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Factors affecting investments in environmental assets by agricultural machinery cooperatives (CUMAs): Evidence from France

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Abstract

Although cooperatives are major actors in the transformation of agricultural systems, very little attention has been paid to the conditions that facilitate or hinder their involvement in the sustainable transition. Drawing on theoretical and empirical approaches, we analyze the effect of social capital on the propensity and proportion of investment in environmental assets in the case of agricultural machinery cooperatives (CUMAs) in France. The number of producers within their CUMA is used as a proxy of the bonding social capital and the CUMA's relationships with external organizations as a proxy of the bridging social capital. Our results show a nonmonotonic relationship between the proxies of social capital and investment in environmental assets by CUMAs. However, the effect differs depending on the subdimension of social capital considered. Interestingly, our results show that the effect of social capital within CUMAs remains even when the cooperatives carry out investment renewals that involve less risk for members.

KEYWORDS

environmental assets, fractional model, social capital

JEL CLASSIFICATION

L31, Q16, C35

1 | INTRODUCTION

Agricultural cooperatives have been portrayed as key players in the transformation of producers' practices. Indeed, empirical studies show that membership in a cooperative has a positive impact on the probability of making a pro-environmental investment (Ma et al., 2018). Sim-

ilarly, by providing inputs and technical assistance to their members, cooperatives may advance their members' practices towards environmentally friendly practices (Candemir et al., 2021). Although research highlights the role of cooperatives in transforming agricultural practices, there is little focus on the internal and external factors that help or hinder their shift to agroecology (Bijman & Höhler,

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2023). The objective of this article is therefore to provide insight by identifying the determinants of investments in environmental assets within agricultural machinery cooperatives (CUMAs) in France with a focus on social capital. Following Bostian et al. (2016), we define environmental investment as all expenditures on agricultural assets that will likely have a positive effect on the environment. CUMAs' environmental investments are multifaceted, targeting various aspects of sustainable agriculture. These include initiatives to reduce the use of phytosanitary products by adopting equipment that facilitates mechanical weeding. They also invest in machinery to enhance farms' protein and fodder self-sufficiency, such as belt swathers, and equipment like direct seeding drills to improve nitrogen autonomy (NA). Additionally, CUMAs prioritize tools such as power harrows to promote soil health and fertility (SHF), as well as slurry tankers to help improve air quality. Recognizing the importance of reducing dependence on fossil fuels, CUMAs also focus on on-farm energy production to support a transition toward renewable energy sources. This study focuses on the effect of social capital on investment propensity and proportion of investments in environmental assets. "Social capital refers to features of social organization, such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefit" (Putnam, 1993, p. 1). Our interest in social capital arises from the fact that all collective action requires a minimum of social capital (Valentinov, 2004). Furthermore, by simultaneously pursuing environmental and economic objectives that may be contradictory, cooperatives expose themselves to tensions (Plateau et al., 2021).

Social capital is often broken down into three dimensions, namely structural, cognitive and relational (Nahapiet & Ghoshal, 1998). The structural dimension pertains to social networks that facilitate cooperation, whereas the relational dimension concerns interpersonal value, including trust and reciprocity. Finally, the cognitive dimension encompasses the shared vision that facilitates the understanding of mutual goals. This study focuses on the structural dimension, which serves as a resource for the creation of the other two dimensions (Deng et al., 2021). We are interested in bonding and bridging social capital, which are subdimensions of structural social capital (Ruben & Heras, 2012). Bonding social capital characterizes the relationships that producers establish within their cooperatives. It also supports specific reciprocity and mobilizes solidarity. Bridging social capital, in contrast, defines the cooperative's relationships with external organizations (Putnam, 2000). Bridging social capital encourages the establishment of links between the cooperative and external assets, while facilitating information diffusion.

This study assumes that social capital may positively affect investment propensity and proportion of invest-

ments in environmental assets. However, social capital also has dark sides (Villena et al., 2011). Excessive bonding social capital can lead to an overly closed network that may hinder cooperatives from adapting to opportunities for external changes (Putnam, 2000; Uzzi, 2018). Similarly, by focusing solely on interactions with external networks, cooperative members could weaken internal interactions, thereby undermining collective action (Ruben & Heras, 2012). CUMAs differ from other agricultural cooperatives in several ways. First, these cooperatives are based on horizontal coordination in which members pool agricultural machinery that can have a direct impact on the environment (Cornée et al., 2024). Second, CUMAs are mainly based on relational governance in which social mechanisms are prioritized (Diakité et al., 2022). These two characteristics make CUMAs very representative of cooperatives that can set environmental objectives while depending on social capital.

The contributions of this study are theoretical and empirical. Theoretically, we extend Fulton and Giannakas' (2012) model of investment by incorporating social capital in a single objective function where CUMAs pursue both economic and environmental objectives. This simple model allows us to highlight the effect of social capital on environmental investment propensity and proportion. Empirically, we analyze the determinants of investment in environmental assets. Studies have analyzed the determinants of the adoption of environmental practices at the producer level (Lee & McCann, 2019; Verhofstadt & Maertens, 2014) and the impact of the cooperative on sustainable investment (Ma et al., 2018). However, to our knowledge, scant studies (Ferrer et al., 2024) have linked investment propensity and proportion of investment in environmental assets at the cooperative level. We use the conditional mixed process framework (Roodman, 2011), which allows us to estimate a system of simultaneous equations associated with a binary selection equation to resolve a potential selection problem. This selection could arise from the fact that after controlling for observable characteristics of CUMAs, unobservable characteristics (e.g., environmental sensitivity) could influence both the propensity and the proportion of investment in environmental assets. Given that the interactions between members and the values of solidarity and reciprocity are stronger among smaller CUMAs (Diakité et al., 2022), we measure bonding social capital by considering the size of the CUMA, whereas the diversity of patrons characterizes the CUMA's external network (Borgatti et al., 1998; Ruben & Heras, 2012). Our results show that social capital affects the environmental investments of CUMAs. Increasing the size of the CUMA above a certain threshold can negatively affect the probability of investing in environmental assets. On the other hand, the relationship between diversity of

patrons and the proportion of environmental investment is negative. As a result, further strengthening the CUMA's relations with external organizations (proxy of bridging social capital) tends to decrease the proportion of investment in environmental assets. Interestingly, our results also show that the effect of the size of the CUMA remains when these cooperatives carry out investment renewals.

The remainder of this article is organized as follows. Section 2 presents the theoretical framework used to study the research question and derives some implications to be tested empirically. In Section 3, the data are presented and discussed. In Section 4, we present the empirical framework. Section 5 presents and discusses the empirical results. Robustness tests are provided in Sections 6 and 7. The last section concludes the paper and puts forth policy recommendations and suggestions for future research.

2 | A SIMPLE THEORETICAL MODEL OF COOPERATIVE INVESTMENT AND SOCIAL CAPITAL

There is no consensus among previous works regarding the objective function of agricultural cooperatives. The discrepancies found in the literature can be explained by the way in which authors conceptualized the cooperative. For example, cooperatives are interpreted as vertically integrated entities aiming to maximize members' profits, an independent firms aiming to maximize its profit, or a coalition in which all members maximize their profit (see Soboh et al., 2009). Recent theory has moved away from these rigid conceptualizations and instead approached the cooperative as a complex organization with multiple, competing or complementary objectives (Cook & Grashuis, 2018). In this article, the CUMA is conceptualized as an organization with both nonenvironmental and environmental objectives. CUMAs are farm machinery service cooperatives (Herbel et al., 2015).

Nonenvironmental objectives include reducing members' machinery costs by choosing appropriate levels of investment (Harris & Fulton, 2000). Environmental commitment may involve the choice of agricultural machinery that is costly but that generates positive environmental externalities. Moreover, since the operation of these cooperatives is primarily based on informal governance mechanisms (Diakit  et al., 2022), social capital is a key parameter in the objective function of CUMAs.

2.1 | CUMA objective function

Let \mathfrak{R}_t denote the objective function of the CUMA, which represents an aggregation of the objective functions of the individual members (Szymańska & Jegers, 2016), Ω_t the

aggregated economic surplus of the members, k_t the social capital, S_t the environmental function of the CUMAs and $t = 1, \dots, T$ time. The CUMA optimization program is:

$$\text{Maximise } \mathfrak{R}_t(\Omega_t, k_t, S_t) \quad (1)$$

We assume that the marginal effect of social capital is:

$$\partial \mathfrak{R}_t / \partial k_t \leq 0 \quad (2)$$

Thus, social capital (k_t) improves not only the ability of sharing groups to sustain themselves over time, but also members' ability to initiate new investment projects owing to mutual understanding and solidarity. Conversely, in the absence of formal governance mechanisms, social capital can also foster the development of opportunistic behavior that tends to lower CUMA member satisfaction (Diakit  et al., 2022). We also assume that the CUMA's objective function is greater than zero when the environmental function is equal to zero ($\mathfrak{R}_t^0(\dots, 0) > 0$). As a result, it is beneficial for a producer to use a CUMA even if it is not environmentally committed. Furthermore, the CUMA makes an environmental commitment if:

$$\mathfrak{R}_t(\dots, S_t) > \mathfrak{R}_t^0(\dots, 0) > 0 \quad (3)$$

2.1.1 | CUMA social capital function (k)

As mentioned in the introduction, social capital (k) can be structural, cognitive, and relational. Within CUMAs, social interactions tend to depend on investments made. For example, Szymańska and Jegers (2016) demonstrated that, in some cases, an agency problem could arise when members' and managers' objectives do not fully overlap. Managers must find a balance between several objectives (e.g., profit and social) that could be linked to CUMAs' total investments, which influence interaction between the members. Therefore, social interaction within the CUMA is a function of investment (I) We also assume that other factors can determine social capital including the technical orientation of the members, the age of the CUMA and, more generally, geographical context (Lucas, 2018). Consequently, k is defined as:

$$k_t = \tilde{k}_t(\theta_t(\cdot), I_t, \xi) \quad (4)$$

where \tilde{k} is a function of θ , a positive, nondecreasing, weighted aggregator¹ of subdimensions of social capital. I represents the total investments of the CUMA and

¹ Beugelsdijk and Smulders (2009) consider a weighted non-linear combinations of structural social capital sub-dimensions, Belay and Wondimu (2024) use a weighted linear combination.

ξ the vector of other factors including the age of the CUMA and, more generally, geographical context. We assume that $\partial k/\partial\theta \equiv \partial \tilde{k}/\partial\theta > 0$, $\partial k/\partial I \equiv \partial \tilde{k}/\partial I \leq 0$ and $\partial k/\partial \xi \equiv \partial \tilde{k}/\partial \xi \leq 0$.

2.1.2 | CUMA environmental function (S_t)

Following Szymańska and Jegers (2016), let us consider that S_t represents the environmental function of the CUMA. S_t depends on the quality of the environment denoted by V_t and ξ_s denotes a vector of the characteristics of the CUMA's environmental sensitivity. The environmental function is therefore defined as:

$$S_t = \tilde{S}_t(V_t, \xi_s) \tag{5}$$

We also assume that the quality of the environment is a function of environmental degradation defined as (Gebremedhin & Swinton, 2003):

$$V_t = V_0 \left(1 - e \left(\sum_{i=1}^T \alpha_{t-1} I_{t-1}, \xi_p \right) \right) \tag{6}$$

Where V_0 represents an initial value of the environment and e is an environmental degradation function. $\alpha \in [0, 1]$ with $\alpha = 1$ if the total amount of the investment is made in environmental assets ($I^E \equiv \alpha I$). By assumption, environmental degradation decreases with the levels of investments in environmental assets ($e'(I^E) < 0$), environmental quality is an increasing function of environmental investment ($V'(I^E) > 0$) and a decreasing function of degradation ($V'(e) < 0$). As the state of the environment can be the result of complex interactions between different actors, the quality of the environment is also a function of public policies. Public decision-makers may influence the quality of the environment by granting subsidies to cooperatives when they make investments in environmental assets. For simplification purposes, we hold the public policies variables (ξ_p) constant.

2.1.3 | Aggregated economic surplus (Ω)

Let us consider a demand function for a service x provided by the CUMA such that (Fulton & Giannakas, 2012):

$$x = r(k) p^{-\eta} \tag{7}$$

where r is a demand shifter, p the price of the service, and η the elasticity of demand. We assume that social capital positively affects demand ($r'(k) > 0$) where k , as defined

above, represents social capital in the cooperative. The rationale for this relationship is that social capital builds mutual trust between members who are willing to invest in collective activities (Diakité et al., 2022).

We assume that the CUMA maximizes the economic surplus of its members by pricing the service at its marginal cost of production m_t . Members can access the machinery service using CUMA at price m_t or using alternative providers at price p_{a_t} . If a member prefers the services offered by the cooperative, Fulton and Giannakas (2012) determined that its surplus (S_t) for a period t is:

$$s_t = \int_m^{p_a} dp^{-\eta} dp = \frac{r}{\eta - 1} \left[\frac{1}{m_t^{\eta-1}} - \frac{1}{p_{a_t}^{\eta-1}} \right] \tag{8}$$

If using the services offered by the CUMA, following Fulton and Giannakas (2012), the net economic surplus Ω_t of the members on a time horizon of T is as follows:

$$E(\Omega_T) = \sum_t^T \delta^t \left(\left[\left(r(k_t)(\eta - 1)^{-1} \right) \left[(m_{t-1}^{\eta-1})^{-1} - (p_{a_{t-1}}^{\eta-1})^{-1} \right] \right] - \bar{w}_{I_{t-1}} \alpha_{t-1} I_{t-1} - (1 - \alpha_{t-1}) w_{I_{t-1}} I_{t-1} \right) \tag{9}$$

Where δ represents a discount factor, w_I is the cost of the investment, \bar{w}_I is the cost of the investment when it is environmental, and the other parameters are as defined above. Equation (9) determines the CUMA's net surplus, that is, the surplus minus the cost of the investment made. The first part of the equation represents the surplus as indicated in Equation (8). The second and third parts of the equation capture the cost of the investment. If alpha is equal to 1, the CUMA invests in environmental assets exclusively. As a result, the third part of the equation vanishes. Similarly, if alpha is between 0 and 1, the CUMA invests in both environmental and nonenvironmental assets.

2.2 | Theoretical implications of the model

The CUMA maximizes its objective function, which depends on its net economic surplus (Ω_t), the social capital (k_t) and an environmental function (S_t) as defined above. The CUMA maximizes the following program:

Maximize $\mathfrak{R}(\Omega_t, k_t, S_t)$
Subject to

$$E(\Omega_T) = \sum_t^T \delta^t \left(\left[\left(r(k_t)(\eta - 1)^{-1} \right) \left[(m_{t-1}^{\eta-1})^{-1} - (p_{a_{t-1}}^{\eta-1})^{-1} \right] \right] - \bar{w}_{I_{t-1}} \alpha_{t-1} I_{t-1} - (1 - \alpha_{t-1}) w_{I_{t-1}} I_{t-1} \right) \tag{10}$$

$$k_t = \tilde{k}_t(\theta_t(\cdot), I_t, \xi) \quad (11)$$

$$S_t = \tilde{S}_t(V_t, \xi_s) \quad (12)$$

$$V_t = V_0 \left(1 - e \left(\sum_{i=1}^t \alpha_{i-1} I_{i-1} \right) \right) \quad (13)$$

Following Gebremedhin and Swinton (2003), substituting (10)–(13) into the utility function yields the unconstrained, undiscounted Hamiltonian:

$$H = \left[\mathfrak{R} \left\{ \left[\begin{array}{l} E \left\{ \sum_t \delta^t \left[(r(k_t)(\eta-1)^{-1}) \left[(m_{t-1}^{\eta-1})^{-1} - (p_{\alpha_{t-1}}^{\eta-1})^{-1} \right] \right] \right\} \right. \right. \\ \left. \left. \begin{array}{l} -\alpha_{t-1} \bar{w}_{I_{t-1}} I_{t-1} - (1 - \alpha_{t-1}) w_{I_{t-1}} I_{t-1}, \\ \tilde{k}_t(\theta_t, I_t, \xi), S_t \left(V_0 \left(1 - e \left(\sum_{i=1}^t \alpha_{i-1} I_{i-1} \right) \right), \xi_s \right) \end{array} \right. \right. \right] \right\} \right] \quad (14)$$

Differentiating Equation (14) with respect to the choice variable I gives the following expression:

$$\begin{aligned} \frac{\partial H}{\partial I} = & \underbrace{\frac{\partial \mathfrak{R}}{\partial \Omega} \frac{\partial r}{\partial k} \frac{\partial k}{\partial I}}_A + \underbrace{\frac{\partial \mathfrak{R}}{\partial k} \frac{\partial k}{\partial I}}_B + \underbrace{\frac{\partial \mathfrak{R}}{\partial S} \frac{\partial S}{\partial V} \frac{\partial V}{\partial e} \frac{\partial e}{\partial I}}_C (\alpha_{t-1}) \\ & - \underbrace{\sum_{i=1}^T \delta^i \bar{w}_{I_{i-1}} (\alpha_{i-1})}_{D_1} - \underbrace{\sum_{i=1}^T \delta^i w_{I_{i-1}} (1 - \alpha_{i-1})}_{D_2} \quad (15) \\ & \underbrace{\hspace{10em}}_D \end{aligned}$$

Equation (15) indicates that an optimal investment must take into account the economic surplus of the CUMA (A in Equation 15) and its noneconomic objectives.

Indeed, optimality of investment implies considering the impact of the investment on social capital (B in Equation 15) as well as on the gain from improving the environment (C in Equation 15). To summarize, Equation 15 shows that the optimal investment (environmental or nonenvironmental) is realized when the marginal gain from the investment (A + B + C) is equal to the marginal cost of the investment (D). Let us examine the corner solutions to analyze the implications of the model. If the fraction of environmental investment equals zero ($\alpha = 0$), the terms C and D_1 vanish. We have optimality in which the marginal gain from the investment (economic surplus and social capital) is equal to its marginal cost. The marginal effect of

the investment on social capital will determine whether it is optimal to continue investments because $\partial k / \partial I$ can be negative or positive. Indeed, the expansion of cooperative business volumes can, at a certain level of investment, lead to a degeneration of social capital. The rationale is that massive investments may require hierarchical governance to the detriment of relational governance (Szymańska & Jegers, 2016; Valentinov, 2004). Similarly, certain types of investment may encourage interaction between CUMA member producers (Lucas, 2018). If the fraction of environmental investment equals 1 ($\alpha = 1$), all investments are in environmental assets and the optimal investment solution takes into account the environmental marginal gain of that investment (C in Equation 15) but also its marginal cost (D_1 in Equation 15). Finally, Equation (15) states that the probability of investing in an environmental asset or its extensive margin is superior to zero ($\alpha > 0$), if and only if:

$$A + B - D_2 < A + B + \tilde{C} - D_1 - D_2 \quad (16)$$

With $\tilde{C} \equiv C\alpha$.

The left-hand side of inequality (16) represents the marginal gain when the CUMA makes zero investment in environmental assets. The right-hand side represents the marginal gain when an environmental investment is made. Intuitively, expression (16) suggests that the propensity of investing in environmental assets increases when the marginal gains associated with these investments are greater than the marginal gains associated with nonenvironmental investments. For simplification purpose, assuming that the proportion of environmental investment (α) and the discount factor (δ) are constant over time, the fraction of investment devoted to environmental assets (intensity of investment in environmental assets or its intensive margin) is as follows:

$$\alpha = \frac{\mathbf{w}_I - A - B}{C - \bar{\mathbf{w}}_I + \mathbf{w}_I} \quad (17)$$

With $\bar{\mathbf{w}}_I = T\delta\bar{w}_I$ and $\mathbf{w}_I = T\delta w_I$.

Equation (17) determines the optimal fraction of investment in environmental equipment. Since we assume that α and δ are constant over time, $\bar{\mathbf{w}}_I$ and \mathbf{w}_I represent the total cost of investment in environmental and nonenvironmental assets respectively over the time horizon T. In Equations (16) and (17) the margins of investment in environmental assets are a function of economic variables (cost of investment) and social capital (k). CUMAFactors, (ξ) including age and, more generally, geographical context and factors related to the environment (ξ_s) including technical orientation of the members, also affect the margins. w_I is the cost of the investment, and \bar{w}_I

is the cost of the investment when it is environmental. The above model suggests that social capital is important to understand investments in environmental assets at the extensive margin (i.e., likelihood of investment) and intensive margin (i.e., environmental investment proportion).

2.3 | Bonding and bridging social capital measurement implications

As stated in the Introduction, this study focuses on the structural dimension of social capital, with a particular emphasis on its subdimensions: bonding and bridging social capital (Herbel et al., 2015; Ruben & Heras, 2012). To measure these subdimensions, we employ two specific proxies. The first one is the size of the CUMA, measured in number of members (Cazzuffi, 2012; Grashuis, 2020) as a proxy for bonding social capital. However, the effect of the size on social capital can be positive or negative.

Larger cooperatives benefit from economies of scale, achieving lower average investment costs. However, they tend to lose social capital as they grow (Diakité et al., 2022; Nilsson et al., 2012). For bridging social capital, we consider the diversity of the external network as a proxy (Borgatti et al., 1998). As for the size, diversity could facilitate the exchange of resources between members. Conversely, it can also involve more heterogeneity within the cooperative, which can be detrimental for the members (Diakité et al., 2022; Grashuis & Cook, 2021). The nonmonotonic effect of these two proxies has implications for the hypotheses tested in the empirical section of the study. In Equation (4), we defined θ as a positive, non-decreasing, weighted aggregator subdimension of social capital. Considering the two subdimensions, Equation (4) becomes:

$$k_t = \tilde{k}_t (\theta_t (\theta_t^{bo}, \theta_t^{br}), I_t, \xi) \tag{18}$$

Where θ_t^{bo} and θ_t^{br} are our proxies of bonding and bridging social capital respectively. As mentioned before, we assume that $\partial k / \partial \theta \equiv \partial \tilde{k} / \partial \theta > 0$. However, the sign of $\partial \theta / \partial \theta^j$ is undetermined ($\partial \theta / \partial \theta^j \leq 0$) for any of our proxies of social capital. Let Λ be a vector of variables explaining the fraction of investment (α) and the probability of investing in environmental assets ($\alpha > 0$). From Equation (18), the marginal effect of a sub-dimension j of social capital can be written as:

$$\frac{\partial g(\alpha|\Lambda)}{\partial \theta^j} = \frac{\partial g(\alpha|\Lambda)}{\partial k} \frac{\partial k}{\partial \theta} \frac{\partial \theta}{\partial \theta^j} \tag{19}$$

Where $g(\alpha|\Lambda)$ is a known function. The right-hand side of Equation (19) captures the effect of social capital on the proportion of investments in environmental assets when a given sub-dimension varies. We assume that $g(\alpha|\Lambda)$ is a strictly increasing cumulative density function (Marbuah, 2019) of k and then, $\partial g(\alpha|\Lambda) / \partial k > 0$. Therefore, the sign of the marginal effect of a given sub-dimension is undetermined since $\partial k / \partial \theta > 0$ while $\partial \theta / \partial \theta^j \leq 0$. Similarly, the marginal effect of a sub-dimension j of social capital on the probability of an environmental investment can be written as:

$$\frac{\partial P(\alpha^* > 0|\Lambda)}{\partial \theta^j} = \frac{\partial P(\alpha^* > 0|\Lambda)}{\partial k} \frac{\partial k}{\partial \theta} \frac{\partial \theta}{\partial \theta^j} \tag{20}$$

Where $P(\alpha^* > 0|\Lambda)$ is a known function and α^* a latent variable. The right-hand side of Equation (20) captures the effect of social capital on the probability of investments in environmental assets when a given sub-dimension varies. As before, the marginal effect of a sub-dimension is determined. Therefore, based on the implications of our model and the literature, we test the following hypotheses:

H1. The effect of the size of the CUMA, as a proxy for bridging social capital, on both the probability (H1a) and proportion (H1b) of investments in environmental assets is nonmonotonic, following an inverted U-shape.

H2. The effect of external network diversity, as a proxy for bonding social capital, on both the probability (H2a) and proportion (H2b) of investments in environmental assets may be either positive or negative.

3 | DATA AND DESCRIPTIVE STATISTICS

Our data, provided by the national federation of CUMAs, concern financial and organizational characteristics of CUMAs and allow us to characterize the environmental issues associated with each type of environmental machinery. In total, we considered a sample of 2680 CUMAs for 2015. To capture information on the CUMA members, the sample was matched with the data provided by the National Department of Agricultural Statistics and Prospective Analysis in France (AGRESTE) and the National Institute of Statistics and Economic Studies (INSEE). We used the 2010 agricultural census data from AGRESTE.²

² We used agricultural census data for 2010, which is the closest to 2015.

TABLE 1 Descriptive statistics of main variables.

Variables	Mean	Standard deviation	Min	Max
Soil health and fertility (SHF)				
Investment in SHF (=1 if yes)	.288	.453	0	1
Value (Euros)	21,158	17,776	0	176,500
Nitrogen autonomy (NA)				
Investment in NA (=1 if yes)	.234	.423	0	1
Value (Euros)	43,981	34,146	0	347,330
Fodder and protein autonomy (FPA)				
Investment in FPA (=1 if yes)	.339	.474	0	1
Value (Euros)	31,492	26,782	0	184,000
Other investments (OTHER)				
Other investment (=1 if yes)	.088	.283	0	1
Value (Euros)	22,291	26,036	0	124,555
Total investment (Euros)	90,922.890	108,44.400	0	87,6174.8
Total environmental investment (Proportion)	.404	.397	0	1
Social capital proxies				
CUMA size (Size)	43.889	52.869	3	1297
External Network diversity (H)	.462	.231	0	1.082
Number of observations			2680	2680

Note: Other investments (OTHER): air quality, reduction of phytosanitary, fossil energy.

3.1 | Dependent variables

We distinguished two types of dependent variables: one in the selection equation that is binary (invest or not) and one designating the proportion of investment in environmental assets α_i . Six types of investment were identified, which are grouped into four investment variables. The first three are investments in equipment likely to improve SHF, those that promote NA on farms, and those that facilitate fodder and protein autonomy (FPA). Based on the classification of the French CUMA Federation, an example of an SHF investment is the use of a no-till drill that allows crops to be planted without massive soil degradation. NA investments include equipment such as manure spreader, while meadow harrows are likely to facilitate FPA. We created a fourth residual category (OTHER) to consider the three other types of investments, including improving air quality (i.e., fertilizer locator), reducing the use of plant protection products by promoting mechanical weeding, using a rotary hoe, for example, and reducing dependence on fossil fuels by favoring on-farm energy production. Equipment such as log splitters or woodchippers could improve the production of wood energy (Figure A1 Online appendix). As shown in Equation (17), the four investments are considered as a proportion of total investments made by the CUMA. Furthermore, there is heterogeneity in the type of investment made by the CUMAs in our sample (Table 1). Although investments in equipment likely to improve FPA are made by the largest number of CUMAs, the largest amounts are invested in NA.

3.2 | Proxies for social capital subdimensions

The size of the CUMA (proxy of bonding social capital) is measured in number of members. Because of the degree of heterogeneity of Size (Figure 1) this variable is log-transformed. Diversity of the external network (proxy of bridging social capital) is measured via the Shannon index H with:

$$H = - \sum (p_i) \times \ln(p_i) \quad (21)$$

Where p_i is the proportion of member patrons³ and non-member patrons. The larger the H, the greater the diversity of the CUMA's external network. As Table 1 shows, the index ranges from 0 for CUMAs with low diversity to 1.082 for CUMAs with maximum diversity.

3.3 | Control variables

Other variables are likely to influence propensity and proportion of investments in environmental assets. First, we

³ Non-member patrons include clients and contacts whose main difference is the level of relationship with the CUMA. In most cases, a contact has access to CUMA machinery via a member, while the client carries out transactions directly with the CUMA. Non-member patrons benefit from cooperative services (Bernard & Spielman, 2009). As a result, they could potentially encourage CUMAs to make specific expensive investments.

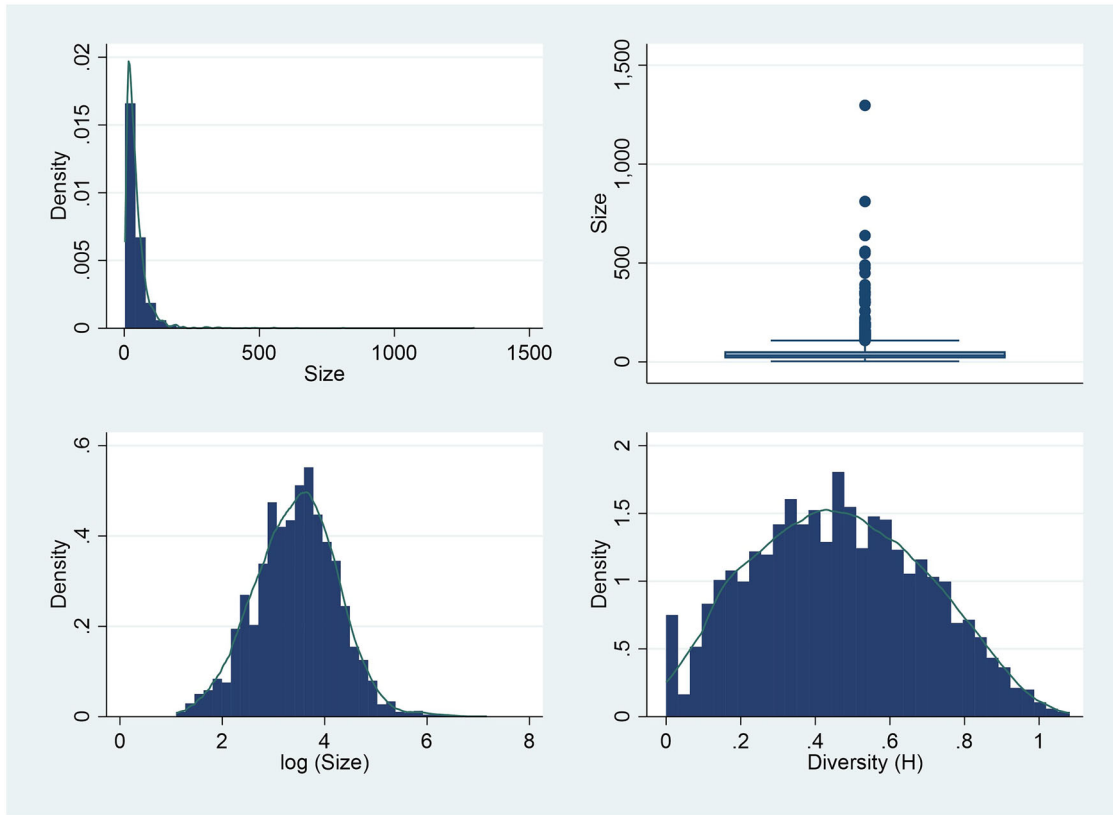


FIGURE 1 Distribution of the number of members in the CUMA and Diversity index.

include variables that capture the financial performance of the CUMA. These variables are the leverage, defined as the ratio of total debt to equity (Lerman & Parliament, 1991), the productivity ratio, a measure of overall efficiency in the use of assets within the cooperative (Parliament et al., 1990) and a cash flow ratio. Following Russo et al. (2000), we also introduced a proxy for the cost of debt (Table A1 in Appendix A). Finally, other variables relating to the CUMA (proportion of workers, age of the CUMA) were included in our model. We considered the age of the CUMA, which could be correlated with social capital. Accordingly, age could positively affect the propensity to invest in the environment because of its potential effect on social capital. To capture a potential nonlinearity effect, we integrated the square of the age, following other authors (Ma et al., 2018). Furthermore, the model considers the geographical context of the CUMA via different variables such as region of membership, population density, farm density, and proportion of usable agricultural land (Gebremedhin & Swinton, 2003; Hagos & Holden, 2006). We also controlled for the technical and economic orientation of members (Franken & Cook, 2015). Finally, we included subsidies received by the CUMA. Table A1 in Appendix A summarizes the control variables.

4 | EMPIRICAL FRAMEWORK

We are interested in the effect of social capital on the investment in environmental assets at the extensive and the intensive margins. We estimated a two-part model: the first part determines the effect of social capital on the CUMA's decision whether to invest in environmental assets, and the second part determines the variables that influence the proportion of investment in environmental assets conditional on a nonzero investment (Cameron & Trivedi, 2009).

4.1 | Estimation strategy

4.1.1 | Equations estimated

We estimated the following nonlinear equations:

$$\varpi_i = 1 [\gamma_1 \theta_i^{bo} + \gamma_2 \theta_i^{bo} \times \theta_i^{bo} + \gamma_3 \theta_i^{br} + \gamma_4 \theta_i^{br} \times \theta_i^{br} + w'_i \gamma + u_i > 0] \tag{22}$$

$$\alpha_i^* = \Phi [\beta_1 \theta_i^{bo} + \beta_2 \theta_i^{bo} \times \theta_i^{bo} + \beta_3 \theta_i^{br} + \beta_4 \theta_i^{br} \times \theta_i^{br} + h'_i \beta + \varepsilon_i] \tag{23}$$

$$\alpha_i = \alpha_i^* \varpi_i \quad (24)$$

with

$$\begin{pmatrix} u_i \\ \varepsilon_i \end{pmatrix} | x_i, w_i : N \left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right), i = 1, \dots, n$$

where ϖ is an indicator variable equal to one if the CUMA i has a nonzero investment ($\alpha > 0$) in environmental assets and zero otherwise; θ^j is a sub-dimension of social capital; w is a vector of control variables including ξ , ξ_p and ξ_s as shown in the theoretical section; γ is a vector of unknown parameters to be estimated, and u is the error term; α_i^* , a latent variable; Φ is a normal standard cumulative distribution; h is a vector of control variables including ξ , ξ_p and ξ_s ; β is a vector of unknown parameters to be estimated and $\alpha \in [0, 1]$ represents the proportion of investment in environmental assets. Equation (22) defines an observed binary variable indicating whether a CUMA has a zero investment in environmental assets ($\varpi = 0$) or not ($\varpi = 1$). Equation (23) defines a latent dependent variable whose data generation is characterized by a fractional probit model. Finally, Equation (24) indicates the observed investment in environmental assets in our data. We introduced the square term of social capital variables to capture a nonlinearity effect on the probability and proportion of an environmental investment. CUMA chooses to make an environmental commitment if $\mathfrak{R}_i(\dots, S_i) > \mathfrak{R}_i^0(\dots, 0) > 0$ (see Equation 3). However, the CUMA's objective is unobservable. What is observed in the data are the CUMA's investment decision and the amount of investment.

We thus model the CUMA objective as an unobserved variable \mathfrak{R} such that (Greene, 2012):

$$\begin{aligned} \mathfrak{R} = & \gamma_1 \theta_i^{bo} + \gamma_2 \theta_i^{bo} \times \theta_i^{bo} + \gamma_3 \theta_i^{br} + \gamma_4 \theta_i^{br} \times \theta_i^{br} \\ & + w'_i \gamma + u_i + w'_i \gamma + u_i \end{aligned} \quad (25)$$

Where \mathfrak{R} is a latent variable indicating the difference between the utilities obtained by purchasing an environmental asset and not purchasing it. In addition, we only observe whether an investment in environmental assets is made or not. Therefore, we have that:

$$\begin{cases} \varpi_i = 1 & \text{if } \mathfrak{R} = \gamma_1 \theta_i^{bo} + \gamma_2 \theta_i^{bo} \times \theta_i^{bo} + \gamma_3 \theta_i^{br} \\ & + \gamma_4 \theta_i^{br} \times \theta_i^{br} + w'_i \gamma + u_i + w'_i \gamma + u_i > 0 \quad (26a) \\ \varpi_i = 0 & \text{if } \mathfrak{R} = \gamma_1 \theta_i^{bo} + \gamma_2 \theta_i^{bo} \times \theta_i^{bo} + \gamma_3 \theta_i^{br} \\ & + \gamma_4 \theta_i^{br} \times \theta_i^{br} + w'_i \gamma + u_i + w'_i \gamma + u_i \leq 0 \quad (26b) \end{cases}$$

(26)

where $\varpi_i = 0$ is a genuine zero, meaning that the CUMA has chosen not to make an investment in environmental assets. Equation (26a) shows that the CUMA will invest in environmental assets only if it derives greater benefit from doing so than if it does not invest in these assets. As for Equation (26b), it shows that the CUMA does not invest in environmental assets when the utility it derives from investing is less than or equal to the case where it does not invest in environmental assets. Furthermore, it is assumed that the error term has a standard normal distribution, implying the following:

$$\begin{aligned} \Pr(\varpi_i = 1 | k_i(\theta_i), w_i) = & \Phi(\gamma_1 \theta_i^{bo} + \gamma_2 \theta_i^{bo} \times \theta_i^{bo} \\ & + \gamma_3 \theta_i^{br} + \gamma_4 \theta_i^{br} \times \theta_i^{br} + w'_i \gamma + u_i) \end{aligned} \quad (27)$$

where Φ is a normal standard cumulative distribution. Equation (27) describes the probability of an investment in environmental assets conditional on independent variables including social capital. Regarding the intensive margin, Equation (17) suggests that the fraction of investment devoted to environmental assets is a function of capital and other variables. In the second part (Equation 21), a fractional model is used as follows (Papke & Wooldridge, 1996):

$$\begin{aligned} E(\alpha_i | k_i(\theta_i), x_i, w_i, \varpi_i = 1) = & G(\beta_1 \theta_i^{bo} + \beta_2 \theta_i^{bo} \times \theta_i^{bo} \\ & + \beta_3 \theta_i^{br} + \beta_4 \theta_i^{br} \times \theta_i^{br} + h'_i \beta + \varepsilon_i) \end{aligned} \quad (28)$$

We consider G to be a cumulative normal distribution. Hence, Equation (28) defines the conditional mean of the proportion of investments in environmental assets as a nonlinear function of the independent variables. u_i and ε_i are assumed to follow a bivariate normal distribution. The rationale behind this assumption is that CUMAs that invest in environmental assets may be different from CUMAs without it in terms of unobservable factors. This may pose a selection problem (Cameron & Trivedi, 2005). Schwiebert and Wagner (2015) proposed a generalized two-part model for fractional response that considers the selection problem:

$$\begin{aligned} E(\alpha_i | k_i(\theta_i), x_i, w_i, \varpi_i = 1) \\ = \frac{\Phi_2(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, \beta_1 \theta_i^j, \beta_2 (\theta_i^j)^2, w'_i \gamma, h'_i \beta; \rho)}{\Phi(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, w'_i \gamma)} \end{aligned} \quad (29)$$

where $\Phi_2(\cdot; \rho)$ denotes the bivariate standard normal distribution, with ρ representing the correlation between

participation and the proportion of investment in environmental assets. If the correlation parameter ρ equals zero, the generalized model reduces to a two-part model (Ramalho & Da Silva, 2009). For a model with dependence, the likelihood function (Schwiebert & Wagner, 2015) is:

$$\log L(\theta) = \sum_{i=1}^n l_i \theta \equiv \sum_{i=1}^n \left\{ (1 - \varpi_i) \log \left(1 - \Phi \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, w'_{i\gamma} \right) \right) + \varpi_i \log \Phi \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, w'_{i\gamma} \right) \right\} + \varpi_i \left[(1 - \alpha_i) \log \left(1 - \frac{\Phi_2 \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, \beta_1 \theta_i^j, \beta_2 (\theta_i^j)^2, w'_{i\gamma}, h'_{i\beta}; \rho \right)}{\Phi \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, w'_{i\gamma} \right)} \right) + \alpha_i \log \left(\frac{\Phi_2 \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, \beta_1 \theta_i^j, \beta_2 (\theta_i^j)^2, w'_{i\gamma}, h'_{i\beta}; \rho \right)}{\Phi \left(\gamma_1 \theta_i^j, \gamma_2 (\theta_i^j)^2, w'_{i\gamma} \right)} \right) \right], \quad (30)$$

The generalized two-part fractional model was implemented in Stata via the conditional mixed process (Wulff, 2019). Because social capital could be endogenous as it depends on the investment (See Section 2.1.1), we use two-stage residual inclusion (2SRI) (Terza et al., 2008) to correct this. We considered the geographical size of the CUMA, measured by the number of communes over which CUMA members are spread as instrumental variable (Kaasa & Parts, 2008). The intuition behind this variable is that bonding social capital will tend to decrease with an increase in the number of communes since the dispersion of members is strong.

On the other hand, an increase in the number of communes over which members are spread could increase the bridging social capital.⁴

4.1.2 | Marginal effect

Following our theoretical model, we determined the marginal effects of the explanatory variables on the probability of investing in environmental assets, the conditional and unconditional means of α_i (Cameron & Trivedi, 2009). Equations (31), (32), and (33) define the marginal probability of positive investments ($\alpha_i > 0$), the conditional and unconditional means of α_i , respectively:

$$P(\alpha_i > 0) = \Phi(v'_{i\gamma}) \quad (31)$$

$$E(\alpha | \alpha > 0) = \frac{\Phi_2(\zeta'_{i\beta}, v'_{i\gamma}; \rho)}{\Phi(v'_{i\gamma})} \quad (32)$$

$$E(\alpha) = \Phi_2(\zeta'_{i\beta}, v'_{i\gamma}; \rho) \quad (33)$$

Where v_i is the set of explanatory variables in Equation (22) and ζ is the set of explanatory variables in Equation (23). By differentiating Equations (31)–(33) with respect to θ^j , we obtained the marginal effects of social capital on the probability of investment and the conditional and unconditional mean (Wulff, 2019). The conditional mean captures the effect of independent variables on the proportion of investment in environmental assets when the CUMA makes an environmental investment. The unconditional mean captures the effect of independent variables across the entire sample.

5 | RESULTS

5.1 | Estimated coefficients

For brevity, we only report the results⁵ of the main variables in Table 2 while Table A2 in the appendix A presents the detailed results. The coefficient of the Size variable is positive (significant at 1%) and its square is negative (significant at 5%) when considering environmental investment propensity.⁶ These results suggest that the effect of the studied social capital variables on the probability of investing in environmental assets is a nonmonotonic and confirms the first part of H1 (H1a) of an inverted U-shape relationship. This result is consistent with previous research (Villena et al., 2011). For the proportion, although the signs of the coefficients for the value and its square are similar to those observed for the probability, neither is statistically significant. Consequently, we reject the second part of our H1 (H1b). In our dataset, we do not observe an effect of size on the proportion of environmental investments. This last result is also found for the effect of the Diversity index on the probability of investing in environmental assets. Neither the coefficient for its value nor the

⁴ The fractional selection model assumes that zero and nonzero investments are generated by different mechanisms. We assessed the robustness of this assumption by estimating a Tobit model with two limits (Cameron & Trivedi, 2009). The results are reported in sec. 5 (Online Appendix). The predicted values look the same, although Tobit seems to underestimate the marginal effect.

⁵ To test the conditional mean, we implemented the RESET test (sec. 3, Online appendix), a general test for functional form misspecification (Cameron & Trivedi, 2005).

⁶ To confirm the nonlinearity, we used the test suggested by Lind and Mehlum (2010). The results (Section- 4, Online appendix) support an inverted-U relationship for log(Size) and a monotonic relationship between Diversity and the probability of investing in environmental assets.

TABLE 2 Estimated coefficients of log (Size) and Diversity index.

Variables	Probability of environmental investment	Proportion of environmental investment
log (Size)	.899*** (.277)	.097 (.329)
log (Size) × log (Size)	−.087** (.035)	−.025 (.036)
Diversity (H)	−.163 (1.723)	−2.727* (1.392)
Diversity (H) × Diversity (H)	.126 (.647)	.672 (.529)
Constant and control variables	Yes	Yes
Observations	2680	2680
log pseudolikelihood	−2739.282	−2739.282
Wald Chi2(31)	58.84	58.84
Prob > chi ²	.001	.001

Note: The constant and control variables are shown in the Appendix A. Bootstrapping standard errors with 500 replications (Terza, 2017).

***, **, and * indicate estimated coefficients significant at $p < .01$, $p < .05$, and $p < .1$, respectively.

TABLE 3 Average marginal effects of log(Size) and Diversity index on investment in environmental assets.

Variables	Probability	Conditional effect	Unconditional effect
Log (Size)	.105*** (.024)	−.220** (.105)	−.127** (.061)
Diversity (H)	−.017 (.441)	−2.083** (.902)	−1.439** (.619)
Control variables	Yes	Yes	Yes
Observations	2680	2679	2679

Note: The calculation of the marginal effect includes the variables and their squares (Williams, 2017). Elasticities of probability and unconditional level were evaluated at the sample means of exogenous variables, using the whole sample.

***, ** and * indicate marginal effect significant at $p < .01$, $p < .05$ and $p < .1$ respectively.

coefficient for its square is statistically significant rejecting our H2a. When examining the results related to the proportion, the estimated coefficient of the Diversity Index is negative (significant at 10%), while the coefficient of the squared value is not significant (although it is positive). In our dataset, the Diversity Index therefore has a negative effect on the proportions.

5.2 | Marginal effects

5.2.1 | Marginal effect of social capital variables

Table 3 presents the net marginal effects of log of Size and Diversity on the probability of investment in environmental assets. On average, the net effect of the log (Size) on the probability of investment is significant and positive.

When the size of a CUMA increases by 10%, the probability of investing in environmental assets increases by approximately⁷ 1.050%. However, Figure 2 shows a nonlinear marginal effect. As shown by the conditional effects (Table 3), once a decision is made to invest in environmental assets, any marginal increase in members tends to reduce the proportion of investment in environmental assets.

Regarding the unconditional effect, a marginal increase in the number of members tends to reduce the proportion of investment in environmental assets. As Table 3 shows, the results regarding conditional and unconditional effects of the diversity of CUMA patrons are qualitatively similar.

⁷ Because the size variable is logarithmic, its effect is $\hat{\beta} \times \log((100 + p)/100)$ where p is a proportion (Benoit, 2011).

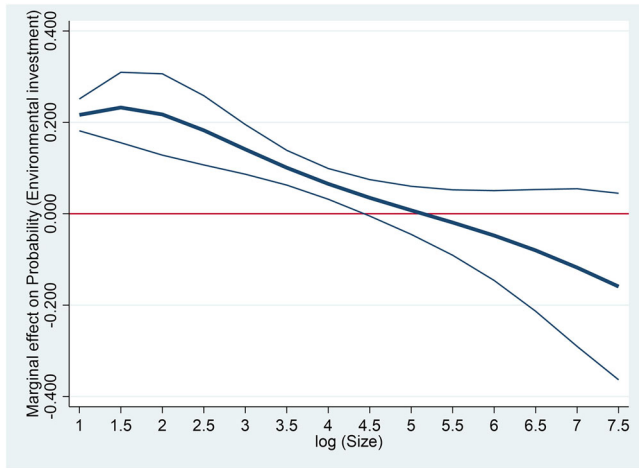


FIGURE 2 Marginal effect of log(Size) on investment in environmental assets probability (90% confidence interval).

5.2.2 | Marginal effect of control variables on investment propensity and the proportion of investment in environmental assets

The marginal effect of leverage on the propensity to invest is positive (See Table A3 in Appendix A). This means that the probability of investment increases when leverage increases. This result is consistent with the notion that borrowing is necessary to develop CUMAs' activities. In addition, the proportion of investment in environmental assets decreases with high debt costs. Detailed results are provided in Table A3 in Appendix A.

6 | ASSESSING HETEROGENEITY

6.1 | Environmental issues

We re-estimated the fractional model to consider the different environmental issues including SHF, NA and FPA separately. The net marginal effect of size on the probability of investment in environmental assets is nonlinear (Table A9, Online appendix). However, our results do not clearly capture the nonlinear effect of size on the proportion of investments in environmental assets except for the FPA.

Rather, the results indicate that once the investment has been made (conditional effect), the addition of members does not improve the proportion of environmental investments (Table A9). Negative unconditional effects were also observed. This result suggests that, within the sample, increasing the number of members does not improve the quantity of environmental investments whatever their type. Furthermore, the effect of diversity is not significant whatever the type of environmental investment.

The detailed results are provided in the Online appendix (sec. 6).

6.2 | Renewal of equipment

Approximately 31% of investment in environmental assets is made in the context of renewal. For the probability as well as for the proportion, the coefficient of the Size variable is positive (significant at 1%) and its square is negative (significant at 1%). These results confirm our H1 of an inverted U-shape relationship between the size of CUMA and investment in environmental assets. When examining the results related to effect of the Diversity index on the probability, the estimated coefficient is positive (significant at 5%), while the coefficient of the squared value is not significant (although it is negative). In our dataset, the Diversity Index therefore has a positive effect on the probability when considering renewal of equipment. However, when considering the proportion, neither the coefficient for the value of Diversity index nor the coefficient for its square is statistically significant. On average, the marginal effect of size on the propensity to renew investment in environmental assets increases with the size of the CUMA.

However, this effect is nonlinear. Even if the renewal of equipment may involve less risk for the members of a CUMA, it still seems important that the CUMA maintain the same conditions of social capital. Similarly, the diversification of patrons seems to increase the probability of renewal of investment in environmental assets. Furthermore, the conditional effects are negative and insignificant while the unconditional effects are positive and insignificant regarding the diversity index. This suggests that increasing the number of members does not increase the proportion of environmental investment. These results are in line with those presented in the previous section. The detailed results are reported in the Online appendix (sec. 7).

7 | DISCUSSION AND CONCLUSION

Social capital is commonly divided into three dimensions: structural, cognitive, and relational (Nahapiet & Ghoshal, 1998). While the literature acknowledges all three dimensions, this study focuses on the structural dimension, which serves as a foundation for developing the other two. Structural social capital refers to the connections among members and nonmembers within an organization (Deng et al., 2021). Specifically, we analyzed two subdimensions of structural social capital: bonding social capital, proxied by the size of the CUMA, and bridging social capital,

proxied by the diversity of patrons. Our findings suggest that the effect of the size of the CUMA on the probability of investing in environmental assets follows a nonmonotonic, inverted U-shaped relationship. However, the size does not significantly affect the proportion of investment in environmental assets. Similarly, the Diversity Index does not significantly affect the probability of investing in environmental assets. However, the Diversity Index shows a negative effect on the proportion of investment in environmental assets. Our analyses imply heterogeneity in the effect of structural social capital on the propensity and the proportion of investment in environmental assets. This result is not surprising given that size and diversity refer to different realities of social capital.

Indeed, the size of CUMAs could reflect a type of bonding social capital that characterizes the relationships between members of a CUMA, while the diversity of the patrons defines the external network of the CUMA. The effect of these two types of structural social capital tends to differ in the literature (Ruben & Heras, 2012). Our results also allow us to identify different determinants of investment in CUMAs. Previous studies have highlighted different factors that tend to influence investment within agricultural cooperatives including financial constraint (Chaddad et al., 2005; Musson & Rousselière, 2020). Financial constraints are mentioned as a hindrance to investment, because cooperatives face credit rationing. Although we do not test for the presence of financial constraints, the introduction of the leverage ratio allows us to capture the capacity of CUMAs to meet their financial obligations. This ratio has a positive marginal effect, implying that investments increase with financial leverage. This result is consistent with the notion that borrowing is necessary to develop CUMA activities.

This study has limitations that are worth mentioning. Because we consider cross-sectional data, our analysis does not capture the dynamic nature of the financial performance variables. Indeed, the financial leverage or debt ratio of a cooperative is likely to evolve over time. In addition, because our study does not consider the other dimensions of social capital is an interesting avenue for future research. Furthermore, future studies could extend our analysis by including the relational and cognitive dimensions of social capital (Deng et al., 2021). Some policy implications derived from the present study are worth noting.

Taken together, our results paint a clear picture of the positive effect of social capital on the environmental involvement of cooperatives. CUMAs can thus make a significant contribution to the agricultural transition given the role of social capital in these cooperatives (Diakit e et al., 2022). Therefore, decision-makers should encourage the development of these cooperatives, especially as

their number is stagnating in certain countries (Diakit e et al., 2022). However, the continued production of social capital can also be an impediment since the possibility of connecting to external networks can reduce the probability of interaction between cooperative members. At the same time, the lack of interaction between CUMA members and external networks could result in introverted cooperatives with limited innovation capabilities (Nahapiet & Ghoshal, 1998). Cooperative decision-makers must therefore attain an optimal quantity of social capital to minimize the negative aspects of social capital on their entities.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX

TABLE A1 Controls variables.

Variables	Definition	Mean	SD	Observations	Source
Leverage	Financial leverage: Total debt/Equity	1.239	1.531	2680	Federation of CUMA
Turnover	CUMA productivity ratio: Turnover/total assets	.154	.108	2680	Federation of CUMA
Cash flow ratio	Ratio of cash flow to Turnover: Cash flow/Turnover	1.274	.086	2680	Federation of CUMA
Cost of debt	Cost of debt (Euros): Interest Expense/(Total Assets-Reserves)	.046	.416	2680	Federation of CUMA
Age	Age of the CUMA (years)	39.489	19.340	2680	Federation of CUMA
Region (Nominal variable)	CUMA geographic region	–	–	2680	Federation of CUMA
TEOF (Nominal variable)	Technical and economic orientation of farmers	–	–	2680	AGRESTE 2010
Population density	Population density (habitant per km ²)	2.249	4.183	2680	AGRESTE 2010
Farms density	Number of farms/usable agricultural area	.018	.009	2680	AGRESTE 2010
Usable agricultural area	Usable agricultural area proportion	.573	.162	2680	AGRESTE 2010
Subsidies	Subsidies received by CUMA (Euros)	74.072	6793	2680	Federation of CUMA
Employee	Number of employees	.092	.438	2680	Federation of CUMA
Geographical size of CUMA (log)	Number of communes over which CUMA members are spread	14.575	15.203	2680	Federation of CUMA

Note: The reported averages relate to nonzero data. TEOF 1 = Cattle, sheep and goats; TEOF 2 = Arable crops; TEOF 3 = Vegetable growing and horticulture; TEOF 4 = Fruit and other permanent crops; TEOF 5 = Pigs and poultry; TEOF 6 = Mixed farming; TEOF 7 = Wine growing.

TABLE A2 Fractional model results.

Variables	Probability of environmental investment	Proportion of environmental investment
log (Size)	.899*** (.277)	.097 (.329)
log (Size) × log (Size)	−.087** (.035)	−.025 (.036)
Diversity (H)	−.163 (1.723)	−2.727* (1.392)
Diversity (H) × Diversity (H)	.126 (.647)	.672 (.529)
Leverage	.221*** (.050)	−.035 (.067)
Leverage × Leverage	−.006 (.005)	.001 (.004)
Employee	−.069 (.071)	−.039 (.058)
log (Age)	.081* (.042)	.022 (.041)
2.REG	−.023 (.193)	.183 (.169)
3.REG	.063 (.173)	.135 (.130)
4.REG	−.219 (.211)	.227 (.206)
5.REG	.212 (.238)	.398** (.200)
6.REG	.051 (.110)	.058 (.087)
7.REG	.036 (.116)	−.019 (.096)
8.REG	−.106 (.215)	−.401** (.165)
9.REG	.102 (.247)	.363* (.196)
10.REG	−.038 (.140)	−.035 (.120)
Farms density	−12.907*** (4.405)	−9.443** (4.531)
Usable agricultural area	−.191 (.181)	−.113 (.138)
Subsidies	−.000 (.000)	−.000 (.000)
2.TEOF	−.159 (.120)	−.256** (.100)

(Continues)



TABLE A2 (Continued)

Variables	Probability of environmental investment	Proportion of environmental investment
3.TEOF	.217 (.200)	-.060 (.138)
4.TEOF	-.272 (.384)	-.213 (.359)
5.TEOF	.118 (.103)	-.037 (.083)
6.TEOF	-.017 (.085)	-.079 (.065)
7.TEOF	-.325** (.164)	-.301* (.173)
Cash flow ratio	.027 (.077)	-.022 (.065)
Turnover	-.500 (.513)	-.430 (.512)
Cost debt	-.578 (.534)	-1.944*** (.616)
Population density	.002 (.006)	
\widehat{v}_{Size}	-.196 (.400)	-.672** (.319)
$\widehat{v}_{Diversity}$	1.092 (1.724)	3.082** (1.394)
Constant	-1.661 (1.073)	1.170 (1.218)
atanhrho_12	1.797* (1.011)	
Observations	2680	2680
log pseudolikelihood	-2739.282	-2739.282
Wald Chi ² (31)	58.84	58.84
Prob > chi ²	.001	.001

Note: REG is for Region with 1 = Auvergne-Rhône-Alpes ; 2 = Bourgogne-Franche-Comté ; 3 = Bretagne ; 4 = Centre-Val de Loire ; 5 = Nord-Pas-de-Calais-Picardie ; 6 = Normandie ; 7 = Nouvelle Aquitaine ; 8 = Occitanie ; 9 = Pays de la Loire ; 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. TEOF as in Table A1. Bootstrapping standard errors with 500 replications (Terza, 2017).

***, ** and * indicate estimated coefficient statistically significant at $p < .01$, $p < .05$, and $p < .1$, respectively.

TABLE A3 Marginal effects.

Variables	Probability	Conditional effect	Unconditional effect
Log (Size)	.105*** (.024)	-.220** (.105)	-.127** (.061)
Diversity (H)	-.017 (.441)	-2.083** (.902)	-1.439** (.619)
Leverage	.073*** (.015)	-.131** (.060)	-.074** (.031)
Employee	-.025 (.025)	-.005 (.054)	-.009 (.035)
Log (Age)	.029* (.015)	-.018 (.035)	-.006 (.022)
2.REG	-.008 (.070)	.194 (.140)	.130 (.096)
3.REG	.022 (.062)	.104 (.112)	.076 (.076)
4.REG	-.082 (.078)	.342* (.189)	.194* (.116)
5.REG	.072 (.081)	.299* (.165)	.234* (.121)
6.REG	.018 (.039)	.033 (.067)	.025 (.047)
7.REG	.013 (.041)	-.037 (.079)	-.024 (.054)
8.REG	-.039 (.082)	-.347** (.140)	-.228** (.100)
9.REG	.036 (.087)	.314* (.170)	.229* (.119)
10.REG	-.014 (.051)	-.016 (.099)	-.012 (.066)
Farms density	-4.574*** (1.580)	-3.141 (3.725)	-3.228 (2.330)
Usable agricultural area	-.068 (.064)	-.020 (.111)	-.029 (.077)
Subsidies	-.000 (.000)	-.000 (.000)	-.000 (.000)
2.TEOF	-.058 (.045)	-.176* (.094)	-.130** (.061)
3.TEOF	.072 (.062)	-.159 (.112)	-.100 (.081)
4.TEOF	-.101 (.149)	-.072 (.321)	-.074 (.185)
5.TEOF	.040 (.035)	-.092 (.075)	-.055 (.051)
6.TEOF	-.006 (.030)	-.071 (.063)	-.051 (.042)
7.TEOF	-.122* (.064)	-.131 (.154)	-.113 (.082)

(Continues)



TABLE A3 (Continued)

Variables	Probability	Conditional effect	Unconditional effect
Cash flow ratio	.009 (.027)	-.035 (.050)	-.022 (.035)
Turnover	-.177 (.182)	-.186 (.372)	-.170 (.274)
Cost debt	-.205 (.190)	-1.662*** (.550)	-1.193*** (.394)
Population density	.001 (.002)	-.001 (.003)	-.001 (.002)
Observations	2680	2679	2679

Note: Standard errors in parentheses. The calculation of the marginal effect includes the variables and their squares (Williams, 2017). Elasticities of probability and unconditional level were evaluated at the sample means of exogenous variables, using the whole sample. REG and TEOF as in Table A1 and Table A2.

***, ** and * indicate estimated marginal effect statistically significant at $p < .01$, $p < .05$, and $p < .1$, respectively.