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# Which factors drive farmers' adoption and continuation of specific climate change mitigation schemes?

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## 1. Introduction and policy context

Due to its characteristics, agriculture largely suffer from climate change (Cook et al., 2016), but it can also fuel it. For instance, carbon-rich agricultural soils may release GHGs in the atmosphere if not properly manged (Bennetzen et al., 2016; Hutchinson et al., 2007). Thus, innovative practices can be introduced to help farms maintain their productivity while increasing climate change mitigation and resilience. These climate-smart agriculture (CSA) practices include water-saving innovation systems; the reduction of the use of nitrogen fertilizers; conservation tillage to reduce GHGs emissions (FAO, 2010). In the EU, Rural Development Programmes (RDPs) of the CAP encompass them (European Commission, 2009). For instance, the RDP of the Veneto Region (Italy) supports specific CSA practices by means of some agri-environmental schemes (AESs).

Despite their benefits at societal levels, CSA practices may be hard to be adopted by those farmers who do not fully perceive the risks of climate change (Lowe et al., 2006) or who are technically unprepared to implement them. Thus, some studies have recently focused on the analysis of the factors driving farmer's decisions to adopt CSA practices (Deressa et al., 2009). However, most of them focus on Africa and Asia, and on soil- and water- related technologies (Brandt et al, 2017; Makate et al., 2019; Khatri-Chhetri et al, 2017). Conversely, just a few works have addressed their adoption in the EU (Long et al, 2016).

To fill this knowledge gap, this work analyses the drivers explaining both the adoption and the continuation of CSA practices in Veneto (Italy). Firstly, adoption is analysed using official data about the number of adopters per municipality. The data aggregated at this territorial scale makes possible to investigate the role of some non-financial factors, such as: farming systems and environmental features at the local level; technology accessibility; the policy design; diffusion patterns driven by social pressure, as well as the role of neighbouring peers. Secondly, the continuation choice with the adopted scheme, after the first five years, is analysed focusing on the role played by farmers' motivational and attitudinal characteristics, as well as by social pressures on this decision. To this end, individual-level data are needed: here, a sample field survey of AES adopters has been carried out.

For both analyses, this paper uses the Veneto Region as a case study area. Since the 1980s, the area of the Po Valley of Veneto Region has represented a priority target area for regulating the use of fertilizers, which caused eutrophication problems in the Venice lagoon (Collavini et al., 2005). To this end, CSA practices may represent a key objective for the regional RDP. In particular, three practices: i) No-tillage (NT), i.e. adopting sod seeding techniques to reduce the use of fertilizers, maintain soil fertility and moisture, and increase the stock of soil organic $CO_2$; ii) Fertilizer reduction (FR), i.e. the reduction by 30% of nitrogen fertilisers on annual crops and their optimised distribution. Unlike NT, FR requires less financial investments in technology but greater technical knowledge about fertilizers; iii) Water and fertilizer reduction (WFR), i.e. FR coupled with a 25% reduction of irrigation volumes. Unlike FR, WFR is limited to the two water-demanding crops: maize and tobacco.

These schemes were first introduced in the 2007-2014 RDP, and then confirmed in the 2015-2020 period. Each AES adopter signed a five-year contract, at the end of which he/she could decide whether to continue or to leave it. However, according to official data, adopters in the 2007-2014 period were a small number, with a scattered distribution across the region: 72 for NT (2,486 ha), 645 for FR (15,102 ha), and 275 for WFR (7,077 ha)[1].

## 2. The empirical strategy

To assess the drivers of AES adoption and continuation, a twofold strategy is adopted. With regard to their adoption, a municipality-level analysis is performed (463 eligible municipalities) using the AES beneficiaries' data available from the official regional datasets. For each of the three schemes, the dependent variable is a count variable: i.e., the number of farmers having adopted AESs in each municipality. Thus a Poisson regression is adopted and specified as: $P(Y_i = y_i) = \frac{e^{-\lambda_i}\lambda^{y_i}}{y_i!}$, for $y_i = 0, 1, 2, ...$, where λ > 0, and the natural log link is defined as: $\lambda_i = \boldsymbol{\beta}'\boldsymbol{x_i}$. For each scheme, two models are estimated. The former (M1) is just an a-spatial Poisson model, encompassing farming factors (share of large agricultural holdings, share of arable crops), technology accessibility factors (irrigation systems and distance to the closest NT contractor), environmental factors (average rainfall and soil type), policy factors (presence of a Nitrate Vulnerable Zone and urban-rural classification of municipality), and spatial diffusion factors (proxied by the share of other AESs beneficiaries in the 2000-2006 RDP) and controlling for the size of the UAA at municipality level. The latter (M2) includes two spatially lagged covariates, accounting for the possible spatial knock-on effects among neighbouring municipalities referring to the spatial diffusion pattern and the size control and the (spatial Poisson model). Spatially lagged covariates are computed according to a row-standardised spatial weights matrix, based on a first-order queen contiguity matrix (Anselin, 1988).

With regard to AES continuation, its underlying drivers are assessed at the individual farmers' scale, thanks to a direct in-depth field survey and selecting a random sample of 66 beneficiaries. The farmer's decision to continue or to drop out the AES is estimated through a single logit model: $\ln\left(\frac{P_i}{1-P_i}\right) = \boldsymbol{x^{i}}'\boldsymbol{\beta} + \varepsilon_i$ where $\boldsymbol{x^i}$ considers the effect of covariates on the log-odds of the leave or continue occurrence for farm *i* under the 2015-2020 RDP. In this case, all the schemes are jointly considered. In line with the theory of reasoned action and planned behaviour (Ajzen and Fishbein, 2005), the covariates used in the model cover farm factors (size and income), farmers' factors (education of the farmer, number of children, full-time, attitude of the farmers towards the environment, risk, and innovation), farmer's perception of peers' judgement.

## 3. Results

As far as AES adoption is concerned (Table 1), the estimated coefficients from the Poisson regressions suggest that the factors under consideration play a different role when each scheme is considered. In M1, the number of NT adopters by municipality is positively affected by the

[1] Figures exclude 70 tobacco-specialised farms, whose behaviour is uninformative for this research.

farming factors, such as a larger share of larger size farms (Ward et al., 2018), and a municipality specialisation in arable crops (due to the specific policy setting). Unlike the distance to the closest contractor with sod seeders and average rainfall, soil type matters: NT adopters are more abundant in municipalities with clayey soils (Giller et al., 2009). As far as policy factors are concerned, number of NT adopters is larger in municipalities classified as NVZs. For this scheme, spatial diffusion patterns are not significant: actually, imitation effects are hindered by the fact that this scheme is particularly demanding in terms of technical requirements. In M2 for NT adopters, none of the spatially lagged covariates are significant.

With regard to both FR and WFR models, in addition to the policy design constraints (i.e. arable crops), also technology accessibility, and especially irrigation issues, represent a major driver. In particular, poor-efficiency irrigation systems and the lack of constraints in the use of water tend to negatively affect the number of FR/WFR adopters. Also, rainfall, as an environmental factor, plays a negative effect (Khatri-Chhetri et al., 2017). As for NT, NVZ positively affects the adoption of FR/WFR schemes. Past experience in other AESs positively affects the number of adopters for both schemes. Moreover, when considering M2, also past AES experiences of farmers in neighbouring municipalities have a positive effect on the number of adopters, suggesting the existence of a social learning process (Moschitz et al., 2015).

**Table 1 – Adoption models: covariates (data at municipality level), sign and significance**

| | | NT | | FR | | WFR | |
|---|---|---|---|---|---|---|---|
| **Name** | **Meaning** | **M1** | **M2** | **M1** | **M2** | **M1** | **M2** |
| Constant | | - ** | - ** | n.s. | n.s. | - ** | - *** |
| *Farming factors* | | | | | | | |
| Holdings_30 ha | % agric. holdings with 30+ ha. of UAA | + * | n.s. | | | | |
| Arable | % of arable crops area | + ** | + ** | + *** | + *** | + *** | + *** |
| *Technology accessibility factors* | | | | | | | |
| Irrigable | % irrigable area | - *** | - ** | n.s. | n.s. | n.s. | n.s. |
| Irrig_poor | % surface irrigation area | | | - *** | - *** | - *** | - *** |
| Irrig_medium | % sprinkler irrigation systems area | | | - * | n.s. | n.s. | n.s. |
| Irrig_no_constr | % areas facing no water constraints | | | n.s. | n.s. | - ** | +** |
| Dist | km to the closest (in 10km) | n.s. | n.s. | | | | |
| *Environmental factors* | | | | | | | |
| Rainfall | Rainfall (avg. of years 2001-2010) | n.s. | n.s. | - *** | - *** | - *** | - *** |
| Soil type | Prevailing soil (baseline: Sands) | | | | | | |
| | Clay | + *** | + *** | | | | |
| | Other | n.s. | n.s. | | | | |
| *Policy factors* | | | | | | | |
| NVZs | Municipality falls into a Nitrate Vulnerable Zone area (baseline: No) | | | | | | |
| | Yes | + ** | + * | + *** | + *** | + *** | + *** |
| Rural | Classification of municipality as urban or rural (baseline: Urban) | | | | | | |
| | Rural | - ** | - ** | n.s. | n.s. | + *** | + *** |
| *Spatial diffusion patterns* | | | | | | | |
| Benef_00_06 | % of AESs beneficiaries in 2000-2006 | n.s. | n.s. | + *** | n.s. | + *** | + * |
| Benef_00_06_lag | Spatial lag of Benef_00_06 | | n.s. | | + ** | | + *** |
| *Size control* | | | | | | | |
| UAA_municip | Square km of UAA at municipality level | + *** | + *** | + *** | + *** | + *** | + *** |
| UAA_municip_lag | Spatial lag UAA_municip | | n.s. | | n.s. | | + * |

Notes: *** statistically significant 1%, ** statistically significant 5%, * statistically significant 10%, n.s.: non-statistically significant
When overdispersion occurs, a quasi-Poisson model has been estimated.

As far as AES continuation is concerned (Table 2), the results of the binomial logit model – which has been estimated using a sample of 66 beneficiaries in the 2007-2014 programming period – suggest that farmers' attitudes towards risk and innovation have a positive effect on their continuation in the practices (Haghjou et al., 2014). Moreover, off-farm income sources (i.e., the existence of a sort of safety net for the farmer) prompt their continuation. The bequest value given by farmers to their farm (proxied by the number of children) positively affects continuation (Lynch and Lovell, 2003) as well as their active presence in the farm (full time employment). With regard to social factors, the appreciation shown by neighbouring farmers on farmers' decisions to continue with CSA practices shows a positive effect (Läpple, 2010).

**Table 2 - Continuation models: covariates (data at farm level), sign and significance**

| Name | Meaning | Model |
|---|---|---|
| Constant | | - *** |
| *Farm factors* | | |
| F_Size | Farm UAA (hectares) | n.s. |
| F_Income | Household income from farming (%) | - *** |
| *Farmer's factors* | | |
| *Socio-demographic characteristics* | | |
| Year_Edu | Number of years of education of the farmer | n.s. |
| Child | Number of children | + *** |
| Full_Time | Full-time farmer (baseline: No) | |
| | Yes | + *** |
| *Attitudes and motivations* | | |
| Envir_Att | Importance to adopt environmentally friendly practices | n.s. |
| Risk_Att | Risk-orientation of the farmer | + ** |
| Inno_Att | Innovation behaviour of the farmer (baseline: No) | |
| | Farmer immediately adopting innovation | + ** |
| *Social factors* | | |
| Soc_Pressure | Perception of peers' judgement towards AESs participation (baseline: otherwise) | |
| | Positive | + ** |

Notes: *** statistically significant 1%, ** statistically significant 5%, * statistically significant 10%, n.s.: non-statistically significant

## 4. Discussion and conclusions

Despite the urgency of adopting and continuing sustainable climate change mitigation behaviours, only a limited number of farmers have so far adopted CSA practices. In particular, financial support – through specific policy measures – might be not enough for steering full and effective implementation. Indeed, farmers' behaviours are also driven by their perception and knowledge of environmental issues, as well as social pressure and spatial diffusion processes. This paper has shed new light on these background factors affect farmers' decisions in the Veneto region, thus contributing to the scarce literature on these topics across developed countries.

It emerges that adoption is steered by the policy design itself. However, targeting is just part of the story and it needs to be tailored actions, encompassing structural and technical constraints, too (e.g. the type of water usage for FR/WFR adoption). Moreover, when considering social learning, its effects are more heterogenous: it plays a role in the FR/WFR adoption but not in the NT adoption, which requires specific technical skills and investments in machinery.

The analysis on CSA continuation has proved the role of farmers' motivations and attitudes, and in particular of risk-orientation, innovation attitudes and higher bequest values attached to the farm. Moreover, also social pressure by peers is crucial. Thus, post-2020 CAP should capitalise on this result by nudging farmers to stimulate their neighbours' acceptance of CSA practices.

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