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Abstract: This study investigates the factors that determine producers' participation in agri-environment (AE) extension activities and their adoption of best management practices (BMPs) in Quebec (Canada). Data were collected from farmers in telephone interviews and the impacts of AE extension activities were analyzed using *average treatment effect* and *local average treatment effect*, estimated with non-parametric approaches. The average effects of AE 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 AE advisory club. The informal diffusion effect is statistically significant for BMPs that have visible impacts.

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

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

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

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).[1] However, given the voluntary nature of the adoption of most conservation practices, farmers need to decide whether to adopt BMPs or not. Agri-environment (AE) extension activities attracted considerable interest because of their capability to improve the performance of producers in the delivery of ecological goods and services (EGS)[2] through BMPs. The farms' response to AE 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. These authors 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). 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. In addition, educational

[1] For example, using a hydrologic *Soil and Water Assessment Tool* (SWAT) model, Michaud *et al.* (2006) identify sustainable cropping practices likely to help meet the target phosphorus (P) load. Tested BMPs include the implementation of sustainable cropping practices, the conversion of a specific portion of the territory to cover crops or permanent prairie land, investments in the protection of flood plains and riparian strips, the rapid soil incorporation of manure….

[2] According to Daily (1997), ecosystems goods are tangible material products that result from ecosystem processes. Brown, Bergstrom and Loomis (2007: 332) define ecosystem services as *"…the specific results of … processes that either directly sustain or enhance human life… or maintain the quality of ecosystem goods."*

opportunities seem to increase directly adoption rates through awareness and information dissemination.

Nonetheless, an important methodological problem that has not addressed sufficiently by many of the previous studies on BMPs adoption is the bias related to potential participation to formal and informal groups' activities. Correlation between participation in activities and BMP adoption could be due to a positive effect caused by the participation in activities. There could also be a *self-selection* effect if farmers that already have more positive environmental attitudes than their peers do participate more eagerly in such activities (see Salhofer and Streicher, 2005). To resolve this selectivity problem, one could use an instrumental variables (IV) approach, wherein an instrument that is correlated with participation in activities but is uncorrelated with BMP adoption is used.[3] 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 analyzing BMP adoption (Strauss *et al.*, 1991; Owens *et al.*, 2003; Feder, Murgai and Quizon, 2004). The focus is typically on estimating the *average partial effect* (APE), which is the partial effect averaged across the population distribution of the unobserved heterogeneity.[4] When the endogenous variable is binary, such as participation in a program, the average partial effect is called the *average treatment effect* (ATE). 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

[3] 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.

[4] 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.

participate in the program, the *average treatment effect on treated* (ATET) is the estimand of most interest (Imbens and Wooldridge, 2009).

The aim of the paper is to identify how AE extension activities affect the adoption of BMPs of a farmer compared with what he would have experienced if he had not participated. We use the concept of ATET to evaluate the effect of AE extension activities on the adoption of BMPs. The estimated ATET is the expected effect on BMP adoption of AE extension activities on a farm randomly drawn from the subpopulation of farms who participate in extension activities (Wooldridge, 2002). Participation in AE extension activities is proxied by adopting an AE support plan. In addition, we hypothesize that membership in an AE advisory club has an impact on the probability to adopt a support plan. We quantify the potential vertical (i.e. formal) and horizontal (i.e. informal) diffusion effects on BMPs adoption of the membership to an AE advisory club. We do so using the concept of *local average treatment effect* (LATE) suggested by Imbens and Angrist (1994). In the LATE, the effect of treatment changes in response to an instrumental variable. Thus, the LATE measures the average treatment effect among those who alter their treatment status because they react to the instrument. We use farmers' membership as instrument when estimating the vertical diffusion effect of AE advisory clubs network activities. The LATE, by restricting the analysis to the subpopulation of farmers who react to membership, estimates the vertical (i.e. formal) impact of AE advisory clubs network on the adoption of BMPs. We made the same reasoning when studying the informal diffusion effect of the AE advisory clubs network. The "vicinity" is used as instrument and, thus, the estimated LATE is the mean effect on BMPs adoption of knowing farmers who are members of an AE advisory club.

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. Additively separable models thus rule out unobserved heterogeneity and are not appropriate given the objectives of the study at hand. Thus, in our estimation procedures, we use non-parametric approaches.[5] They avoid delicate functional form and independence assumptions. 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 apply the non-parametric IV estimation of LATE with covariates proposed by Frölich (2007). Applying Frölich's (2007) approach, we allow for confounding factors, that is, factors that influence the potential probability to adopt and the decision to participate in AE extension activities and the instrument (membership or "vicinity"). We then try to mitigate some of the difficulties of improper instrumental variable because of inadequate covariates.

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

2. Methodological Approach

2.1. Conceptual framework: a simple model of participation decision

In this section, we present a model of participation in AE extension activities and BMPs adoption that gives an economic interpretation of the treatment effects that we estimate. Our simplified

[5] Non-parametric empirical applications 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).

framework assumes that the producer maximizes utility function that depends on his consumption c and his quality of life, $\hbar$:[6]

(1) $$u = u\left(c\left(g_a, g_{na}\right), \hbar \mid \iota\right)$$

where g_a is the producer consumption of an agricultural good and g_{na} a vector of non-agricultural good. The producer heterogeneity is captured by the parameter ι. The production function is:

(2) $$q_i\left(q_a, q_e\right) \geq 0$$

where q_a is the level of production of the agricultural good and q_e is the level of production of ecological goods and services which is produced jointly with agricultural good using the following technology:

(3) $$q_e = f\left(q_a\left(\lambda\right), \lambda\left(e\right)\right)$$

where the parameters λ and e are respectively the vector of adopted BMPs and participation in AE extension activities. We assume that $\partial\lambda/\partial e \geq 0$ and $\partial q_e/\partial\lambda \geq 0$. However, the direction of the impact of λ in the level of production of the agricultural good is unknown *a priori*. Finally, the quality of life is "produced" according to the following production technology:

(4) $$\hbar = h\left(q_e, \alpha\left(q_e, .\right)\right)$$

where α represents the "ambient" level of EGS. Then, EGS is a private commodity as is a public commodity because of the existence of public spillovers. We assume that $\partial\hbar/\partial q_e \geq 0$.

[6] The framework used in the present paper is close to Singh, Squire and Strauss (1986) households' behavior modeling under market failures and Harrington and Portney (1987) or Jakus (1994) models of defensive behavior. 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 inputs and/or outputs markets 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 the lack of markets for most of the EGS. In addition, there is joint-effect, reduction of pollutant affecting the welfare of producer through their production function and their health. To focus only on the most relevant aspect, we abstract from certain considerations.

Equations (1), (2), (3) and (4) provide a simplified behavioral model of farmers' decisions. The decision of participation in AE extension activities contributes to utility through the preference effect and, as they change the price function, through the production effect because of joint production of agricultural goods and EGS. The estimated treatment effects are the total effect and there will be heterogeneity in the effect of AE extension activities even if the production effect is the same. Depending on the concavity or convexity of $\partial u / \partial e$, the average effect of participating in AE extension activities can be positive, negative, or zero. We model participation as a discrete choice, where the observed choice is an expression of a continuous latent variable reflecting the propensity to choose a specific option among different alternatives. Farmers will adopt a BMP if they believe that it will enhance their utility, all others factors considered. They then weigh -with varying uncertainty- the costs and benefits of the adopted practice to determine the degree to which the BMP will affect other facets of their daily life, specifically, whether the BMP is compatible with their habits and values.

2.2. Estimation methods

Average treatment effect of the participation in AE extension activities

Participation in AE extension activities is modeled as a discrete choice taking the value of 1 when the producer participates and 0 otherwise. The estimated *average treatment effect* (ATE) is the expected effect that farmers have gained because of their participation in AE extension activities.

To define the ATE and following the notation of Frölich (2007), let us consider the model:

(5) $$\lambda_i = \varphi\left(e_i, \mathbf{x}_i, \varepsilon_i\right)$$

(6) $$e_i = \varsigma\left(\mathbf{x}_i, \upsilon_i\right)$$

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; $e \in \{0,1\}$ is the fact that the producer participate in AE extension activities assumed to be endogenous; ε and υ are unobserved variables, and $\mathbf{x}_i$ is the vector of observed covariates.[7] The expected ATE is defined as:

(7) $$ATE = E\left(\lambda \mid e=1\right) - E\left(\lambda \mid e=0\right)$$

where *E* represents the expectation symbol. The treatment effect is estimated non-parametrically using propensity-score matching estimators and given a conditional dependence assumption (Frölich, 2006):

(8) $$\frac{1}{n}\sum_{i=1}^{n}\left\{\hat{m}_1\left(\tau_i\right) - \hat{m}_0\left(\tau_i\right)\right\}$$

where $\hat{m}_e(\cdot)$ is a non-parametric regression estimator of $m_e(\cdot) = E\left[BMP = \lambda \mid \tau(\mathbf{x}) = \rho, Participation = e\right]$ conditional on the propensity score $\tau(\mathbf{x}) = P\left(e=1 \mid X = \mathbf{x}\right)$.[8] The estimator of the treatment in (8) is consistent provided that $\hat{m}_e$ is consistent and that the support of $\mathbf{x}$ are identical in the subpopulations where $e=0$ and $e=1$.

[7] The causal interpretation of φ is that for a farmer unit *i* the variables ε_i, υ_i and $\mathbf{x}_i$ are defined by nature and e_i and λ_i are determined by (5) and (6) respectively.

[8] The propensity score is defined as the probability of adoption for the farm *i* given a set of farm characteristics. We assume additive separability of treatment effects and ignore potential interaction effects between different BMPs adoption. Matching and weighting by the propensity score have the advantage that they do not require high-dimensional non-parametric regression of the mean outcome (Frölich, 2007). Pufahl and Weiss (2009) use a *pair matching* estimator in a study of AE programs in Germany. In the present study we use a *ridge matching* estimator. Usually, ridge matching was the best estimator (lower mean square error) particularly in small samples (Frölich, 2004). Imbens and Wooldridge (2009) provide a recent revue of matching methods.

However, given the voluntary nature of the participation in AE extension activities, the estimated *average treatment effect on the treated* (ATET) is most of interest. The ATET is the expected effect that participants in AE extension activities have gained because of their participation:

(9) $$ATET = E\left(\tilde{\lambda}^1 \mid e=1\right) - E\left(\tilde{\lambda}^0 \mid e=1\right)$$

The ATET is obtained by dividing the estimated ATE - weighted by the propensity score - by the probability of a positive participation.

Average treatment effect of the AE advisory clubs network

As Rogers (2003) asserts, social systems can be characterized as *heterophilous* or *homophilous*. *Heterophilous* social systems tend to encourage change from system norms. There is interaction between people from different backgrounds introducing a vertical and formal linkage system. *Homophilous* social systems tend toward system norms. Most interaction within them is between people from similar backgrounds in a horizontal system. People and ideas that differ from the norm appear strange and undesirable.

Heterophilous linkage that can increase access to information and BMP adoption is studied using the instrumental variable (IV) estimation of LATE and membership in an AE advisory club as an instrument. As describe in Table A1, producers can be distinguished into four types according to their reaction at an external intervention, i.e., membership in an advisory club (see Imbens and Ingrist, 1994): *never-participant*, *complier*, *defier* and *always-participant*. The *compliers* are farmers who participate in AE extension activities because they adhered in an AE advisory club. Consistent with Heckman’s (1997) definition, the estimated LATE measures the expected effect on the probability to adopt, of the change in participation in AE extension activities because of adhesion in an AE advisory club.

To define the non-parametric LATE estimator let us now consider the following triangular model:

(10) $\lambda_i = \varphi(e_i, z_i, \mathbf{x}_i, \varepsilon_i)$

(11) $e_i = \varsigma(z_i, \mathbf{x}_i, \upsilon_i)$

where $z = \{0,1\}$ is the membership status taking the value of 1 if the producer is a member of a club and 0 otherwise; the other variables have been defined above. The LATE is :[9]

(12) $LATE = E\left(\left(\lambda \mid e(z=1)\right) - \left(\lambda \mid e(z=0)\right)\left(\lambda^1 - \lambda^0\right)\right)$

Frölich (2007) define the propensity score matching estimator of a LATE model as:

(13) $$\hat{\varpi} = \frac{\sum_i \left(\hat{m}_{\tau_1}(\hat{\tau}_i) - \hat{m}_{\tau_0}(\hat{\tau}_i)\right)}{\sum_i \left(\hat{\mu}_{\tau_1}(\hat{\tau}_i) - \hat{\mu}_{\tau_0}(\hat{\tau}_i)\right)}$$

where $\hat{\tau}_i$ is the propensity score estimator; $\hat{m}_z(\cdot)$ and $\hat{\mu}_z(\cdot)$ are the nonparametric estimators of the conditional mean function $m_z(\cdot) = E\left[BMP = \lambda \mid \tau(\mathbf{x}) = \rho, z\right]$ and $\mu_z(\cdot) = E\left[Participation = e \mid \tau(\mathbf{x}) = \rho, z\right]$ respectively.[10]

Beside the estimated LATE, the fractions of *compliers* and *never-participants* are estimands of interest. They are given, respectively, by equations (14) and (15):

(14) $\Pr(\varpi = c) = \int \left(E\left[Participation \mid \mathbf{x}, z=1\right] - E\left[Participation \mid \mathbf{x}, z=0\right]\right) dF_x$

(15) $\Pr(\varpi = n) = \int \left(E\left[1 - Participation \mid \mathbf{x}, z=1\right]\right) dF_x$

[9] 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 who adoption are highly affected by membership. These farms are likely to respond more dramatically to change in participation status than the average farm.

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

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 (2006), we can identify the expected treatment outcome for the *always-participants* by

(16) $$E\left[\hat{\lambda}^1 \mid \varpi = a\right] = \frac{\int E\left[\hat{\lambda}\left(Participation\right) \mid \mathbf{x}, z = 0\right] dF_x}{\int E\left[\left(Participation\right) \mid \mathbf{x}, z = 0\right] dF_x}$$

and the non-treatment outcome of the *never-participants* by

(17) $$E\left[\hat{\lambda}^0 \mid \varpi = n\right] = \frac{\int E\left[\hat{\lambda}\left(1 - Participation\right) \mid \mathbf{x}, z = 1\right] dF_x}{\int E\left[\left(1 - Participation\right) \mid \mathbf{x}, z = 1\right] dF_x}$$

We made the same reasoning for informal, i.e. *homophilous*, diffusion impact of AE advisory clubs network. The “vicinity” is used as instrumental variable. Nevertheless, whether living close to or far from a member of an AE advisory club is an active choice, that choice, however, might itself be related to characteristics that affect the decision to adopt or not a given BMP. The estimated LATE measures the expected impact in adoption caused by the change in participation in AE extension activities because of living close to a member of an AE advisory club.

Finally, in line with Viet (2008), Frölich and Lechner (2006) and Behrman, Cheng and Todd (2004), confidence intervals (CI) of the treatment effects are simulated using bootstrapping methods. The problem is that the distribution from which estimates of ATET and LATE originate is unknown; so standard errors are not determinable (Behrman *et al.*, 2004; Reynolds and DesJardins, 2009). The bootstrap consisted in drawing with replacement from the original sample and repeating the entire estimation process (see Brownstone and Valleta, 2001; Wooldridge, 2002).[11] The percentile

[11] Politis, Wolf and Romano (1999) and Imbens and Wooldridge (2009) provide a proof on the validity of this approach of subsampling.

approach is used to construct the 95% bootstrapped CI of the treatment effects (Davidson and Hinkley, 1997).

3. Data and definition of variables

Data are from a survey implemented between February and March 2009. The year of reference was 2008 and the dataset consists to 200 observations. Definition of variables used and their corresponding summary statistics are listed in Table A2.

Producers Attributes

The residence location (*Residence*), the level of education (*Education*), the gender (*Gender*) and the age (*Age*) of the primary producer are modeled through dummy variables that take a value of zero or one. Five age groups were formed: <35, [35;45[, [45;55[, [55;65[and ≥65. *Residence* takes a value of one when the producer lives on his farm as does *Gender* when the primary producer is a female. *Education* takes the value of 1 when secondary school is completed and 0 otherwise. Environmental awareness (*Environmental*) may be an important determinant when considering BMP adoption. It is proxied by a variable that takes a value of 1 if the primary farm operator has participated in a biodiversity conservation program and/or has a perception of a decrease in biodiversity and 0 otherwise. We introduce farm management experience (*Experience*) through a continuous variable. Finally, access to and use of technical information (*Information*) is introduced through a binary variable that takes the value of one when the primary producer has used the information provided by the Phytosanitary Alert Network (*Pan*) and 0 otherwise.

Farm attributes

The main production is divided into 6 groups: bovine production, milk production, hog production, other animal productions, cereals and other crop productions. We introduce the main productions through binary variables. The farm size is proxied by its total gross revenue (TGR). The TGR

(*Revenue*) is grouped into five categories: <$50,000, [$50,000;$100,000[, [$100,000;$250,000[, [$250,000;$500,000[, ≥$500,000. The potential impact of farm specialization is estimated using the contribution of the main production to the TGR (*Share*). It is introduced through a continuous variable with values between 0 and 1. Type of farm (*Ownership*) is a binary variable that takes the value of 1 if the farm is individually owned and 0 otherwise. The share of rented land (*Rent*) is introduced through a continuous variable taking values between 0 and 1. Land quality (*Land*) is introduced through a binary variable. It takes the value of 1 if the producer has observed land degradation due to water or wind.

External characteristics

Geographical region (*Region*) is considered through categorical variables without a particular order. River quality (*River*) is introduced through binary variables. *River* takes the value of 1 if the producer has observed sediments or pollutants in the rivers or if the banks of the rivers are degraded. Finally, the variable *Loss* takes the value of 1 if the producer has experienced destruction of his production by animals or plants; otherwise, *Loss* takes the value of 0.

Participation in AE extension Activities

The participation of producers in AE extension activities is proxied by their adoption of a comprehensive environment tool called AE support plan. Quebec's minister of agriculture introduced it in order to help producers to enhance their environmental performances.[12] It is a voluntary process realized with the assistance of an advisor. The AE support plan is modeled 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 the AE advisory clubs

[12] The AE support plan is based on a scan that evaluates *(i)* the disposal capacity of fertilizers; *(ii)* whether a farm's AE practices comply with regulatory requirements; and *(iii)* other farming practices that involve the environment (e.g., erosion control, odor reduction, and optimization of pesticide use). During the process, the priorities identified by the farm and its particular business features are taken into account (MAPAQ, 2003).

network.[13] In addition, 40.34% of producers that are not members of an advisory clubs claimed to have a neighbor or a friend that is a member. In that case, the variable *vicinity* take the value of 1 and 0 otherwise.

BMPs

Six BMPs are analyzed and are all introduced through binary variables that take the value of 1 if the BMP is adopted and 0 otherwise. The first studied BMP is related to compliance with the regulatory norms on soil and manure analyses. It takes the value of 1 if the analyses was done in the last 12 months for manure and 5 years for soil. Producer adoption decisions regarding conservation tillage is studied. Consistent with Davey and Furtan (2008), we define conservation tillage as tillage that retains most of the previous crop residue on 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 meter 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 1 presents preliminary analysis of the analyzed BMPs. It shows that the proportions of adopters are different – significant at 5% level – in the subpopulations of producers with and without a support plan. When the comparison is based on membership in an AE advisory club, the results are more mixed.

[13] Environmental responsibilities of Quebec farmers have arisen from various AE initiatives that inspired the creation of AE advisory clubs in 1993. Today, the network has more than 8,300 members grouped into 83 clubs and served by more than 300 advisors. It has the strong support of the *Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec* (MAPAQ) and the *Union des producteurs agricoles* (UPA). A description of the AE advisory clubs network activities is available at http://www.clubsconseils.org/accueil/affichage.asp?B=763. Accessed April 8, 2009.

4. Empirical results

4.1. Factors affecting the decision of participation in AE extension activities

Factors affecting the decision of participating in AE extension activities, proxied by the adoption of an AE support plan, are estimated using non-parametric Probit. Table A3 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 AE extension services compared with farmers age 45 and under. Farmers that have completed secondary school and have more experience with farm management have a higher probability of participating, as do farmers with environmental awareness, which increases the probability of deciding to have an AE support plan by 27.4%.[14]

Only the smallest farms, i.e., with TGR below $50,000, have a lower probability of adopting an AE 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 productions. However, there is a difference for the other animal and crop productions, with 39.8% and 37% less probability, respectively, of participating in AE extension activities compared with hog production, the base production. As expected, having observed soil degradation has a positive marginal effect; it increases the probability of having AE 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.

[14] Kaiser, Wolfing and Fuhrer (1999) indicate that awareness of environmental concerns usually precedes the adoption of a desirable attitude about the issue of interest. Although, Kaiser *et al.* (1999) do not find strong relationship between behaviour and awareness. In developing countries context, Ecobichon (2001) and Heong *et al*. (2002) also report a general awareness of chemical inputs secondary effects but not necessarily an influence farmers' production behaviour. Tucker and Napier (2001) find that although some Midwestern US farmers were aware of potential negative consequences of chemical inputs use, this awareness does not necessarily influence farmers' production behaviour.

4.2. Average effect of AE extension activities

For each studied BMP, the estimated ATET measures AE extension activities' impact on the expected probability of adopting for the subgroup of producers with an AE support plan. A positive value of the ATET suggests that the subgroup of producers with a support plan have a greater probability to adopt because of having it. Table 2 reports ATET and their corresponding bootstrapped 95% confidence intervals.

The average positive impact is higher for the immediate incorporation of manure. The value of 0.128 indicates that participating in AE extension activities increases the probability of adopting by 12.8%. 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 pollutant, e.g., phosphorus and nitrogen, and, manure odours). Because of increasingly stringent regulations and growth in rural residential areas, diligence in environmental protection has become a major consideration for farmers as reported by Deaton *et al*. (2005). The (positive) average impact on the adoption of hydraulic infrastructures and the non-use of mineral fertilizers are also important, respectively at 9.7% and 8.9%. The latter result corresponds to Pufahl and Weiss (2009) who observe a reduction (9.4% of expenditures) in fertilizers expenditures when studying the impact of AE programs[15] in Germany.

For conservation tillage, although statistically significant, the positive impact of AE extension activities is lower. This could be due to the mixed results of studies of the impact of this BMP on the profitability of farms.[16] The average impact on the adoption of soil and manure analyses is the lowest of statistically significant impact. This is an expected result because this BMP is related to

[15] However, the analyzed AE programs are measures in which farmers receive compensation payments for the adoption of BMPs (Pufhal and Weiss, 2009).

[16] Smith *et al.* (1996) indicates that conservation tillage is not economically competitive while Mooney and Williams (2007) shows that it is under some circumstances.

compliance with the regulatory norms and is suggested to farmers few years ago. Finally, AE extension activities have no statistically significant impact for the establishment and the maintenance of a riparian buffer zone.[17]

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

4.3. Average effects of the AE advisory clubs network

Average heterophilous effect of the AE advisory clubs network

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 AE extension activities, will not change their status even if they join an AE advisory club. The *compliers* are farmers who use an AE support plan because of membership in an AE advisory club. Their estimated fraction is 0.344 with a bootstrapped 95% CI of [0.185; 0.484]. 34.4% of farmers in the database react to membership in an AE advisory club by the adoption of an AE support plan.

Table 3 reports the results of the estimated LATE of compliers with their corresponding 95% confidence intervals. The estimated LATE are positive and statistically significant for the majority of the studied BMPs indicating a vertical linkage that can increase access to information and the spread of ideas. The values of the ATET (see Table 2) and the LATE (see Table 3) are different indicating a non homogenous treatment effect of adherence to an AE advisory club. The differences between estimated ATET and LATE imply that farmers decisions to react to adhesion is based on factors that also determine the gains of AE extensions activities (Heckman, 1997).

[17] From an individual landowner's perspective, benefits may not clearly outweigh cost when establishing and maintaining a riparian buffer zone (see Brethour *et al.*, 2007).

Although the AE advisory clubs network has adopted the support plan as a working tool, the estimated LATE provide only a measure the effectiveness of the network.[18]

Soil and manure analyses realization is the BMP with the greatest average impact of membership in an AE advisory club. The result of 71.7% (LATE=0.717) is the expected mean effect on the probability of adoption of analyses for farmers that decide to use an AE support plan because they are members of an AE advisory club. The probability of adoption is, on average, augmented by 71.7%. This is quite a large effect but expected because this BMP is related to compliance with regulatory norms. In a report on the evaluation of the AE advisory clubs network activities, Sogémap (2007) indicates that adherence is largely due to regulatory reasons at 67%. The treatment outcome for the *always-participants* is 0.972 while it the non-treatment outcome for the *never-participants* is 0.999 for soil and manure analyses. These results indicate a small difference in the average probability to adopt for the two groups even if we expect a negative treatment effect for both groups.

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 AE advisory clubs network activities on the level of adoption. However, the results indicate statistically non-significant effects for the injection of manure into the soil within 24 hours of the initial spreading and riparian buffer zone establishment and maintenance (see Table 3). This result is consistent with Prokopy *et al.* (2008) who also report inconclusive relationship of networking and the decision to adopt some of BMPs related to livestock management, landscape management and soil management. Nevertheless, Sobels, Curtis and Lokie (2001) find that increase in social capital play a role in the success of Landcare program in Australia.

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

Average homophiilous effect of the AE advisory clubs network

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 AE extension activities, will not change their status even if "vicinity" with a member of an AE advisory club. The estimated fraction of *compliers* is lower than for the membership at 0.220 with a bootstrapped 95% CI of [0.044; 0.38]. Twenty two percent of farmers in the database react to "vicinity" by the adoption of an AE support plan.

Table 4 reports the horizontal diffusion impact of the AE advisory clubs network. For the entire population of producer, we try to identify the gain from knowing at least one member of an AE advisory club. Positive significant impacts are found for the implementation of riparian buffer, the construction of hydraulic infrastructures and the non-use of mineral fertilizers at 22.7%, 14.9% and 4.7% respectively. Interestingly, for the two first BMPs, the effects are visible suggesting that "visit and training" as an approach to the extension may be efficient when promoting BMPs adoption. The statistically non-significant impact for immediate incorporation of manure is expected given the results of the formal diffusion effects. Our results show a negative impact of the "vicinity" on the conservation tillage. We had no expectation about the direction of the impact of the "vicinity" because of the mixed results of the economics studies about the profitability of conservation tillage.[19] The "vicinity" has a non-significant impact on the realization of manure and soils analyses.

[19] See footnote 16.

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 AE extension activities is proxied by Quebec farmers' adoption of an AE support plan. Data was collected from farmers through a telephone interview 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 the use of AE extension activities and the adoption of six BMPs, as was the link between BMP adoption and the AE advisory clubs network.

The average impacts of the AE extension activities on BMPs adoption are estimated using *average treatment effect on treated* (ATET). 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 AE advisory clubs network effects on the probabilities to adopt BMPs are estimated using the concepts of *local average treatment effect* (LATE). Membership in an AE club is used as instrumental variable when studying the vertical linkage (*heterophilous*, i.e., people with dissimilar characteristics) that can increase adoption. The advisory clubs network was found to have a statistically significant positive effect for most of the studied BMPs. Nevertheless, it has no effect on the probability to establish and to maintain a riparian buffer zone as is 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. We found a positive significant diffusion effect for the BMPs with visible impacts.

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 AE extension activities and the AE advisory the clubs network play an important role in disseminating information and raising awareness of BMP adoption and ultimately on the supply of ecological goods and services. The results also confirm that, like for most of the other factors affecting BMPs 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 as a useful technique for empirical evaluation of extension activities and/or institutions. It provides an adequate way to deal with the potential endogeneity and treatment heterogeneity issues of the extension and advisory activities when analyzing 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.

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Table 1. Results for z-tests (two-side) of equal proportions of BMPs' adopters

	AE support plan		
BMPs	non-adopters (Std. err.)	adopters (Std. err.)	z statistic (Prob. >|z|)
Soil and manure analyses	0.610 (0.048)	0.977 (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	0.657 (0.048)	0.523 (0.053)	1.860 (0.063)
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)
	AE advisory clubs network		
BMPs	non-members (Std. err.)	members (Std. err.)	z statistic (Prob. >|z|)
Soil and manure analyses	0.669 (0.043)	0.986 (0.014)	-5.094 (0.000)
Conservation tillage	0.545 (0.050)	0.672 (0.059)	-1.606 (0.108)
Immediate incorporation	0.494 (0.054)	0.474 (0.066)	0.242 (0.809)
Riparian buffer	0.608 (0.045)	0.567 (0.061)	0.550 (0.583)
Non-use of mineral fertilizers	0.620 (0.044)	0.754 (0.052)	-1.884 (0.059)
Hydraulic infrastructures	0.707 (0.046)	0.828 (0.047)	-1.754 (0.079)

Table 2. AE support plan average treatment effect on treated (ATET)

BMPs	Average impact	Bootstrapped 95% CI of the average impact
Soil and manure analyses	0.058	[0.034; 0.083]
Conservation tillage	0.070	[0.010; 0.129]
Immediate incorporation	0.129	[0.054; 0.203]
Riparian buffer	-0.034	[-0.083; 0.015]
Non-use of mineral fertilizers	0.089	[0.033; 0.145]
Hydraulic infrastructures	0.097	[0.047; 0.146]

Table 3. AE advisory clubs network vertical diffusion effect

	Mean (Sd. Err.)	95% Bootstrapped CI
Soil and manure analyses		
Treatment effect of the *compliers* (LATE)	0.717 (0.159)	[0.489 ; 1.029]
Non-treatment outcome of the *never-adopters*	1.000 (0.000)	[1.000 ; 1.000]
Treatment outcome of the *always-adopters*	0.970 (0.033)	[0.910 ; 1.000]
Conservation tillage		
Treatment effect of the *compliers* (LATE)	0.415 (0.288)	[<0.001 ; 0.948]
Non-treatment outcome of the *never-adopters*	0.556 (0.170)	[0.310 ; 0.871]
Treatment outcome of the *always-adopters*	0.551 (0.091)	[0.399 ; 0.712]
Immediate incorporation		
Treatment effect of the *compliers* (LATE)	0.110 (0.270)	[-0.309 ; 0.587]
Non-treatment outcome of the *never-adopters*	0.441 (0.151)	[0.200 ; 0.698]
Treatment outcome of the *always-adopters*	0.607 (0.087)	[0.465 ; 0.743]
Riparian buffer		
Treatment effect of the *compliers* (LATE)	0.208 (0.153)	[-0.072 ; 0.440]
Non-treatment outcome of the *never-adopters*	0.707 (0.174)	[0.431 ; 1.000]
Treatment outcome of the *always-adopters*	0.743 (0.072)	[0.625 ; 0.853]
Non-use of mineral fertilizers		
Treatment effect of the *compliers* (LATE)	0.368 (0.203)	[0.052 ; 0.721]
Non-treatment outcome of the *never-adopters*	0.688 (0.171)	[0.408 ; 1.007]
Treatment outcome of the *always-adopters*	0.629 (0.093)	[0.479 ; 0.792]
Hydraulic infrastructures		
Treatment effect of the *compliers* (LATE)	0.329 (0.182)	[0.031 ; 0.651]
Non-treatment outcome of the *never-adopters*	0.751 (0.166)	[0.483 ; 1.000]
Treatment outcome of the *always-adopters*	0.843 (0.068)	[0.727 ; 0.941]

Table 4. AE advisory clubs network horizontal diffusion effects

BMPs	Average impact	Bootstrapped 95% CI of the average impact
Soil and manure analyses	0.019	[-0.003 ; 0.042]
Conservation tillage	-0.150	[-0.192 ; -0.108]
Immediate incorporation	-0.005	[-0.068 ; 0.058]
Riparian buffer	0.227	[0.194 ; 0.260]
Non-use of mineral fertilizers	0.047	[0.0145 ; 0.078]
Hydraulic infrastructures	0.149	[0.094 ; 0.204]

The value in bold is non significant.

Appendix

Table A1. Type of farmers according to the reaction to an external intervention

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

Table A2. Summary statistics of variables used in the analysis

Variables (unity)	Mean	Standard deviation	Min.	P50	Max.
Producers attributes					
Age (1: <35, 2:[35;45[, 3:[45;55[, 4:[55;65[, 5:≥65)	3.09	1.12	1.00	3.00	5.00
Gender (Female=1)	0.11	0.31	0.00	0.00	1.00
Management experience (years)	22.89	12.04	0.00	22.00	59.00
Education (> primary=1)	0.88	0.33	0.00	1.00	1.00
Place of *residence* (Farm=1)	0.86	0.35	0.00	1.00	1.00
Environmental sensitivity (participation in biodiversity project or observation of decrease in biodiversity =1)	0.19	0.39	0.00	0.00	1.00
Pan (Use of information provided by the Pan=1)	0.45	0.50	0.00	0.00	1.00
External characteristics					
Production *loss* (losses due to animals or plants =1)	0.48	0.50	0.00	0.00	1.00
River quality (accumulation signs =1)	0.78	0.42	0.00	1.00	1.00
Region	-	-	-	-	-
Farm attributes					
Revenue ($1,000) (1:<50, 2:[50;100[, 3:[100;250[, 4:[250;500[, 5:≥500)	4.18	1.97	1.00	4.00	7.00
Main production (animal production=1)	0.7	0.46	0.00	1.00	1.00
Share of the main production in the (TGR)	0.85	0.18	0.20	0.90	1.00
Land quality (degradation signs=1)	0.41	0.49	0.00	0.00	1.00
Ownership type (Individually owned=1)	0.41	0.49	0.00	0.00	1.00
Rent (share of rented land)	0.16	0.24	0.00	0.00	1.00
AEES activities					
Member of an AEAC (=1)	0.36	0.48	0.00	0.00	1.00
Having an *AEP* (=1)	0.47	0.50	0.00	0.00	1.00
Diffusion effect (knowing=1)	0.40	0.49	0.00	0.00	1.00
BMPs (binary variable)					
Soil and manure analyses	0.78	0.41	0.00	1.00	1.00
Immediate incorporation of manure	0.51	0.50	0.00	1.00	1.00
Non-use of mineral fertilizers	0.53	0.50	0.00	1.00	1.00
Riparian buffers implementation	0.84	0.36	0.00	1.00	1.00
Conservation tillage	0.40	0.49	0.00	0.00	1.00
Hydraulic infrastructures	0.75	0.43	0.00	1.00	1.00

Table A3. Non-parametric Probit estimation of factors affecting the adoption of an AE 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[	**-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)	**0,961**	**0.323**	**0,464**	**0,038**
Management experience (years)	**0,047**	**0.018**	**0,017**	**0,008**
Residence (Farm=1)	-0,456	-0.180	0,362	0,208
Information (Use RAP=1)	*-0,412*	*-0.161*	*0,238*	*0,083*
Environmental sensitivity (=1)	**0,701**	**0.274**	**0,302**	**0,020**
Revenue (TGR) in $				
[0; 50000[	**-0,843**	**-0.304**	**0,394**	**0,033**
[50000; 100000[	-0,468	-0.174	0,439	0,286
[100000; 250000[	-	-	-	-
[250000; 500000[	-0,108	-0.042	0,329	0,744
[500000;)	0,554	0.218	0,385	0,150
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				
Bovine production (=1)	-0,598	-0.218	0,480	0,213
Milk production (=1)	0,105	0.042	0,354	0,767
Hog production (=1)	-	-	-	-
Other animal productions (=1)	**-1,389**	**-0.398**	**0,623**	**0,026**
Cereals (=1)	0,089	0.035	0,406	0,826
Other crop productions (=1)	**-1,150**	**-0.370**	**0,533**	**0,031**
Land quality (Degradation=1)	**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
Pseudo R^2	0.209			

Notes: Values in bold (italic) denote significance at 5% (10%) levels (two-tailed test). The marginal effect is calculated at the discrete change of binary variables form zero to one.

Table A4. Non-parametric Probit estimation of factors affecting adherence in an AE advisory club

Variables	Coefficient	Marginal effect	Standard error	Prob.>chi-square
Age				
(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**	**-0.420**	**0.102**	**0.009**
[65;)	**-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 (years)	**0.038**	**0.013**	**0.006**	**0.026**
Residence (Farm=1)	0.521	0.161	0.099	0.165
Information (Use RAP=1)	-0.209	-0.073	0.083	0.387
Environmental sensitivity (=1)	0.454	0.167	0.118	0.140
Revenue (TGR) in $				
[0; 50000[	*-0.793*	*-0.239*	*0.103*	*0.057*
[50000; 100000[	-0.002	-0.001	0.151	0.997
[100000; 250000[				
[250000; 500000[	-0.225	-0.076	0.112	0.513
[500000;)	0.434	0.160	0.142	0.240
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				
Bovine production (=1)	-0.682	-0.199	0.112	0.161
Milk production (=1)	-0.463	-0.155	0.115	0.197
Hog production (=1)				
Other animal productions (=1)	**-1.803**	**-0.328**	**0.051**	**0.026**
Cereals (=1)	-0.282	-0.093	0.126	0.487
Other crop productions (=1)	**-1.126**	**-0.284**	**0.083**	**0.031**
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	**-0.054**	**-0.019**	**0.007**	**0.008**
Production losses	**0.753**	**0.258**	**0.084**	**0.003**
Pseudo R^2	0.253			

Notes: Values in bold (italic) denote significance at 5% (10%) levels (two-tailed test). The marginal effect is calculated at the discrete change of binary variables form zero to one.