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Analysis

A nonparametric analysis of the impact of agri-environmental advisory activities on best management practice adoption: A case study of Québec ☆

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ABSTRACT

This study investigates the factors that determine producers' participation in agri-environmental advisory activities and their adoption of best management practices (BMPs) in Québec (Canada). Data were collected from farmers via telephone interviews, and the impacts of agri-environmental extension activities were analyzed 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 producers' membership in an agri-environmental advisory club. The informal diffusion effect is statistically significant for BMPs that require advanced technical knowledge.

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 (AE hereafter) extension activities have attracted considerable interest because of their ability to improve the performance of producers in the delivery of ecological goods and services (EGS) through BMPs.

A large body of literature has explored 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 that "the results are clearly inconclusive on what factors consistently determine BMP adoption" (p. 308).

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 behavior.

A major methodological problem that has not been addressed sufficiently by many of the previous studies on BMP adoption in agriculture is the bias related to producers' participation in extension activities[1] in order to expand their knowledge and uptake of ecologically sensible production approaches. The correlation between participation in such 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, whereby an instrument is correlated with participation in activities but is uncorrelated with BMP adoption.[2] However, identification and estimation of the parameters of interest are more

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[1] Examples are extension services, farmer education programs, and various forms of formal and informal training.

[2] The first step is to estimate an equation describing the participation in advisory activities and use it to calculate the inverse Mills ratio, which is included 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 BMP 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.

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complicated when the partial effect of participation 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 analyzing BMP adoption (Strauss et al., 1991; Owens et al., 2003; Feder et al., 2004). The focus is typically on estimating the *average partial effect*, which is the partial effect averaged across the population distribution of the unobserved heterogeneity (Wooldridge, 2005).[3]

When the endogenous variable is binary, e.g. participation in a program, the *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 most interesting estimand (Imbens and Wooldridge, 2009).

The aim of the paper is to identify how AE extension activities in the province of Québec (Canada) affect the adoption of BMPs by a farmer compared with what he would have experienced had he not participated in the activities. 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 of extension activities on the adoption of BMPs for farms that participate in extension activities. In addition, we quantify the potential vertical (i.e. formal) and horizontal (i.e. informal) diffusion effects of the AE advisory clubs on the adoption of BMPs. We do so using the concept of *local average treatment effect* (LATE) suggested by Imbens and Angrist (1994). The constant-effects assumption of AE advisory clubs on the probability to adopt a given BMP is clearly unrealistic.[4] Intuitively, only a subset of the population of farmers is affected by AE advisory clubs in terms of probability to adopt. The LATE measures the effect of the activities of advisory clubs among producers who decide to participate in extension activities because of the 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. 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.

Distinguishing causal effects from correlation is a key objective of research, regardless of the adoption of environmental friendly practices. The present analysis is one of the few analyses of agri-environmental activities using the latest evaluation econometric techniques. To our knowledge, the use of the concept of *local average treatment effect* to isolate the effect of a particular "agent", i.e. the AE clubs network, on the probability to adopt environmental friendly practices is the first one. By applying Frölich's (2007) nonparametric IV estimation methods to analyze the impact of AE advisory clubs, we allow for factors that influence probability to adopt a BMP, but which could also affect participation in extension activities and membership in an AE advisory club.[5] It adequately resolves the potential endogeneity and treatment heterogeneity issues of the extension, advisory or regulatory activities when analyzing their impact on the supply of ecological goods and services.

The remainder of the paper is structured as follows. Section 2 describes AE extension activities in the province of Québec while Section 3 presents our empirical approach. Section 4 outlines aspects of our data and Section 5 presents and discusses the results of the estimations. The last section concludes the paper.

2. Institutional Background: AE Extension Activities in Québec

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). It updated and simplified the existing regulation and reinforced pollution control measures for farming operations. The regulation took immediate effect for new facilities or herd increases, whereas existing farms were given until 2010 to fully comply with its provisions. In November 2002, the Québec government adopted the Québec 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 Québec adopted a guideline on odors 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, the Québec Department of Agriculture (Ministère de l'Agriculture des Pêcheries et de l'Alimentation du Québec) launched a "farm-by-farm" agri-environmental strategy in 2004 based on a comprehensive environmental tool called the AE support plan (support plan hereafter). It is the provincial equivalent of the federal environmental farm plan. The support plan involves obtaining a comprehensive portrait of a farm's environmental situation, formulating an action plan and implementing the solutions described in the support plan. Farming practices that involve the environment (e.g., regulatory requirements, erosion control, manure disposal capacity and odor reduction, 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 for which some farmers obtain assistance from an advisor belonging to an AE advisory club.[6]

The creation of advisory clubs in 1993 was inspired by various AE initiatives by Québec farmers. Consultations conducted in 1996 showed that the advisory clubs successfully educated and engaged farmers in sustainable agriculture. The Québec Department of Agriculture and the farmers' union (Union des Producteurs Agricoles, UPA hereafter) were eager to make AE advisory activities accessible to more farmers.[7] Activities of advisory clubs relate to guidance for management of fertilizer, reducing pesticide use, including methods of integrated pest management, conservation practices, and management and protection of watercourses. Activities are oriented toward individual producers and groups. They include individual support for

[3] 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.

[4] The reasons to join a club most often cited are: adopt conservation farming to comply with environmental requirements or not, gain new skills in AE and obtain neutral advice (SOGEMAP, 2007).

[5] Blackman et al. (2010) estimate the impact of participation in Mexico's clean industries program using ATT. However Blackman et al. (2010) cannot isolate the effects of regulatory activities for participants. The estimated ATT of participation in the program could then be biased upward. In addition, regulatory activities for participants are not randomly assigned and are correlated with participation to the program. We do not expect membership in AE advisory clubs to be randomly assigned. It may be correlated with adoption of BMPs or having a support plan. If some characteristics that determine participation BMPs adoption are the unobserved variables in the error term, then it is likely that they also influence having a support plan and/or membership in a club.

[6] AE advisory club advisors contribute to about half of the support plans. The other actors are independent consultants, advisors from producers' cooperatives and from input industries (nutrients, fertilizers, e.g.).

[7] In 2008, the advisory club network had more than 8300 members grouped into 83 clubs, served by more than 300 advisors. A partnership agreement between the Québec 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).

developing plans (fertilization plans, rotation plans, and management plans for riparian buffers), advisories to achieve balance (phosphorus and nutrient balance) and soil sampling. Group activities 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 that farms are facing.

The February 2008 report by the Commission sur l'avenir de l'agriculture et de l'agroalimentaire du Québec (Quebec Commission on the Future of Agriculture and Agri-food) indicates that the progress of Québec 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 have helped them formulate and implement support plans (CAAAQ, 2008).

In the present study, we evaluate the relevance of support plans as a tool to improve farmers' environmental practices. The support plan is used as a proxy of farmers' participation in AE advisory activities.

Second, we evaluate the relevance of the advisory clubs network as an appropriate way to persuade producers to adopt a support plan, and to subsequently improve their environmental practices.[8] As mentioned before, the support plan is produced with the assistance of an advisor. Since 2004, the advisors in the advisory clubs have routinely used the support plan; advisory clubs' activities drive BMP adoption only via the adoption of a support plan.

The choice of BMPs analyzed in the present paper is intended to reflect AE objectives related to land use and water quality.

3. Estimation Methods

The dominance of family businesses is an important characteristic of the farm sector in Québec (CAAAQ, 2008). It complicates the theoretical and empirical analyses of the impact of AE 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 BMPs 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 the farmer, some of which, however, may not be fully observed (unobserved heterogeneity). We should not expect to find homogenous responses to extension activities across individual farms.[9]

We estimate the treatment effect averaged across the population distribution of unobserved heterogeneity using non-parametric approaches.[10,11] These approaches avoid delicate assumptions about functional form and independence. In addition, the endogeneity of regressors that is not of main interest may not affect the estimated relationship between the regressor of interest and the outcome (Frölich, 2008).

We rely on the non-parametric instrumental variables (IV) estimation of the *local average treatment effect* with covariates proposed by Frölich (2007) to estimate the potential vertical and horizontal diffusion effects of the advisory clubs. Applying Frölich's (2007) approach let us allow for confounding factors that are factors that influence the potential probability of adopting a given BMP and could also influence the decision to adopt a support plan as well as membership in an AE advisory club. The approach proposed to accommodate covariates in the estimation of LATE avoids the curse of dimensionality, i.e. the requirement of a large number of observations to obtain a good estimate.

3.1. Measuring the Impact of AE 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.[12] The estimated *average treatment effect* is the expected effect on the outcome (adoption of the BMP) that producers gain 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 for a recent review of the treatment effect). The ATT is the expected effect that participants in extension activities experience because of having adopted a support plan:

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

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 externals', farms' and farmers' characteristics; $s \in \{0, 1\}$ shows whether the producer has a support plan or not and is assumed to be endogenous. The ATT is estimated non-parametrically using propensity-score matching estimators (Imbens and Wooldridge, 2009).

3.2. Measuring the Impact of AE Advisory Clubs on BMP Adoption

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). We hypothesize that AE advisory clubs have diffusion effects on the adoption of BMP through the adoption of a support plan. We also hypothesize that AE advisory clubs have vertical (i.e. formal) and horizontal (i.e. informal) diffusion effects. We measure the impact of AE advisory clubs using the concept of *local average treatment effect* suggested by Imbens and Angrist (1994) along with nonparametric estimators (Frölich, 2007). As Oreopoulos (2006: p. 152) notes, "when responses to treatment vary, different instruments measure different effects." We exploit this fact and use two instruments to evaluate AE advisory clubs' activities: (i) membership as an instrumental variable for the vertical diffusion effect and (ii) "vicinity" as an instrumental variable for the horizontal diffusion effect.

[8] Evaluating the impact of advisory clubs network is an important issue because it receives financial assistance from the Prime-Vert program. A portion of the Prime-Vert funding is provided by the federal government of Canada through its strategic agricultural framework (Boutin, 2005).

[9] One of the key issues when modeling farmers' behavior is whether production decisions are independent from consumption and other utility-related decisions. If farmers face input and/or output market imperfections or other resource constraints, optimal production decisions may entail meeting household consumption objectives without market intermediation (de Janvry and Sadoulet, 2006). This is the case for EGS because of the lack of markets for most EGS. In addition, there is a joint-effect, namely the reduction of pollutants affecting the welfare of producers through their production function and their health.

[10] 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 this study.

[11] Non-parametric empirical applications of treatment effect models in evaluations of policies in the agri-environmental context are limited. Examples using ATT estimations are Lynch et al. (2007), Lynch and Liu (2007) and Pufahl and Weiss (2009). Blackman et al. (2010) evaluate voluntary environmental regulation programs for various industrial sector (chemicals, electronics, oil refining, and pharmaceuticals) using ATT estimations.

[12] Because of the use of the support plan as a proxy of participating in AE extension activities, we use the two terms interchangeably below.

Table 1
Type of farmer *i* according to reaction to an intervention **z** (the instrument).

Participation in AE extension activities (z)		Type
Before intervention	Reaction to intervention	
Support plan$_{i,z=0}=0$	Support plan$_{i,z=1}=0$	*Never-participant*
Support plan$_{i,z=0}=1$	Support plan$_{i,z=1}=0$	*Defier*
Support plan$_{i,z=0}=0$	Support plan$_{i,z=1}=1$	*Complier*
Support plan$_{i,z=0}=1$	Support plan$_{i,z=1}=1$	*Always-participant*

Producers can be distinguished into four types according to their reaction to the instrument (see Imbens and Angrist, 1994): *never-participant*, *complier*, *defier* and *always-participant* (Table 1).

The *compliers* (c) are farmers who were induced by the instrument (e.g. membership) to adopt a support plan, as opposed to *never-participants* (n), who would not adopt a support plan irrespective of the instrument, and *always-participants* (a), who would adopt a support plan irrespective of the instrument. Consistent with Imbens and Angrist (1994), for estimating the LATE, we assume that AE advisory clubs' activities induce farmers to participate in extension activities (treatment), which in turn impacts the adoption rate of BMP (the outcome). The LATE is the average treatment effect for the subpopulation of farmers for whom the advisory clubs' activities have an effect:

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

where $z=\{0,1\}$ is the instrumental variable taking the value of 1 or 0; the other variables have been defined above. Eq. (2) is estimated using a propensity score matching estimator (Frölich, 2007; Frölich and Lechner, 2010). The estimated LATE returns the effect of extension activities for farms whose adoption is highly affected by the instrument.

The proportion of farms affected by the instrument and its impact on the level of adoption could be used as a justification or not for investment in the AE advisory club network by provincial and federal governments of Canada.[13] Aside from the estimated LATE, the fractions of *compliers* and *never-participants* are estimands of interest for public policy planning. They are given, respectively, by Eqs. (3) and (4):

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

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

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* 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

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

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

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

3.2.1. 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 the instrument. Using membership as an instrument for participation in extension activities 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.

Participating in advisory clubs is voluntary (i.e. not random), and farmers' innate managerial ability is typically the unobserved characteristic that often causes endogeneity of the support plan treatment. If this is the unobserved variable in the error term, then it is likely that managerial ability also influences the decision to participate in advisory clubs. Thus, membership in an advisory club is a valid instrument only after conditioning on some covariates (Frölich, 2007: p. 36). As Frölich (2008: p 221) asserts, conditioning the instrument by some covariates "could also contain variables to "block" any direct causal path from Z [the instrument] to Y [the outcome]."

3.2.2. Measuring Horizontal Diffusion Effects

The horizontal, i.e. homophilous, diffusion effects of the AE advisory club 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 neighbor who is a member of an agri-environmental advisory club?" Nevertheless, regardless of whether living near 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 on adoption following participation in extension activities because of the "neighborhood effect."[14]

Further, the vicinity may be problematic if the unobserved factors determine whether or not a farmer knows (or seeks out) an advisory club member. Conditioning on covariates makes the instrumental variables and the outcome independent.

3.3. 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 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).[15]

In line with Viet (2008), Frölich and Lechner (2010) and Behrman et al. (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 the entire estimation process 999 times (see Brownstone and Valletta, 2001).[16]

4. Data Description

Data are obtained from a survey and the coordinates of the farms were provided by the Québec Department of Agriculture upon authorization by the Commission on Access to Information. Data are from a telephone survey conducted between February and March 2009. The year of reference is 2008 and the dataset consists of 190

[13] Obviously, the rationale for investing in an AE advisory club network requires an assessment of the ecological and cost-effectiveness of its activities. Measuring the impact of the clubs on the probability of adoption will provide useful information for analyses on effectiveness.

[14] Holloway et al. (2002) have adopted the "village" definition of "neighbors." The authors use spatial econometrics to estimate "neighborhood effects" in high-yielding variety adoption among Bangladeshi rice producers.

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

[16] See Politis et al. (1999) and Imbens and Wooldridge (2009) for proof of the validity of this subsampling approach.

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

BMPs	Proportion of adopters		
	Control group (Std. err.)	Treatment group having an SP (Std. err.)	z statistic (Prob.|Z|>|z|)
Manure analyses	0.610 (0.049)	0.978 (0.016)	−6.153 (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)	0.505 (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)

observations.[17] The survey targeted agricultural enterprises (i) registered in the MAPAQ farm 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 strata. The portrait of Québec producers formed the basis of the sampling strategy. Table A1 defines the variables used as covariates in the analysis and their corresponding summary statistics.[18] Producers' and farms' attributes are taken into account, along with some external characteristics.

The support plan is modeled as a discrete choice taking the value of 1 when the producer has a support plan and 0 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 neighbor or a friend that is a member. In that case, the variable vicinity takes the value of 1 and 0 otherwise.

The choice of BMPs analyzed aims at reflecting AE objectives related to land use and water quality. The BMPs are introduced through binary variables that take the value of 1 if the BMP is adopted and 0 otherwise. Six BMPs are analyzed and only one of them is related to compliance with regulatory norms.

The first studied BMP 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.

Secondly, we analyze producer adoption decisions regarding conservation tillage. 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.

Third, the BMP associated with the management of manure takes the value of 1 when the manure is injected into the soil within 24 h of the initial spreading and 0 otherwise.

Fourth, we study the establishment and maintenance of a riparian buffer zone that takes the value of 1 when a riparian buffer zone larger than 1 m is established and maintained and 0 otherwise.

Fifth, 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 0.

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 for most of the BMPs the differences in proportion of adopters are significant, at a level of 5%. Exceptions are immediate incorporation of manure and the establishment and maintenance of a riparian buffer zone. However, we do not know if the existing differences are due to participation in extension activities or if the differences are only because of *self-selection* effect.

5. Empirical Results

5.1. Factors Affecting Participation in AE Extension Activities

Factors affecting the decision to participate in AE extension activities, proxied by the adoption of a support plan, are estimated using a Probit. Table A2 presents the results. The estimated model is statistically significant at 1% or better.

Results show that farmers that have more experience with farm management have a higher probability of participating: 18.9% (statistically significant at 10%). When a farmer possesses environmental awareness, this increases the probability of deciding to have a support plan by 31.9%.

Only the larger farms in animal production, i.e. with total gross revenue (TGR) above $250,000, have a higher probability of adopting a support plan. They are 38.2% more likely to use a support plan than the reference class (big farms in plant production). This is an expected result because of controversies regarding animal farming operations and new measures introduced since 2002 (see Boutin, 2005). For the other classes of TGR, the differences are statistically non-significant. Individually owned farms are less likely to adopt a support plan: −22.1%.[19] Finally, as expected, the probability of having a support plan decreases with the proportion of rented land (significant at the 10% level).

From the parameter estimates of the Probit model (Table A2), the bounded propensity scores are calculated for every farm and used for the matching analysis of the impact of participation in AE extension activities on the adoption of the studied BMPs.[20]

5.2. Evidence of Heterogeneity of Participation in AE Extension Activities and Balancing Tests

Fig. 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.

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 order the comparison and treatment groups by the propensity scores calculated from the Probit model. Each group is divided into two strata with an equal number of observations and, 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 rejected only for management experience. These results indicate that the matching removes systematic differences between the “treated” farmers, i.e. farmers with a support plan, and the comparison group in their observed characteristics. From the 91 farms with a support plan, 75 were matched to farms without a support plan but with similar propensity scores.

5.3. Average Effect of AE Extension Activities

For each studied BMP, the estimated average treatment effect on treated (see Eq. (1)) measures the impact of AE extension activities on the expected probability of adopting BMPs 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

[17] The starting sample consists of 376 farms, and 215 interviews were conducted. The non-response rate was 42.81%.

[18] Subdivisions of the variables *Age*, *Total gross revenue* and *Production* are different when studying the impact of advisory clubs. Their statistics are available from the authors upon request.

[19] Tax incentives, limited liability and eco-compliance can explain this result. Further, incorporation might be an indicator of management ability.

[20] We test and reject the hypothesis of interaction between different probabilities to adopt the selected BMPs. We then assume additive separability of the treatment effect. In their study of BMP adoption in Québec, Ghazalian et al. (2009) used a multivariate probit model. The only correlation coefficient found to be statistically different from zero is the coefficient related to solid and liquid manure control practices.

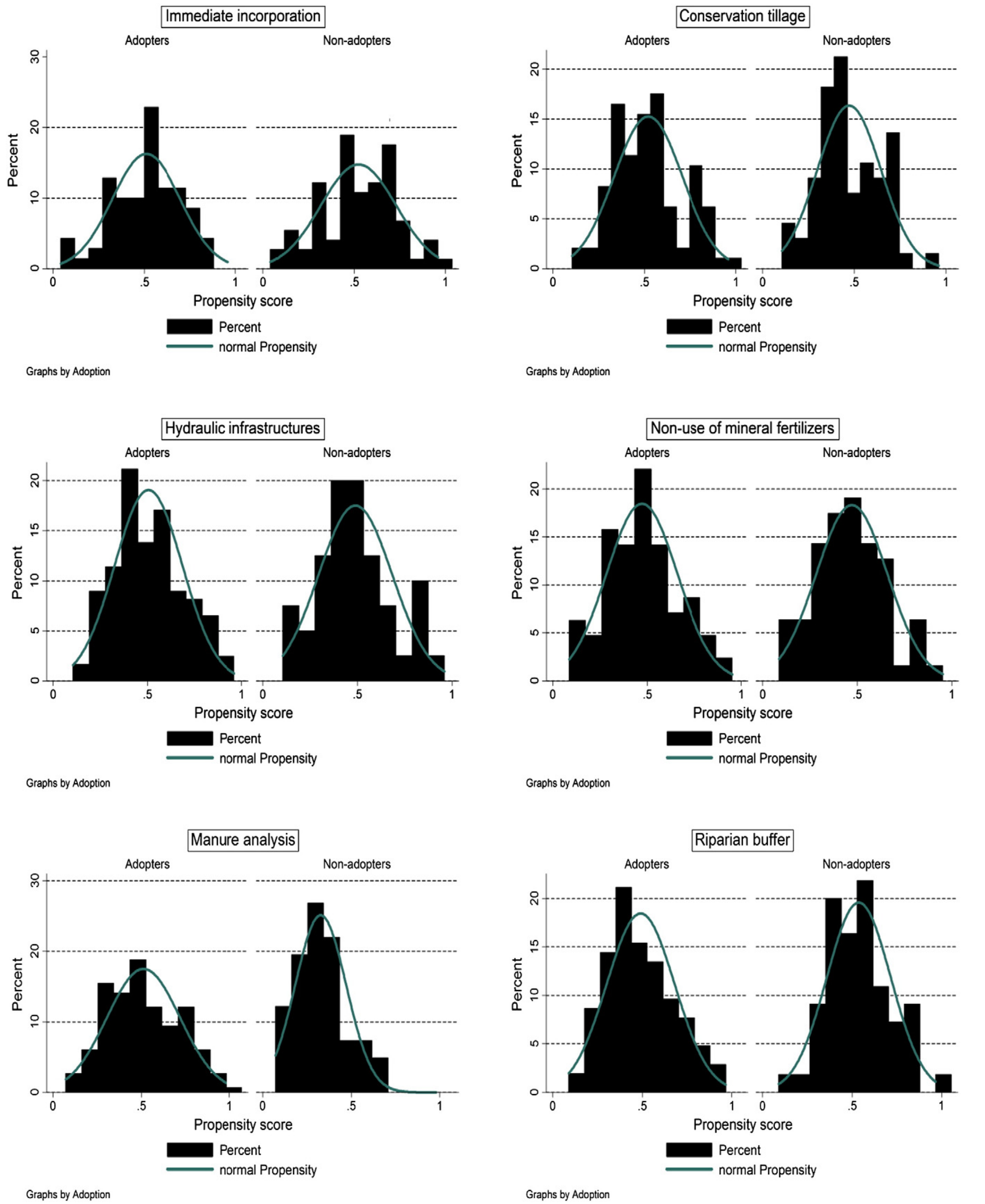

Fig. 1. Histogram of propensity scores for adopters and adopters of the selected BMPs.

probability of adopting BMPs. Table 4 reports ATT and their corresponding bootstrapped 95% confidence intervals.

The average positive impact is higher for manure analysis. The value of 0.203 indicates that participating in extension activities increased the probability of adopting the BMP by 20.3%. This is an expected result because this BMP is related to compliance with the incoming regulatory norms. The ATTs for investment in the construction of run-off control structures (hydraulic infrastructures)

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

Variables	p-value for equality of means in the participants and control groups	
	Stratum 1 Pr(|T|>|t|)	Stratum 2 Pr(−T|>−t|)
Producers attributes		
Age		
Young farmer (=1 if operator <45 years)	0.376	0.257
Management experience (=1 if >15 years)	0.013	0.023
Education (>primary school=1)	0.790	0.459
Place of residence (live on farm=1)	0.340	0.410
Environmental sensitivity (participation in biodiversity project=1)	0.248	0.115
Information (use of information provided by the PAN)	0.489	0.917
External characteristics		
Production losses (losses due to animals/plants=1)	0.937	0.402
River quality	0.629	0.889
Region	0.365	0.904
Farm attributes		
Total gross revenue (TGR) in $1000		
Animal production		
0;250[	0.966	0.845
[250;+∞[	0.349	0.115
Vegetal production		
[0;250[	0.914	0.198
[250;+∞[	0.550	0.641
Share of the main production in the TGR	0.515	0.801
Land quality (degradation signs=1)	0.788	0.840
Ownership type (individually owned=1)	0.192	0.249
Share of rented land	0.390	0.751

and immediate incorporation are also high at 17.4% and 14% respectively. 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 odors). Deaton et al. (2005) also reported that diligence in environmental protection has become a major consideration for farmers because of growth in rural residence. People are less receptive to production practices with visible environmental impact, such as manure spreading.

The average positive impact on the adoption of the non-use of mineral fertilizers is also notable at 14.6%. This result corroborates to Pufahl and Weiss (2009), who observe a 9.4% reduction in fertilizer expenditures when studying the impact of AE programs in Germany. Participation in extension activities increases the probability to establish and maintain a riparian buffer zone by 4.3%. The low impact of extension activities can be due to the fact that, from an individual landowner's perspective, benefits may not clearly outweigh costs when establishing and maintaining such a zone (see Brethour et al., 2007). Moreover, establish and maintain a riparian buffer is one of the oldest practices recommended to farmers, and producers receive

Table 4
Agri-environment SP average treatment effect on treated (ATT).

BMPs	Average impact (Std. err.)	95% confidence interval of the average impact
Manure analyses	0.203 (0.033)	[0.162;0.290]
Conservation tillage	0.109 (0.021)	[0.087;0.173]
Immediate incorporation	0.140 (0.019)	[0.096;0.170]
Riparian buffer	0.043 (0.022)	[0.006;0.111]
Non-use of mineral fertilizers	0.146 (0.030)	[0.098;0.215]
Hydraulic infrastructures	0.174 (0.027)	[0.150;0.257]

Table 5
Robustness check of the estimated ATT.

BMPs	"Naïve" estimator[a]		ATT estimation	
	Estimate	Bias [normalized shift]	Nearest neighbor matching	Kermel matching
Manure analyses	0.259 (0.060)	0.922 [0.281]	0.200 (0.103)	0.229 (0.059)
Conservation tillage	0.169 (0.084)	0.581 [0.291]	0.207 (0.101)	0.134 (0.106)
Immediate incorporation	0.188 (0.093)	0.551 [0.341]	0.147 (0.031)	0.157 (0.104)
Riparian buffer	0.041 (0.049)	0.113 [0.363]	−0.034 (0.105)	0.007 (0.060)
Non-use of mineral fertilizers	0.216 (0.072)	0.156 [1.385]	0.122 (0.123)	0.188 (0.092)
Hydraulic infrastructures	0.178 (0.058)	0.108 [1.648]	0.220 (0.121)	0.187 (0.092)

[a] Marginal effect of the SP in the decision to adopt.

financial support when implementing riparian buffers. For conservation tillage, the positive impact of extension activities is 10.9%. This could be due to the mixed results of studies of the impact of this BMP on the profitability of farms (Mooney and Williams, 2007).

Overall, the results of Table 4 show that, for most of the studied BMPs, the support plan reached its objective, i.e., to help producers enhance their environmental performance. The higher impact of AE extension activities on the adoption of manure analysis also indicates that AE extension activities help farmers to adapt to regulatory norms.

Agriculture and forestry sectors have significant potential to expand their supply of EGS (Swinton et al., 2006). King (2007) mentions that developing capable institutions and practices in supplying ecological goods and services (EGS) requires knowledge about the appropriate incentives or government tools for effecting change. For a limited number of BMPs, this study shows that the support plan can be a useful tool to address key environmental issues of the agricultural sector such as water quality improvement, biodiversity, climate change and energy efficiency and reducing and rationalizing the use of pesticides.

5.3.1. Robustness of the Results

To assess the robustness of our results, we performed several additional estimates (see Table 5). Specifically we start by estimating a "naive" model with having a support plan as an explanatory variable. Column 1 of Table 5 gives the results of the estimation of the "naive" model. The impact of the support plan is the marginal effect of having it on the probability to adopt the BMP. We use the approach proposed by Altonji et al. (2005, 2008) to evaluate the potential bias that would be implied by selection on the unobservables when estimating the "naive" model.[21] The results reported in Column 2 are the potential bias due to unobservables on the estimated effect of the AE extension activities. For example, for manure analyses, the "naive" estimate ($\hat{\alpha}$) of the marginal effect of having a support plan is 0.259 (Column 1) and the calculated normalized bias due to unobservables is 0.922 (Column 2). We calculate the normalized shift in the distribution of the unobservables using Altonji et al.'s (2008: 175–178) approach:

$$\frac{\hat{\alpha}}{bias} = \frac{0.259}{0.922} = 0.281.$$

This result indicates that, for manure analyses, the distribution of unobservables would have to be 28.1% greater than the shift in observables to explain the entire support plan effect. Column 2 of

[21] Altonji et al. (2005, 2008) argue that, under certain conditions, selection on unobservables is comparable in magnitude to the selection on observables in terms of its influence on the probability to adopt the BMP.

Table 6
Agri-environmental advisory clubs network vertical diffusion effect.

BMPs	Average impact (Std. err.)	95% confidence interval of the average impact
Manure analyses	0.816 (0.104)	[0.611;1.020]
Conservation tillage	0.301 (0.076)	[0.153;0.450]
Immediate incorporation	0.321 (0.064)	[0.196;0.445]
Riparian buffer	0.028 (0.028)	[−0.028;0.084]
Non-use of mineral fertilizers	0.470 (0.126)	[0.222;0.717]
Hydraulic infrastructures	0.382 (0.062)	[0.216;0.503]

Table 5 indicates that the highest shifts in the distribution of unobservables are observed for the non-use of mineral fertilizers and for the investment in the construction of run-off control structures (hydraulic infrastructures): 1.385 and 1.648 respectively. Overall, our calculations suggest that selection due to unobservables is unlikely to bias the impact of extension activities.[22]

The robustness of the ATT estimations is also tested using kernel (based on a distance-weighted average of all observations "reasonably close" to the treatment observation) and nearest neighbor (based on the single closest control observation to the treatment observation) matching estimators (Columns 3 and 4 of Table 5). The results confirm that the ridge matching is the best estimator in terms of lower standard error (see Table 4), which is expected in small samples (Frölich, 2004).

5.4. Average Effects of AE Advisory Clubs

5.4.1. Average Vertical Diffusion Effect of AE Advisory Clubs

The vertical diffusion effect of AE advisory clubs is studied using membership as an instrument. In the first step, factors affecting membership in an AE advisory club are estimated using a Probit model. Table A3 in Appendix A reports the parameter estimates for the model. The estimated model is statistically significant at 1% level or better. From the parameter estimates of the Probit, scores are calculated for every farm and used for the matching analysis of the impact of the AE advisory clubs.

The estimated fraction of *never-participants* (see Eq. (4)) 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 AE extension activities do not change their status even if they join an advisory club. The fraction of *compliers* (see Eq. (3)), i.e., the population who reacts to the advisory clubs network activities by effective participation in AE extension activities 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 6 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.

Manure analysis realization is the BMP for which membership in an advisory club has the greatest average impact. The result of 81.6% (LATE = 0.816) 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 81.6%. This is quite a large effect but it is expected because this BMP is related to compliance with regulatory norms that took effect in 2010. In a report on the evaluation of the AE advisory clubs' activities, SOGEMAP (2007) indicates that membership is largely motivated by regulatory considerations, at 67%.

The results of Table 6 also indicate that the estimated LATE on the level of adoption for the injection of manure into the soil within 24 h of the initial spreading, the 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 et al. (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 riparian buffer zone establishment and maintenance, at 2.8%. By comparison, Ghazalian et al. (2009) report that belonging to a club augments the probability of establishing and maintaining a riparian buffer by 16%.[23] Nevertheless, Prokopy et al. (2008) obtain 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 presents the detailed results of the analysis of the impact of membership in an AE advisory club. It shows that, for most of the studied BMPs, *compliers* benefit more from the activities of the advisory clubs. For example, for conservation tillage, the treatment outcome for the *always-participants* is 0.563, while it is 0.911 for the *compliers*. Interestingly, for riparian buffer zone implementation and maintenance, the control outcome for the *never-participants* is 0.715 while it is 0.439 for the *compliers*. This result indicates that the *never-participants* group consists of producers who are more likely to implement a riparian buffer without assistance from advisors in the club network. This result is also found for manure analyses and hydraulic infrastructures. From a policy maker's perspective, the lower control outcomes for the *compliers* suggest that the agreement between the Québec Department of Agriculture and UPA on advisory services for sustainable development of farms may have reached its objectives for the subgroup of *compliers*. They need advisory assistance to implement a riparian buffer zone and hydraulic infrastructures, and to perform manure analyses.

For conservation tillage, immediate incorporation and non-use of mineral fertilizers, the control outcome for the *compliers*, is higher than for the *never-participants*, indicating that the latter group does not participate even if they need help from an advisor. For these BMPs, some producers are "*resistant non-adopters*" and/or "*conditional non-adopters*" as defined in Defrancesco et al. (2007). They define *resistant non-adopters* as producers who do not participate and *conditional non-adopters* as farmers who participate because of easier-to-fit measures and higher payments. These authors found that *resistant non-adopters* and *conditional non-adopters* have a more market-oriented approach. The mixed results of the studies of economic gains of these BMPs can justify non-adoption.

5.4.2. Average Horizontal Diffusion Effect of AE Advisory Clubs

The vertical diffusion effect of AE advisory clubs is studied using membership as an instrument. 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 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 7 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. Our

[22] As mentioned in footnote #2, one way to correct for the selection on unobservables would be the Heckman (1979) approach. The model is weakly identified in the present study because there are no evident variables that would explain participation in extension activities but that do not have a direct effect on adoption.

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

results show that, as expected, "neighborhood effects" are also BMP specific.

Positive impacts are found for manure analyses, construction of hydraulic infrastructures and non-use of mineral fertilizers at 2.1%, 10.5% and 13.1% respectively. For these BMPs, the neighborhood effect increases the probability to adopt BMPs.[24] Interestingly, the implementation of these three BMPs demands 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 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 possible visible environmental gain (e.g. reduction of manure odors) of this BMP.

Table 7
Agri-environmental advisory clubs network horizontal diffusion effect.

BMPs	Average impact (Std. err.)	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]

Table 8
Alternative estimations of AE advisory clubs vertical diffusion effect.

BMPs	"Naive" estimator[a]		ATE estimation using Ridge matching
	Estimate	Bias [normalized shift]	
Manure analyses	0.142 (0.051)	0.444 [0.490]	0.251 (0.021)
Conservation tillage	0.116 (0.095)	0.506 [0.243]	0.086 (0.040)
Immediate incorporation	−0.006 (0.107)	−0.337 [−0.187]	−0.005 (0.039)
Riparian buffer	0.040 (0.065)	0.527 [0.093]	0.046 (0.035)
Non-use of mineral fertilizers	0.156 (0.076)	0.303 [0.721]	0.121 (0.048)
Hydraulic infrastructures	0.030 (0.082)	15.555 [0.007]	0. 096 (0.028)

[a] Marginal effect of the membership in an AE advisory club in the decision to adopt.

5.4.3. Alternatives Estimations of AE Advisory Clubs Effect

We carried out a number of additional estimates of the impact of clubs (see Table 8). We made a "naive" estimation of the advisory club network effect using membership as an explanatory variable of the probability to adopt and used the approach proposed by Altonji et al. (2005, 2008) to evaluate the potential bias that would be implied by selection on the unobservables. Column 1 of Table 8 gives the results of the estimation of the "naive" model whereas Column 2 indicates the potential bias. The impact of the advisory clubs is the marginal effect of membership on the probability to adopt the BMP. Given the value of the standard errors, with the exception of manure analysis, the effect of the advisory clubs is found to be non-significant. Our calculations of the normalized shift in the distribution of the unobservables suggest that selection due to unobservables is unlikely to bias the impact of advisory clubs' activities. (results of column 2 of Table 8).

We also estimated the average treatment effect (ATE) to see how close these estimands and the LATE are. The LATE may differ from the ATE when those influenced by the instrument are not representative of the overall population. Column 3 of Table 8 gives the results of the ridge matching estimator of the ATE. The values of the ATE presented in Table 8 and the LATE (see Table 6) are different, indicating that belonging to an advisory club has a non-homogenous impact on the farmers' decision to participate 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 on the members of the clubs.[25]

6. Conclusion

This study investigated the factors determining farmers' participation in AE extension activities and the impact of their participation on the adoption of various environmental best management practices (BMPs). Participation in AE extension activities is proxied by Québec farmers' adoption of an AE 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 AE extension activities. We analyze the link between participation in AE extension activities and the adoption of six BMPs, as well as the link between BMP adoption and the AE advisory club network.

The average impacts of the AE extension activities on BMP adoption are estimated using average treatment effect on treated. Then, we estimate the impact of the clubs' activities on producers who adopt a support plan because of these activities. In most of the BMPs, extension activities have a positive statistically significant impact on the probability of adopting, with a higher effect for manure analyses. The AE 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 an 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, they have no effect on the probability of establishing and maintaining a riparian buffer zone. In addition, the informal relationship, i.e. the possible horizontal diffusion effect of the advisory clubs, is studied using "vicinity" as an instrumental variable. Indeed, in the local average treatment effect, different instruments measure different effects. We found a positive significant diffusion effect for only three of the studied BMPs.

The number of observations used in the present study limits the extent to which the results can be generalized. Nonetheless, our results clearly indicate that in Québec, AE extension activities and advisory clubs play an important role in disseminating information, raising awareness of BMP adoption and ultimately affect 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 and/or institutions. It provides an adequate way of dealing with the potential endogeneity and treatment heterogeneity issues of the extension and advisory activities when analyzing their impact on the supply of ecological goods and services. Our results suggest that government policies that invest in social capital may help create a sufficiently enabling environment for the adoption of BMPs.

[24] Holloway et al. (2002) found a "neighborhood effect" significantly different from zero. Defrancesco et al. (2007) also suggest that local behavioral influences have to be taken into account when designing and communicating agri-environmental measures.
[25] As mentioned by Heckman (1997: p 456), the LATE assumes that the intervention has no effect on non-switchers. It is what Imbens (2010) addresses when discussing internal versus external validity issues (pp. 417–420).

Appendix A

Table A1
Statistics of controls variables used in the analysis of AE extension activities.

Variables	Full sample N = 190 Mean (Sd. err)	Treatment group (with a SP) N = 101 Mean (Sd. err)	Control group (without SP) N = 89 Mean (Sd. err)
Producers attributes			
Young farmer (= 1 if operator < 45 years)	0.289 (0.033)	0.290 (0.045)	0.289 (0.047)
Management experience(= 1 if > 15 years)	0.695 (0.039)	0.755 (0.043)	0.640 (0.048)
Education (> primary school = 1)	0.889 (0.023)	0.911 (0.030)	0.870 (0.034)
Place of residence (live on farm = 1)	0.858 (0.025)	0.867 (0.036)	0.850 (0.036)
Environmental sensitivity (participation in biodiversity project = 1)	0.195 (0.029)	0.250 (0.046)	0.140 (0.035)
Information (use of information provided by the phytosanitarian alert network = 1)	0.463 (0.036)	0.422 (0.052)	0.500 (0.050)
External characteristics			
Production losses (losses due to animals/plants = 1)	0.500 (0.036)	0.544 (0.053)	0.460 (0.050)
River quality	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			
Animal production			
[0 ; 250[	0.553 (0.036)	0.533 (0.053)	0.570 (0.049)
[250 ; + ∞[	0.147 (0.026)	0.222 (0.044)	0.080 (0.027)
Vegetal production			
[0 ; 250[	0.253 (0.032)	0.300 (0.045)	0.219 (0.042)
[250 ; + ∞[	0.047 (0.015)	0.044 (0.022)	0.050 (0.022)
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)	0.368 (0.035)	0.356 (0.050)	0.380 (0.049)
Ownership type (individually owned = 1)	0.395 (0.036)	0.333 (0.050)	0.450 (0.050)
Share of rented land (%)	0.267 (0.027)	0.222 (0.033)	0.307 (0.041)
BMPs (binary variable)			
Manure analyses	0.784 (0.030)	0.978 (0.016)	0.610 (0.049)
Immediate incorporation	0.514 (0.041)	0.547 (0.058)	0.420 (0.060)
Non-use of mineral fertilizers	0.668 (0.034)	0.756 (0.048)	0.590 (0.049)
Riparian buffer implementation	0.654 (0.038)	0.705 (0.052)	0.605 (0.055)
Conservation tillage	0.595 (0 039)	0.683 (0.052)	0.506 (0.056)
Hydraulic infrastructures	0.755 (0.034)	0.853 (0.039)	0.654 (0.053)

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

Variables	Coefficient	Marginal effect	Std. err.	Prob. > chi-square
Producers attributes				
Young farmer (= 1 if operator < 45 years)	0.214	0.085	0.265	0.419
Management experience (= 1 if > 15 years)**	0.485	0.189	0.274	0.077
Education (> primary school = 1)	0.215	0.084	0.333	0.517
Place of residence (live on farm = 1)	− 0.101	− 0.041	0.305	0.739
Environmental sensitivity* (participation in biodiversity project = 1)	0.828	0.319	0.298	0.005
Information*** (use of information provided by the PAN = 1)	− 0.351	− 0.139	0.214	0.102
External characteristics				
Production losses (losses due to animals/plants = 1)	0.075	0.023	0.207	0.717
River quality	0.227	0.090	0.225	0.313
Region	− 0.005	− 0.002	0.017	0.313
Farm attributes				
Total gross revenue (TGR) in $1000				
Animal production				
[0 ; 250[	0.394	0.156	0.486	0.418
[250 ; + ∞[	1.042	0.382	0.529	0.049
Vegetal production				
[0 ; 250[	0.324	0.129	0.522	0.535
[250 ; + ∞[	–	–	–	–
Share of the main production in the TGR(%)	− 0.244	− 0.097	0.611	0.690
Land quality (degradation signs = 1)	− 0.314	− 0.124	0.229	0.172
Ownership type (individually owned = 1)*	− 0.562	− 0.221	0.227	0.013
Share of rented land (%)**	− 0.529	− 0.210	0.308	0.086
Pseudo R^2	0.166			

Note: The marginal effect is calculated at the discrete change of binary variables from zero to one.
* Denotes significance at 5% level.
** Denotes significance at 10% level.
*** Denotes significance at 15% level (two-tailed test).

Table A3
Probit estimation of factors affecting adherence in an AE advisory club.

Variables	Coef.	Marginal effect	Std. err.	Prob. >chi^2
Producers attributes				
Age (in years) reference group = [0; 35[				
[35;45[*	−1.467	−0.367	0.080	0.003
[45;55[*	−1.395	−0.420	0.120	0.005
[55;65[*	−1.679	−0.453	0.102	0.009
[65;.]*	−2.567	−0.378	0.051	0.005
Management experience (in years)*	0.038	0.013	0.006	0.026
Gender (female = 1)	0.079	0.028	0.155	0.854
Education (>primary school = 1)	−0.346	−0.128	0.167	0.426
Place of residence (live on farm = 1)	0.521	0.161	0.099	0.165
Environmental sensitivity (participation in biodiversity project = 1)	0.454	0.167	0.118	0.140
Information*** (use of information provided by the PAN = 1)	−0.209	−0.073	0.083	0.387
External characteristics				
Production losses (losses due to animals/plants = 1)*	0.753	0.258	0.084	0.003
River quality	0.221	0.078	0.090	0.378
Region*	−0.054	−0.019	0.007	0.008
Farm attributes				
Total gross revenue (TGR) in $1000				
[0;50[**	−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 the main production in the TGR (%)	0.393	0.137	0.251	0.586
Main production (animal production = 1)*	–1.803	–0.328	0.051	0.026
Land quality (degradation signs = 1)	−0.284	−0.099	0.086	0.254
Ownership type (individually owned = 1)	0.040	0.014	0.098	0.887
Share of rented land (%)	0.230	0.080	0.136	0.558
Pseudo R^2	0.213			

Note: The marginal effect is calculated at the discrete change of binary variables from zero to one.
* Denotes significance at 5% level.
** Denotes significance at 10%.
*** Denotes significance at 15% level (two-tailed test).

Table A4
AE advisory clubs network vertical diffusion effect.

		Average impact (Std. err.)	95% CI of average impact
Manure analysis	Treatment outcome of compliers	0.936 (0.069)	[0.801;1.071]
	Control outcome of compliers	0.148 (0.049)	[0.052;0.244]
	Treatment outcome of always participants	0.977 (0.007)	[0.964;0.990]
	Control outcome of never-participant	1.000 (0.000)	[1.000;1.000]
Conservation tillage	Treatment outcome of compliers	0.911 (0.062)	[0.789;1.033]
	Control outcome of compliers	0.610 (0.049)	[0.514;0.705]
	Treatment outcome of always participants	0.563 (0.027)	[0.511;0.615]
	Control outcome of never-participant	0.418 (0.043)	[0.333;0.502]
Immediate incorporation	Treatment outcome of compliers	1.000 (0.002)	[0.997;1.003]
	Control outcome of compliers	0.991 (0.021)	[0.950;1.032]
	Treatment outcome of always participants	0.715 (0.023)	[0.670;0.759]
	Control outcome of never-participant	0.505 (0.054)	[0.400;0.611]
Riparian buffer	Treatment outcome of compliers	0.909 (0.078)	[0.757;1.061]
	Control outcome of compliers	0.439 (0.091)	[0.262;0.617]
	Treatment outcome of always participants	0.696 (0.021)	[0.655;0.736]
	Control outcome of never-participant	0.715 (0.082)	[0.555;0.876]
Non-use of mineral fertilizers	Treatment outcome of compliers	0.898 (0.055)	[0.790;1.006]
	Control outcome of compliers	0.577 (0.037)	[0.503;0.650]
	Treatment outcome of always participants	0.569 (0.027)	[0.516;0.622]
	Control outcome of never-participant	0.452 (0.036)	[0.381;0.523]
Hydraulic infrastructures	Treatment outcome of compliers	0.984 (0.024)	[0.937;1.031]
	Control outcome of compliers	0.601 (0.056)	[0.492;0.711]
	Treatment outcome of always participants	0.816 (0.022)	[0.773;0.860]
	Control outcome of never-participant	0.741 (0.057)	[0.629;0.854]

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