliers*	0.997 (0.026)	[0.994 ; 0.999]
Control outcome of *compliers*	0.930 (0.086)	[0.921 ; 0.938]
Treatment outcome of *always-participants*	0.455 (0.003)	[0.449 ; 0.460]
Control outcome of *never-participants*	0.509 (0.005)	[0.499 ; 0.519]
Non-use of mineral fertilizers		
Treatment outcome of *compliers*	0.911 (0.128)	[0.897 ; 0.924]
Control outcome of *compliers*	0.495 (0.172)	[0.480 ; 0.511]
Treatment outcome of *always-participants*	0.641 (0.004)	[0.634 ; 0.649]
Control outcome of *never-participants*	0.660 (0.006)	[0.649 ; 0.671]
Hydraulic infrastructures		
Treatment outcome of *compliers*	0.947 (0.090)	[0.934 ; 0.957]
Control outcome of *compliers*	0.642 (0.144)	[0.627 ; 0.657]
Treatment outcome of *always-participants*	0.803 (0.003)	[0.797 ; 0.808]
Control outcome of *never-participants*	0.690 (0.007)	[0.675 ; 0.704]