Arrangements coopératifs, investissement environnemental et performance des coopératives agricoles

Daniel Diakité

To cite this version:

Daniel Diakité. Arrangements coopératifs, investissement environnemental et performance des coopératives agricoles. Economies et finances. Agrocampus Ouest; Université Laval (Québec, Canada), 2023. Français. NNT : 2023NSARE064 . tel-04574794

HAL Id: tel-04574794
https://theses.hal.science/tel-04574794

Submitted on 14 May 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

THÈSE DE DOCTORAT DE

L'INSTITUT AGRO RENNES ANGERS
L'UNIVERSITE LAVAL QUEBEC

ECOLE DOCTORALE N° 640
Ecole doctorale Sciences économiques et sciences de gestion Pays de la Loire
Spécialité : Sciences Economiques

Par

Daniel DIAKITE

Arrangements coopératifs, investissement environnemental et performance des coopératives agricoles

Thèse présentée et soutenue à l'Université Laval (Québec), le 14 Septembre 2023
Unité de recherche : Centre de Recherche en économie de l'Environnement, de l'Agroalimentaire, des Transports et de l'Énergie (CREATE) / Structures et Marchés Agricoles, Ressources et Territoires (SMART)
N° d'ordre : 2023-14
N° de série : E-64

Rapporteurs avant soutenance :

Sonia TELLO-ROZAS	Professeure, UQAM
Laure LATRUFFE	Directrice de recherche, INRAE, Bordeaux, Sciences économiques

Composition du Jury :

Président :	Maurice DOYON	Professeur titulaire, Université Laval
Examinateurs :	Alphonse Gbemayi SINGBO	Professeur adjoint, Université Laval
	Aude RIDIER	Professeure, Institut Agro-Rennes Angers
Dir. de thèse :	Lota D. TAMINI	Professeur titulaire, Université Laval
Dir. de thèse :	Rousselière DAMIEN	Professeur, Institut Agro-Rennes Angers

Co-encadrement :

Sébastien Caillault	Maître de conférences, Institut Agro Rennes-Angers
Simon Cornée	Maître de conférences HDR, Université de Rennes

Arrangements coopératifs, investissement environnemental et performance des coopératives agricoles

Thèse en cotutelle
Doctorat en Agroéconomie

Daniel Diakité

Sous la direction de :

Lota D. Tamini, directeur de recherche
Damien Rousselière, directeur de recherche

Résumé

Cette thèse s'intéresse d'une part à la gouvernance des Coopératives d'Utilisation de Matériel Agricole (CUMA), d'autre part à son effet sur les investissements en actifs environnementaux et l'implication de ces investissements sur la performance des CUMA. Dans le premier essai, nous analysons la nature des mécanismes de gouvernance dans le contexte des CUMA au Québec. Nous étudions comment ces mécanismes se combinent pour minimiser différents problèmes de gouvernance. À partir d'une étude de cas multiples, nos résultats montrent que les problèmes de gouvernance en CUMA concernent à la fois les problèmes de coordination et de motivation. Pour corriger ces défaillances organisationnelles, nous constatons que les CUMA combinent les mécanismes de gouvernance formels et informels (capital social) en mettant toutefois l'accent sur les mécanismes informels tels que la confiance mutuelle. Les membres de la CUMA auront recours aux mécanismes informels, en utilisant les mécanismes formels en complément lorsque cela est nécessaire. Ce premier essai nous a ainsi permis de mettre en évidence la pertinence d'étudier les relations interpersonnelles au sein de la coopérative dans un contexte où les mécanismes formels sont défaillants ou inappropriés pour minimiser les problèmes de gouvernance. Dans le deuxième essai, nous analysons théoriquement et empiriquement l'effet du capital social sur la propension et la proportion de l'investissement en actifs environnementaux dans le contexte de la France en utilisant la taille des CUMA comme « proxy » du capital social. En France, la taille des CUMA (en nombre de membres) reste variable avec des CUMA de plus de 150 membres et des plus petites de moins de 50 membres. L'importance de la taille découle de son effet négatif sur le capital social et positif sur les performances économiques (Feng et al., 2016). Le plus souvent, les coopératives de grande taille bénéficient des économies d'échelle et d'une utilisation efficiente des actifs. Cependant, à un certain seuil, les problèmes d'interaction au sein des grands groupes peuvent l'emporter sur les gains des économies d'échelle. Si tel est le cas, il existerait une taille optimale au-delà de laquelle la coopérative attendrait une zone de déséconomie d'échelle. À partir du modèle d'investissement de Fulton et Giannakas (2012), nous générons des hypothèses que nous testons empiriquement sur 2680 CUMA en 2015. Nos résultats montrent que, bien que positif, l'effet de la taille sur la propension à investir dans des équipements environnementaux est non linéaire (en U inversé). Cependant, conditionnellement à l'investissement en actifs environnementaux, l'augmentation marginale de la taille de la coopérative affecte négativement la proportion de l'investissement en

actifs environnementaux. De même, nous constatons que l'augmentation du revenu moyen des adhérents accroît la probabilité d'un investissement en actifs environnementaux. Cependant, une fois l'investissement réalisé, l'augmentation du revenu n'implique pas nécessairement une augmentation de l'investissement. Les effets différenciés des variables sur les probabilités et la proportion de l'investissement en actifs environnementaux suggèrent également le rejet du modèle Tobit par rapport à un modèle de sélection fractionnel (Schwiebert & Wagner, 2015). Ce résultat suggère que la propension d'un investissement en actifs environnementaux et sa proportion sont déterminés par des facteurs différents. Dans le troisième essai, nous analysons l'effet des investissements environnementaux sur la performance des CUMA. Nous modélisons la performance de la coopérative via un modèle stochastique dynamique dans lequel l'investissement est traité comme une variable endogène de la frontière de production. L'intérêt du modèle dynamique réside dans le fait que les CUMA réalisent des investissements communs en input quasi fixe. De même, en traitant l'investissement comme une variable endogène, notre modèle permet de capter l'effet des variables de contrôle affectant l'investissement tout en conservant le caractère dynamique de la production. Nous utilisons une approche en deux étapes qui nous permet, dans la première, d'estimer l'effet des investissements environnementaux sur l'efficience de la CUMA. Dans la deuxième étape, nous utilisons une méthode non paramétrique pour générer un indice de productivité de Malmquist décomposé en un indice de changement technique et technologique. Nous estimons par la suite l'effet des investissements environnementaux sur ces indicateurs de performance. À partir des données de panel sur la période 2010-2016, nos résultats empiriques montrent qu'une augmentation marginale des investissements environnementaux entraîne une augmentation moyenne de la productivité de 0.214. On observe que les performances passées ont un impact négatif sur les performances actuelles de la CUMA. Cependant, ne considérant que l'effet des nouveaux investissements en actifs environnementaux, l'augmentation moyenne de la productivité est de 0.217. Cela suggère qu'il est avantageux pour la CUMA d'investir dans des équipements environnementaux de premier choix.

Abstract

This thesis focuses on the governance of Cooperatives for the Use of Agricultural Equipment (CUMAs) and on the effect of governance on environmental investments and the implication of these investments on CUMA performance. In the first essay, we analyse the nature of governance mechanisms in the context of CUMAs in Quebec. We study how these mechanisms combine to minimize different governance problems. Based on a multiple case study, our results show that governance problems in CUMAs concern both coordination and motivation problems. To address these organisational failures, we find that CUMAs combine formal and informal (social capital) governance mechanisms, but with an emphasis on informal mechanisms such as trust. CUMA members will resort to informal mechanisms, using formal mechanisms as a complement when necessary. This first essay has thus allowed us to highlight the relevance of studying interpersonal relations within the cooperative in a context where formal mechanisms are failing or inappropriate to minimise governance problems. In the second essay, we theoretically and empirically analyse the effect of social capital on the propensity and proportion of environmental investment in the French context using CUMA size as a proxy for social capital. In France, the size of CUMAs (in terms of number of members) remains variable, with CUMAs of more than 150 members and smaller ones of less than 50 members. The importance of size stems from its negative effect on social capital and positive effect on economic performance (Feng et al., 2016). Most often, larger cooperatives benefit from economies of scale and efficient use of assets. However, at some point, interaction problems within large groups may outweigh the gains from economies of scale. If this is the case, there would be an optimal size beyond which the cooperative would expect an area of diseconomy of scale. Using the investment model of Fulton and Giannakas (2012), we generate hypotheses that we test empirically on 2680 CUMAs in 2015. Our results show that, although positive, the effect of size on the propensity to invest in environmental equipment is non-linear (inverted U-shaped). However, conditional on environmental investment, the marginal increase in the size of the cooperative negatively affects the proportion of environmental investment. Similarly, we find that increasing average income increases the probability of environmental investment. However, once the investment is made, the increase in income does not necessarily imply an increase in environmental investment. The differential effects of the variables on the probabilities and proportion of environmental investment also suggest the rejection of the Tobit model over a

fractional selection model (Schwiebert & Wagner, 2015). This result suggests that the propensity for environmental investment and the proportion of investment are determined by different factors. In the third test, we analyse the effect of environmental investments on CUMA performance. We model the performance of the cooperative via a dynamic stochastic model in which investment is treated as an endogenous variable of the production frontier. The interest of the dynamic model lies in the fact that CUMAs make common investments in quasi-fixed input. Similarly, by treating investment as an endogenous variable, our model captures the effect of control variables affecting investment while maintaining the dynamic nature of production. We use a two-stage approach that allows us, in the first stage, to estimate the effect of environmental investments on the efficiency of the CUMA. In the second step, we use a non-parametric method to generate a Malmquist productivity index decomposed into an index of technical and technological change. We then estimate the effect of environmental investments on these performance indicators. Using panel data over the period 2010- 2016, our empirical results show that a marginal increase in environmental investments leads to an average increase in productivity of 0.214. We observe that past performance has a negative impact on the current performance of the CUMA. However, considering only the effect of new environmental investments, the average increase in productivity is 0.217. This suggests that it is advantageous for the CUMA to invest in early environmental equipment.

Table des matières

Liste des figures

Liste des tableaux

Liste des abréviations

ACI	: Alliance Coopérative Internationale
CERUL	: Comité d'Éthique de la recherche de 'Université Laval
CUMA	: Coopérative d'Utilisation de Matériel Agricole
DEA	: Data Envelopment Analysis- Analyse par Enveloppement des données
EARL	: Exploitation Agricole à Responsabilité Limitée
EVI	: Extra Value Index- Index de la Valeur Extra
GAEC	: Groupement Agricole d'Exploitation en Commun
HCCA	: Haut Conseil de la Coopération Agricole
INSEE	: L'Institut National de la Statistique et des Études Économiques
LR	: Likelihood Ratio- Ratio de Vraissemblance
MAPA	: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
OLS	: Ordinary Least Squares – Moindres Carrés Ordinaires
ONU	: Organisation des Nations Unies
PIB	: Produit Intérieur Brut
ROA	: Return on Assets – Rentabilité des Actifs
ROE	: Return on Equity – Rentabilité des Capitaux propres

Dédicace

Je dédie cette thèse à :

- *A mon père, Moussa Diakité et son Épouse Tantie Rachelle*
- *A ma mère, Feue Anne Coulibaly*
- *A Pierrette Coulibaly, mon épouse*
- *A Nana-Rose, Seba, David, Néma, Sara, Issiaka et Naomie*

(…) We used to view society in dichotomous terms-states or markets (sometimes emphasizing their complementarity). But there are a host of other institutional arrangements and player (Stiglitz, 2017, p. 25)

Remerciements

Cette thèse est l'aboutissement de plus de quatre années de travail. Sa réalisation n'aurait été possible sans l'implication et le soutien de plusieurs personnes que je voudrais remercier. Premièrement, je voudrais remercier mes directeurs de thèse, Damien Rousselière et Lota D. Tamini pour leur disponibilité et le soutien financier dont j'ai pu bénéficier durant tout ce cursus. Leurs critiques objectives, leurs rigueurs et la patience dont ils ont fait montre m'ont permis de surmonter les défis intellectuels auxquels j'ai pu faire face pendant cette thèse.

Je tiens à remercier Annie Royer, mon encadrant à l'Université Laval pour sa disponibilité et sa réactivité pendant la rédaction du premier article de cette thèse. Merci Annie ! Mes remerciements vont également à l'endroit de mes encadrants Sébastien Caillault et Simon Cornée pour leur qualité d'écoute et pour les remarques constructives.
Un spécial merci au Doyen de la faculté d'économie à l'université de Daloa, pour ses orientations et son appui durant toutes ses années de formations!

A Carl Gaigné et Maxime-Marie les deux membres de mon comité de suivi, je dis aussi sincèrement merci pour les orientations et le suivi pendant toute ma thèse. Merci au personnel administratif de l'Université Laval (Québec), de l'unité SMART à L'institut Agro Rennes-Angers pour l'accueil chaleureux dont j'ai bénéficié.

Cette thèse a bénéficié d'un financement régional du Pays de la Loire dans le cadre du RFI ("Food for Tomorrow - Cap Aliment" (Région Pays de la Loire, France). Qu'il me soit permis d'exprimer toute ma reconnaissance au Pays de la Loire pour le financement de cette thèse.

J'aimerais exprimer aussi ma gratitude à Bruno Guérard, le répondant des CUMA au Québec pour sa disponibilité et son appui qui m'ont permis de mieux appréhender la réalité des CUMA au Québec. Merci à la Fédération Nationale des CUMA (FNCUMA) et surtout aux coopérateurs qui ont accepté de me recevoir et de répondre à mes nombreuses questions. Un immense merci à M. Caillault pour sa disponibilité.
J'adresse mes sincères remerciements au Pasteur Lorenzo et son épouse, ainsi qu'aux membres du groupe les Voix de l'Amour- Aristide, Antoine, Kévin et toutes les choristes- pour les excellents moments passés ensemble. Merci aussi aux amis du groupe de croissance pour leurs appuis et leurs encouragements.

Toute ma reconnaissance va à l'endroit de ma famille, pour le soutien spirituel.
A toi, *Pierrette Tiéfigué Coulibaly mon épouse,* merci pour ta patience et pour tous les sacrifices consentis. Je suis profondément reconnaissant de t'avoir! Un gros merci à toi.

Finalement, rien n'aurait été possible sans Lui, Celui qui est le début et la fin de toutes choses. Merci à mon Dieu qui m'a soutenu, encouragé, dans le silence, mais avec une grande fidélité. Merci pour tout !

Avant-propos

Les chapitres de la présente thèse constituent des articles publiés ou à soumettre à des revues scientifiques avec comité de lecture. Le chapitre 1 est un article publié et réalisé avec A. Royer, professeure titulaire à l'Université Laval (Québec), D. Rousselière et Lota D. Tamini mes directeurs de thèse. Je suis le principal auteur de cet article, soumis le 27 Juillet 2021, puis accepté le 17 Juin 2022 dans le Journal of Co-operative Organization and Management. Le chapitre 2 est un article réalisé avec D. Rousselière, Lota D. Tamini mes directeurs de thèse, S. Caillault et S. Cornée mes encadrants. Il fait l'objet de révisions pour être soumis pour évaluation à une revue avec comité de lecture. Je suis le principal auteur de cet article. Le chapitre 3 est un article réalisé avec Lota D. Tamini et D. Rousselière. Il fait aussi l'objet de révisions pour être soumis à une revue scientifique. Je suis le principal auteur de cet article.

Introduction

Plus de 12 % des personnes déclarées actives appartiennent à l'une des trois millions de coopératives dans le monde. Ces coopératives constituent une source d'emploi pour 10 % de la population tandis que les 300 principales coopératives réalisent 2 146 milliards de dollars US de chiffres d'affaires (Monitor World Cooperative, 2021). L'importance des coopératives repose non seulement sur leur poids économique, mais aussi sur leur implication environnementale. Même si le rapport entre le mouvement coopératif et l'environnement n'est que faiblement abordé dans la littérature coopérative (Draperi, 2018; Glasbergen, 2000), l'engagement environnemental coopérative devient un sujet d'intérêt dans la littérature (Filippi, 2020). L'adoption volontaire de standards internationaux tels que ISO 26000[1] est un exemple d'initiatives justifiant l'implication environnementale des coopératives (Filippi, 2020). Cette implication-peut se décliner aussi sous la forme d'investissements environnementaux, c'est-à-dire des investissements permettant à une organisation de minimiser son impact environnemental (Bhuiyan et al., 2021; Bostian et al., 2016). Cependant, bien que les preuves d'un engagement environnemental des coopératives existent, l'implication économique de cet engagement reste une question peu abordée. Lorsque cette question est abordée, les résultats empiriques suggèrent différentes interprétations ce qui dénote de la complexité du lien entre les pratiques environnementales et la performance économique (Schaltegger & Synnestvedt, 2002). Contrairement aux questions environnementales, la performance coopérative constitue un sujet récurrent dans la littérature coopérative, soit en comparaison avec les organisations détenues par des investisseurs privés (Porter & Scully, 1987; Soboh et al., 2012) soit en relation avec leur gouvernance (Gardner et al., 2022). Traditionnellement, les coopératives sont considérées comme des organisations moins performantes en raison de leurs principes[2] et de la structure des droits de propriété reposant sur la propriété commune[3]. Les caractéristiques de ces organisations causent des sous-optimalités qui limitent leur performance (Grashuis & Cook, 2018).

[1] ISO 26000 est un standard international volontaire qui a pour objectif d'aider les organisations à renforcer leur responsabilité sociale.

[2] Les 7 principes coopératifs proposés par l'Alliance Coopérative Internationale (ACI) sont : (1) Adhésion volontaire de tous ; (2) Contrôle démocratique des membres ; (3) Participation des membres ; (4) Autonomie et indépendance ; (5) Éducation et formation ; (6) Coopération entre coopératives ; (7) Engagement envers la communauté (International Cooperative Alliance, 2015)

[3] Précisément, une coopérative est utilisée et contrôlée par ceux qui en sont propriétaires et la financent. Elle redistribue les bénéfices en fonction de l'utilisation des membres (Dunn, 1988).

Par exemple, en prônant l'adhésion ouverte, les coopératives s'exposent à des comportements opportunistes[4] de la part des nouveaux adhérents, susceptibles de bénéficier des investissements passés sans en avoir subi le coût (Liang & Hendrikse, 2016). L'adhésion ouverte peut impliquer également un problème de sélection adverse qui fait en sorte que les producteurs à faible qualité de produits sont incités à réaliser des transactions avec la coopérative en raison des prix élevés. En favorisant l'adhésion ouverte, les coopératives s'exposent par ailleurs, à des comportements du type « *passager clandestin* » générant une utilisation sous optimale des ressources parce que ces organisations fonctionnent sur un régime de propriété commune (Vitaliano, 1983). De même, puisque la propriété est commune, un nouveau membre aurait les mêmes revendications sur les flux de trésorerie que les anciens ainsi que des droits similaires de participation aux processus de prise de décision. La répartition égale des droits de propriété, combinée à l'absence d'un marché permettant aux anciens membres de capter la valeur de leur investissement cause une désincitation à l'investissement (Cook, 1995).

L'évolution des formes organisationnelles coopératives relance toutefois le débat sur la performance des coopératives avec l'émergence des formes coopératives non traditionnelles à la fois en Europe[5] et aux États-Unis (Bijman et al., 2014; Grashuis & Cook, 2018). En effet, les coopératives traditionnelles se caractérisent par une application stricte des principes coopératifs, des droits résiduels non transférables, non appréciables, encaissables, une propriété réservée aux membres qui sont utilisateurs et investisseurs (Chaddad & Cook, 2004). En ce qui concerne les coopératives non traditionnelles, d'autres principes tels que l'adhésion fermée, la transférabilité et l'appréciabilité des droits de propriété sont prônés ce qui limite les sources d'inefficience (Grashuis & Cook, 2018). En exemple, les coopératives de nouvelle génération s'écartent des coopératives traditionnelles en relâchant la restriction sur la transférabilité du droit résiduel (Chaddad & Cook, 2004). Les membres de ces coopératives sont tenus d'acquérir des droits de livraison proportionnels à leurs transactions, non remboursables, mais pouvant être rachetés par d'autres membres après validation du conseil d'administration (Nilsson, 1997).

---

[4] Williamson définit l'opportunisme comme suit : « Par opportunisme, j'entends la recherche de l'intérêt personnel avec ruse. Cela inclut, mais n'est guère limité à des formes flagrantes telles que le mensonge, le vol et la tricherie (…). Plus généralement, l'opportunisme se réfère au caractère incomplet ou divulgation déformée d'informations (…) » (Williamson, 1985, p. 47)

[5] Le rapport récent du Haut Conseil de la Coopération Agricole, HCCA (2018) illustre la diversité des formes organisationnelles à l'intérieur de l'Union européenne.

Les coopératives de membres investisseurs sont aussi un exemple de coopératives non traditionnelles qui s'écartent des coopératives traditionnelles en relâchant la restriction sur la distribution des bénéfices. Dans ces coopératives, le surplus est redistribué proportionnellement à l'investissement et aux transactions. D'autres formes de coopératives non traditionnelles sont décrites dans Chaddad et Cook (2003) dans le contexte nord-américain avec différentes spécificités telles que l'élargissement des droits des propriétés aux investisseurs extérieurs. En Europe, l'étude de Bijman et al. (2014) constate l'émergence de coopératives non traditionnelles. Par exemple, ces auteurs montrent que certaines coopératives européennes s'éloignent du principe *un membre- une voix* en adoptant le vote proportionnel qui consiste à donner aux membres un nombre de voix fonction du volume de leurs transactions avec la coopérative. D'autres coopératives permettent les transactions économiques avec les des tiers non-membres,[6] ce qui s'écarte du principe propriétaire-utilisateur.

Cette thèse s'intéresse aux Coopératives d'Utilisation de Matériel Agricole (CUMA). Ces coopératives sont présentes à la fois en Europe et en Amérique du Nord. En France, selon la Fédération Nationale des CUMA, on dénombre 10 322 CUMA représentant 199 000 adhérents (FNCUMA, 2021) tandis qu'au Québec, seulement 64 CUMA sont en activités selon le Ministère de l'Agriculture des Pêcheries et de l'Alimentation ce qui représente un recule de 4.5 % sur les dix dernières années (Gouvernement du Québec, 2023). Malgré la création d'un réseau associatif en 2015, les travaux scientifiques sur les CUMA sont rares. Les coopératives de machineries sont aussi présentes en Suède (De Toro & Hansson, 2004), mais très peu documentées. Nous traitons les CUMA comme des coopératives empruntant certains traits de coopératives non traditionnelles. En effet, les CUMA se démarquent des coopératives traditionnelles en relâchant par exemple le principe de la libre adhésion[7]. Contrairement à d'autres types de partage de machinerie, l'organisation d'une CUMA repose sur les ''branches d'activité'' représentant un sous-groupe de membres adhérents qui partagent une machinerie spécifique. L'admission d'un

[6] En France, les services fournis par les coopératives aux tiers non-membres ne peuvent dépasser plus de 20 % du chiffre d'affaires de la coopérative
https://www.legifrance.gouv.fr/
.

[7] La définition de la libre adhésion proposée par l'Alliance coopérative Internationale est problématique dans la mesure ou elle suggère la libre entrée des membres sans discrimination tout en les soumettant aux critères internes de sélection de la coopérative (International Coopérative Alliance, 2015). Dans le cas des CUMA, l'adhésion ne dépend pas que de l'aptitude du membre entrant à utiliser les services, elle dépend aussi de la volonté du groupe d'accepter un nouveau. Cette volonté peut reposer sur des critères subjectifs.

nouveau membre au sein d'une branche ne peut se faire qu'après la validation du conseil d'administration de la coopérative et des membres existants de la branche. Une autre distinction est que la CUMA a la possibilité de faire varier l'apport en capital suivant l'utilisation de l'équipement (Kenkel & Long, 2007). **Précisément, cette thèse analyse la gouvernance des CUMA, l'effet de cette gouvernance sur les investissements en actifs environnementaux et la performance de ces coopératives**. Dans la suite de ce chapitre, nous commençons par préciser les concepts de gouvernance, d'investissement en actifs environnementaux et de performance avant d'aborder la discussion permettant de déboucher sur nos questions spécifiques de recherche.

0.1 Concepts utilisés

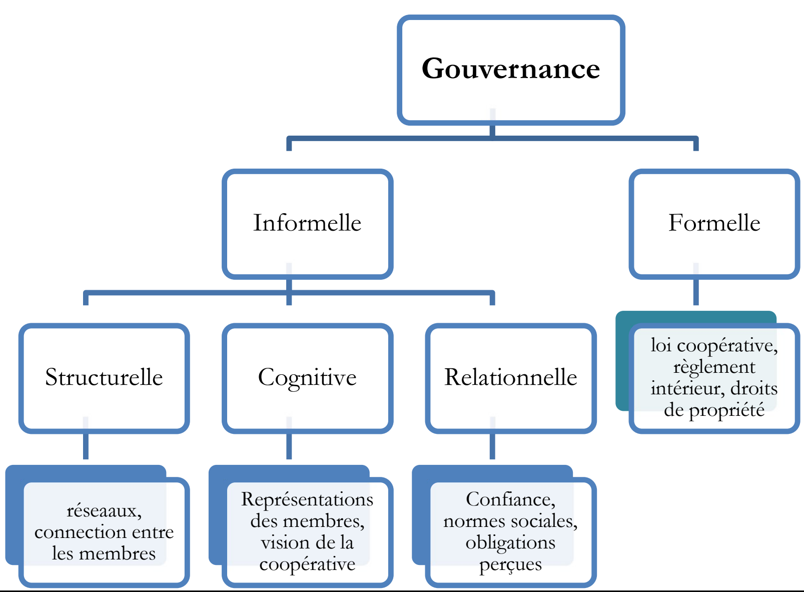
0.1.1 Gouvernance

Il existe de nombreuses définitions de la gouvernance, certaines semblent difficilement utilisables empiriquement tandis que les autres s'éloignent de l'identité coopérative. La gouvernance fait référence « *à un système d'autorité, de direction et de contrôle qui garantit une gestion assurant au mieux les intérêts des propriétaires* »(Bijman et al., 2014, p. 643). Pour ces auteurs, la gouvernance renvoie aussi *« aux structures et aux procédures de prise de décision au sein d'organisation* » (Bijman et al., 2014, p. 643). D'autres auteurs mettent l'accent sur l'organisation des transactions (Feng & Hendrikse, 2008, p. 7). Charreaux (1997), décrit la gouvernance comme « *l'ensemble des mécanismes organisationnels et institutionnels ayant pour effet de délimiter les pouvoirs et d'influencer les décisions des dirigeants, autrement dit, les mécanismes qui « gouvernent » leur conduite et définissent leur espace discrétionnaire* ». Les définitions ci-dessus sont difficiles à utiliser pour la conduite de recherche empirique, s'appliquent difficilement au contexte des coopératives agricoles ou font l'hypothèse implicite d'un opportunisme[8] au niveau des dirigeants de la coopérative tout en ignorant les comportements opportunistes présents à l'échelle des membres(Iliopoulos & Valentinov, 2012). Valiorgue et Hollandts (2016, p. 15) fournissent une définition empiriquement utile en désignant la gouvernance comme « *l'ensemble des institutions, des règles et des pratiques qui encadrent le pouvoir de décision du dirigeant et organisent les relations avec les sociétaires* ». Cette définition est assez flexible pour

[8] Williamson définit l'opportunisme comme suit : « Par opportunisme, j'entends la recherche de l'intérêt personnel avec ruse. Cela inclut, mais n'est guère limité à des formes flagrantes telles que le mensonge, le vol et la tricherie (…). Plus généralement, l'opportunisme se réfère au caractère incomplet ou divulgation déformée d'informations (…) »(Williamson, 1985, p. 47)

prendre en compte à la fois la structure des droits de propriété, le rôle des organes de gestion (Bijman et al., 2014), les règles qui encadrent les dirigeants ainsi que les mécanismes d'organisation. Nous l'utilisons donc dans la suite de la thèse. Il à noter que les institutions, les règles et pratiques au sein de la coopérative peuvent être formels ou informels (Liang et al., 2018). La gouvernance formelle émane de la loi coopérative qui fixe les règles juridiques et les pratiques des coopératives (Fici, 2013) tandis que la gouvernance informelle ou relationnelle repose sur les normes sociales telles que le capital social (Poppo & Zenger, 2002). Par définition, le capital social "fait référence aux caractéristiques de l'organisation sociale, telles que les réseaux, les normes et la confiance, qui facilitent la coordination et la coopération pour un bénéfice mutuel" (Putnam, 1993, p. 1). Conceptuellement, le capital social se compose de trois dimensions distinctes (Figure 0 1) : structurelle, cognitive et relationnelle (Nahapiet & Ghoshal, 1998). La mesure du capital social peut être opérationnalisée en fonction de ces dimensions. La dimension structurelle inclue les réseaux tandis que l'aspect cognitif met l'accent sur les représentations des membres des coopératives. Quant à la dimension relationnelle, elle comprend les valeurs sociales telles que la confiance.

Figure 0 1 : Gouvernance relationnelle et formelle selon Nahapiet et Ghoshal (1998)



Source : Inspiré de Nahapiet et Ghoshal (1998)

0.1.2 Investissement (environnemental)

L'investissement peut être définit comme étant « l*a formation de capital – l'acquisition ou la création de ressources destinées à être utilisées dans la production* » (Coen et al., 2008). La décision d'investissement est critique dans la mesure où elle implique le choix d'une action parmi des actions alternatives (Turtiainen & Von Pischke, 1986), un choix pouvant déterminer les gains futurs de la coopérative (Cotterill, 1987). L'investissement présente différentes caractéristiques. Premièrement, il est volontaire. Dans une coopérative, il reflète à la fois les préférences individuelles des membres et celles de la coopérative. En effet, la décision d'investir est privée (réservée aux membres), cependant, la quantité d'investissement à réaliser peut-être soumise à l'organisation coopérative (Condon, 1990). Ensuite, différents attributs peuvent être associés à l'investissement. Ils peuvent être conventionnels, environnementaux (Khalil & Nimmanunta, 2022), éthiques ou socialement responsables[9] (Michelson et al., 2004). Contrairement aux investissements conventionnels, les autres types d'investissements (environnementaux, éthiques, socialement responsable) sélectionnent des actifs respectant les critères environnementaux, sociaux, éthiques et de bonne gouvernance (Revelli & Sentis, 2012). Par ailleurs, bien que les concepts d'investissement environnemental et éthique sont souvent utilisés de façon interchangeable, il est important de noter qu'ils diffèrent (Talan & Sharma, 2019). En effet, les investissements environnementaux se focalisent uniquement sur des enjeux environnementaux tandis que les investissements éthiques englobent en plus des enjeux environnementaux, d'autres enjeux, notamment sociaux.

Notre intérêt porte principalement sur les investissements environnementaux qui permettent à une organisation de minimiser son impact environnemental. Ces investissements peuvent être liés à l'acquisition d'une nouvelle technologie (Bostian et al., 2016), à l'implémentation d'un système de gestion environnementale, à la recherche et le développement (Bhuiyan et al., 2021). Toutefois ce travail se limite aux investissements en actifs environnementaux réalisés par la CUMA. Ces coopératives encouragent des pratiques agricoles respectueuses de l'environnement en privilégiant des équipements pouvant limiter l'impact environnemental des adhérents L'application des investissements environnementaux aux coopératives renvoie toutefois à un débat plus large sur la relation entre les coopératives et l'environnement qui reste peu documenté. Par exemple, pour Drapéri (2018) dans un contexte marqué par les défis environnementaux,

[9] La terminologie varie selon les pays : *investissement éthique* est privilégié au Royaume-Uni tandis qu'investissement *socialement* responsable est utilisé aux États-Unis (Michelson et al., 2004).

l'engagement environnemental serait un enjeu et une condition à la réalisation d'un projet coopératif.

0.1.3 Déterminants de l'investissement

Plusieurs facteurs peuvent déterminer l'investissement coopératif qu'il soit environnemental ou non. Ces facteurs peuvent être internes ou externes. Les facteurs internes concernent les dimensions de la gouvernance interne de la coopérative. En effet, certains auteurs (Cook, 1995) indiquent que les coopératives sont limitées dans leur capacité à investir en raison du manque de clarté de leurs droits de propriété causant différents problèmes de gouvernance[10]. Ces problèmes incluent le problème d'horizon et de portefeuille. Le problème d'horizon est lié au fait que la période sur laquelle un membre de la coopérative bénéficie du droit de rendement résiduel sur un actif est en général plus courte que la durée de vie de cet actif (Porter & Scully, 1987). Malgré un support conceptuel, les preuves empiriques du problème d'horizon sont rares et peu concluantes. Pour certains auteurs, le problème d'horizon a tendance à limiter les incitations d'investissement chez les membres âgés (Cook, 1995). Pour Olesen (2007), les membres ont plutôt tendance à surinvestir. Fahlbeck (2007) ne trouve pas de problème d'horizon en s'intéressant aux membres des coopératives suédoises tandis que les résultats de Franken et Cook (2019) suggèrent le contraire. Un autre problème susceptible de limiter l'investissement est le problème de portefeuille (Royer, 1999). Ce problème vient du fait que les investissements réalisés par la coopérative ne correspondent pas nécessairement aux préférences individuelles des adhérents (Olesen, 2007). Le problème de portefeuille peut se décliner sous sa forme latérale et verticale (Plunkett, 2005). Dans le premier cas, une forte diversification des produits au sein de la coopérative tend à limiter l'investissement en raison des conflits entre des adhérents spécialisés. Le problème de portefeuille vertical, quant à lui, découle des conflits entre les membres présentant des caractéristiques différentes, au sein d'une coopérative se focalisant sur un seul produit. Par exemple, comparativement aux exploitations de petites tailles, les grandes exploitations seraient plus favorables aux projets d'investissements innovants de la coopérative (Franken & Cook, 2019). D'autres auteurs constatent que les problèmes de gouvernance liés aux droits de propriété s'accentuent avec l'hétérogénéité des membres (Cook, 2018). L'hétérogénéité des membres a tendance à accentuer l'hétérogénéité des préférences d'investissement, aggravant

[10] Les autres problèmes évoqués dans la littérature sont : le passager clandestin, le problème de contrôle et les coûts d'influence (Royer, 1991)

de ce fait le problème de portefeuille. Cependant, l'effet d'hétérogénéité reste contrasté, car pouvant être bénéfique pour la coopérative (Groos et al., 2021). D'autres déterminants internes de l'investissement concernent la capacité de la coopérative à accéder au financement externe (Chaddad et al., 2005). Les CUMA dépendent largement du financement extérieur pour le financement de leurs investissements. En France, 65 % de l'investissement est financé par les emprunts tandis qu'au Québec, les emprunts représentent environ 80 % de l'investissement (FNCUMA, 2021; MAPAQ, 2018). En présence d'une contrainte financière, les CUMA sont limitées dans leurs investissements. L'effet de la contrainte financière est accentué par d'autres caractéristiques telles que la taille. En effet, les firmes de petites tailles sont plus enclines à la contrainte financière en raison de leur âge, ce qui les rend plus vulnérables aux imperfections du marché (Schaller, 1993). Chaddad et al.(2005) obtiennent des résultats similaires en testant l'hypothèse de la présence d'une contrainte financière sur les coopératives aux États-Unis. Le capital social constitue aussi un déterminant de l'investissement (Alho, 2015; Knack & Keefer, 1997). Le capital social est important surtout dans un contexte où les mécanismes de coordinations formels sont défaillants au sein de la coopérative (Diakité et al., 2022). L'absence de capital social limite l'implication des membres tout en fragilisant la pérennité de la coopérative (Nilsson et al., 2012). Par ailleurs, différents facteurs externes peuvent influencer l'investissement des coopératives, notamment les politiques publiques (Ferrier & Porter, 1991) ou le contexte sociogéographique (Filippi, 2014). Par exemple, une législation fiscale favorable[11] et l'octroi de subvention publique sont susceptibles d'améliorer la capacité d'investissement des coopératives en baissant les coûts d'accès aux inputs (Ferrier & Porter, 1991). Ces politiques peuvent aussi affecter négativement les coopératives en masquant leur inefficience (Porter & Scully, 1987), ou limiter leur champ d'action (Chomel, 2006). Finalement, le contexte sociogéographique est susceptible d'encourager (ou de décourager) l'investissement au sein de la coopérative en raison des effets de pairs en membres (Filippi, 2014) , ou des préférences et des caractéristiques sociales des parties prenantes (Kassinis & Vafeas, 2006).

[11] En France, les CUMA sont exonérées de l'impôt sur les sociétés. L'avantage de cette exonération réside notamment dans la capacité des coopératives à produire à un coût moyen faible comparativement aux firmes (Porter & Scully, 1987)
https://www.impots.gouv.fr

0.1.4 Performance des cooperatives agricoles

Théoriquement, le concept de performance des coopératives est ambigu (Rousselière et al., 2020). Dans une entreprise classique, la notion de performance est généralement associée à la maximisation du profit (Friedman, 2007). Pour une coopérative agricole, cette notion va plus loin que la seule rentabilité financière et économique pour prendre en compte l'efficacité sociale et la légitimité institutionnelle (Bagnoli & Megali, 2011). L'efficacité sociale inclue l'utilisation responsable des intrants par la coopérative, les impacts sociaux et économiques de la coopérative sur les membres mais aussi, les retombées de l'activité coopérative pour la société globale sur le long terme (Mertens & Marée, 2012). De plus, une coopérative doit prouver sa légitimité institutionnelle, c'est-à-dire sa capacité à s'inscrire dans un cadre légal défini. Afin de prendre en compte son caractère multidimensionnel, la performance coopérative peut être définie comme étant « *sa production élargie, c'est-à-dire à l'ensemble constitué de l'output, des impacts directs et des impacts indirects sous forme d'externalités* » (Porter & Scully, 1987)

0.2 Gouvernance coopérative, investissement en actifs environnementaux et performance

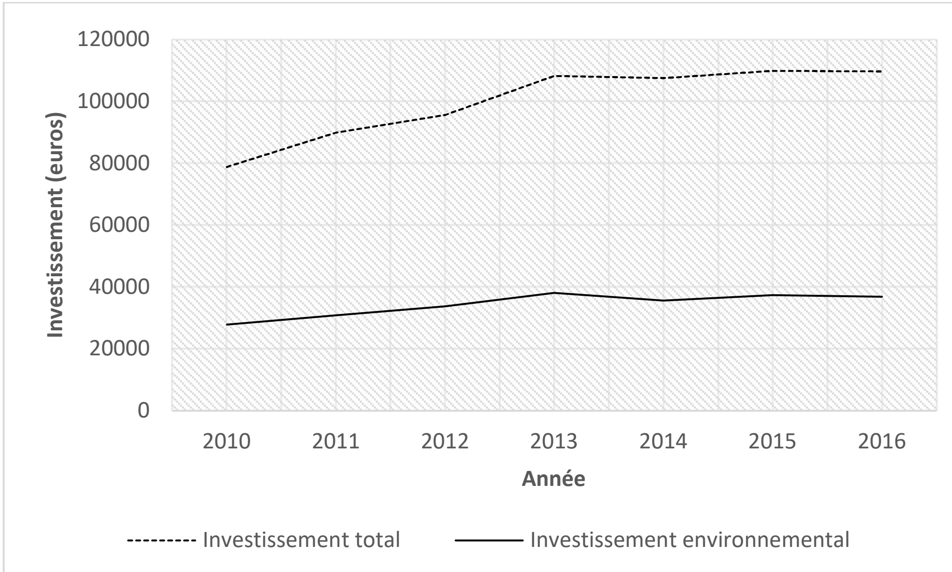
0.2.1 Gouvernance coopérative : importance du capital social

Comme indiqué dans les définitions, la gouvernance coopérative prend en compte aussi bien les mécanismes formels qu'informels. Bien que s'inscrivant dans un cadre légal formel, plusieurs études montrent l'importance de la gouvernance informelle. En effet, les coopératives sont considérées comme des organisations fondées sur le capital social puisque « *la coordination interne et l'allocation des ressources dans les coopératives sont principalement déterminées par la qualité des relations interpersonnelles entre ses membres* » (Valentinov, 2004, p. 10). En France, l'émergence et la longévité des CUMA repose sur l'étroitesse des liens entre les membres (dimension relationnelle du capital social) et sur une organisation en fédération favorisant un rapprochement des CUMA (dimension structurelle du capital social) (Herbel et al., 2015). Malgré son importance, le rôle du capital social est ambigu et variable selon la présence ou l'absence d'une gouvernance formelle. En effet, un excès de capital social peut induire un manque d'objectivité dans la coopérative, ou une recrudescence des comportements opportunistes (Villena et al., 2011). Dyer et Singh (1998) suggèrent que les mécanismes relationnels tels que la confiance encouragent les abus par un comportement opportuniste exacerbé entre les partenaires. D'autres auteurs montrent que le rôle du capital social est plus important lorsqu'il est complémentaire aux mécanismes de gouvernance formels (Liang et al., 2018; Slade Shantz et al., 2020). Avec ces études, l'importance du capital social est moins concluante. Les raisons des divergences dans les résultats peuvent s'expliquer par les différences méthodologiques. Les études ne captant que les aspects positifs du capital social sont théoriques sans une vérification empirique de leurs hypothèses (Nilsson et al., 2012; Valentinov, 2004) tandis que les études mettant aussi en avant ses aspects négatifs sont pour la plupart empiriques (Villena et al., 2011). Par ailleurs, bien que les études empiriques relativisent l'importance du capital social, elles posent à leur tour des problèmes méthodologiques. Par exemple, ces études utilisent le plus souvent une approche quantitative ce qui peut soulever un problème de mesure du capital social. L'analyse du capital social nécessite d'une part une approche méthodologique appropriée puisque ce concept est complexe (Stiglitz, 2000). D'autre part, le fait que les CUMA s'insèrent dans un cadre légal défini interroge la façon dont le capital social et la gouvernance formelle interagisse ensemble et comment le capital social peut influencer les investissements en actifs environnementaux.

0.2.2 Actifs environnementaux : déterminants et performance des CUMA

Les CUMA sont considérées comme des coopératives d'investissement (Le Guernic, 2021) L'intérêt de l'investissement réside dans le fait que les CUMA diversifient leurs investissements en intégrant la dimension environnementale. En moyenne, les investissements en actifs environnementaux en CUMA ont suivi une tendance plutôt croissante (Figure 0 2)

Figure 0 2: : Évolution des investissements moyens
Cas des CUMA en France sur la période 2010-2016



Source : Calcul de l'auteur

Compte tenu de leur impact environnemental potentiel, l'enjeu pour les décideurs est d'identifier les facteurs pouvant stimuler l'investissement en actifs environnementaux en CUMA. L'effet des facteurs externes tels que les subventions est souvent relevé. En effet, l'octroi des subventions aux CUMA en France marque la volonté des décideurs publics à encourager l'implication environnementale de ces coopératives. Cependant, d'autres facteurs internes sont susceptibles d'influencer les investissements environnementaux coopératifs en raison de leurs spécificités. Par exemple, puisque les bénéfices liés aux investissements environnementaux ne sont obtenus que sur le long terme (Bhuiyan et al., 2021), le problème d'horizon pourrait freiner la capacité des CUMA à réaliser des investissements en actifs environnementaux. En plus, les CUMA favorisent des collaborations horizontales informelles entre les adhérents ce qui est favorable à l'adoption de pratiques environnementales (Lucas et al., 2019). En d'autres termes, le capital social est susceptible d'influencer l'implication environnementale des CUMA. Une compréhension approfondie des facteurs susceptibles d'influencer l'investissement en actifs environnementaux des CUMA implique donc la prise en compte des facteurs externes et internes. Finalement, en adoptant des pratiques environnementales, les coopératives visent également une amélioration de leur performance (meilleur revenu des adhérents via une différenciation des produits (Filippi, 2020)). Différentes études ont investigué la relation entre les investissements en actifs environnementaux et la performance des firmes (Bostian et al., 2016). A notre connaissance, aucune étude n'a été réalisée dans le contexte des coopératives agricoles, plus spécifiquement dans le cas des CUMA. En effet, les exemples empiriques d'un engagement environnemental sont rares. Un article démontrant l'implication environnementale des coopératives est celui de Filippi (2020) où l'auteure questionne la responsabilité sociale des coopératives agricoles en France. Des questions restent toutefois posées sur les effets de cette implication environnementale sur la performance des coopératives. En se basant sur l'importance du capital social pour les CUMA et les limites des études existantes, considérant les enjeux sociaux liés aux investissements environnementaux et la problématique de leurs effets sur la performance des CUMA, cette thèse s'intéresse à trois questions spécifiques :

- Quelle est la nature et la relation entre les mécanismes de gouvernance formelle et informelle, comment ces mécanismes se combinent à l'échelle des membres d'une CUMA ?
- Quels sont les déterminants de l'investissement en actifs environnementaux en CUMA ?
- Quel est l'effet des investissements en actifs environnementaux sur la performance des CUMA ?

Nous abordons ces trois questions à travers trois essais réalisés au Québec (Canada) et en France. L'émergence des CUMA est relativement récente au Québec. Il faut attendre les années 1991 pour voir la première CUMA émerger dans le Bas-Saint-Laurent[12] à partir d'un groupe de 10 producteurs. Aujourd'hui, on en dénombre une soixantaine (MAPAQ, 2018). En France, la mise en place des CUMA se situe dans l'après 2e guerre mondiale où l'achat collectif de la machinerie agricole, surtout pour les petites exploitations. Aujourd'hui, près d'un agriculteur sur deux adhère à une CUMA (FNCUMA, 2021).

[12] Le Bas-Saint-Laurent est une région administrative située au nord-est de la ville de Québec. Cette région est fortement agricole, 35 % de l'industrie bioalimentaire, selon le Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ, 2019)

0.3 Une démarche globale s'appuyant sur une méthode mixte : De l'étude de cas aux analyses économétriques sur les frontières de production

Afin de répondre aux trois questions, cette thèse utilise une méthode mixte, c'est-à-dire une méthode combinant approche qualitative et quantitative. Jonhson et al.(2007) proposent la définition suivante des méthodes mixtes : *« La recherche par méthodes mixtes est le type de recherche dans lequel un chercheur ou une équipe de chercheurs combine des éléments des approches de recherche qualitative et quantitative (par exemple, l'utilisation de points de vue qualitatifs et quantitatifs, la collecte de données, l'analyse, les techniques d'inférence) avec l'objectif général d'assurer l'ampleur et la profondeur de la compréhension et de la corroboration »* (Johnson et al., 2007, p. 123). La combinaison des approches qualitatives et quantitatives peut se faire de différentes façons à savoir (Starr, 2014) : (i) conduire une phase qualitative exploratoire suivie d'une approche quantitative permettant de généraliser les résultats ; (ii) compléter une étude quantitative suivie d'entretiens approfondis permettant d'enrichir les résultats ; (iii) utiliser de façon simultanée l'approche qualitative et quantitative dans l'analyse des résultats.

0.3.1 Étude de cas multiple

Nous utilisons une méthode qualitative pour analyser la première question de recherche et générer différentes hypothèses en lien avec la gouvernance des CUMA. Précisément, nous utilisons une étude de cas multiple basée sur des entretiens semi-dirigés (Yin, 2018). L'intérêt de l'étude de cas multiples par rapport à l'étude de cas simple est sa robustesse puisque plusieurs CUMA sont interrogées. Bien que cette étude se focalise sur l'étude de cas multiple, il existe d'autres méthodes qualitatives alternatives. Ces méthodes présentent différentes limites comme la montre le Table 0 1.

Table 0 1 : Approches qualitatives non retenues

Autres stratégies	Auteurs	Faiblesses dans le contexte de l'étude
Recherche historique	(Yin, 2018)	S'appuie uniquement sur les faits passés et donc ne reflète pas nécessairement le contexte actuel des CUMA
Enquête		La rigidité du questionnaire
Analyse d'archive		Les CUMA ont été très peu documentés et les données existantes n'ont souvent pas été actualisées.
Théorie ancrée[13]	(Glaser & Strauss, 2017)	L'objectif de notre question de recherche n'est pas d'aboutir nécessairement à une théorisation, mais plutôt d'analyser en profondeur la gouvernance des CUMA

Source : Auteur

0.3.2 Mesure de la performance coopérative

0.3.2.1 État de l'art sur la mesure de la performance coopérative

En raison du caractère multidimensionnel des coopératives, Nicholls (2009) indique que l'analyse de la performance des entreprises sociales nécessite une définition claire de ce qu'on cherche à mesurer et de la façon de le mesurer. Globalement, les études empiriques portant sur les coopératives sont diversifiées quant à ce qui est mesuré et à la méthodologie adoptée. Dans ces études, la façon de mesurer la performance est fonction des objectifs de la coopérative Soboh et al., 2009), de la perspective de l'étude pouvant être focalisée sur la rentabilité financière, économique ou non de la coopérative, de son impact sur les groupes d'intérêts en présence (membre, organe de gestion, société globale) (Hind, 1999).

En termes d'objectifs, Soboh et al.(2009) passent en revue une grande partie de la littérature sur la mesure de la performance des coopératives de commercialisation. Leur revue montre que la plupart des études théoriques mesurent la performance en mettant l'accent sur le profit des membres en adoptant une approche néoclassique de maximisation du profit. Par ailleurs, la performance coopérative est modélisée aussi en prenant en compte des critères économiques tels que le revenu des membres, le prix bord-champ, la qualité du produit ou l'efficience (Getnet & Anullo, 2012; Pennerstorfer & Weiss, 2013). Particulièrement, l'efficience a été largement utilisée dans la littérature coopérative via des modèles de frontières stochastiques ou non

[13] La théorie ancrée permet de formuler une théorie à partir d'une observation empirique d'un phénomène (Creswell & Creswell, 2007)

paramétriques. L'intérêt de ces modèles est leur capacité à modéliser la performance de la coopérative en prenant en compte l'ensemble des inputs. D'autres mesures de performance mettent davantage l'accent sur les ratios financiers (la liquidité, la productivité, la solvabilité) (Harris & Fulton, 1996). Ces ratios donnent un aperçu rapide de la condition de la coopérative dans différents domaines (Soboh et al., 2009). Cependant, en raison de la multiplicité des objectifs coopératifs, Franken et Cook (2015a) proposent que la performance coopérative soit conceptualisée comme un construit combinant deux variables latentes : (i) une variable latente captant la performance financière et instrumentée par le ROA (return on assets), le ROE (return on equity) et l'EVI (extra-value index)[14] ; (ii) une autre variable latente pour capter la performance non financière mesurée par la compétitivité, la satisfaction des membres et l'atteinte des objectifs. La mesure de la performance coopérative concerne aussi leur impact sur les groupes d'intérêt en présence, notamment les sociétaires ainsi que la société globale (Verhofstadt & Maertens, 2015). Les méthodes d'évaluation d'impact appliquées aux coopératives agricoles sont multiples (Rousselière et al., 2020). Le Table 0 2 présente un résumé des principales méthodes de mesure de la performance coopérative rencontrées dans la littérature.

Les méthodes de comptage permettent d'évaluer la performance de la coopérative en inventoriant les actifs détenus ou les revenus générés (Deller et al., 2009; Ketilson, 1998). D'autres méthodes (MCS ou Modèle d'équilibre général calculable) permettent d'évaluer l'impact de la coopérative au niveau macroéconomique. Par exemple, Karaphilis et al. (2017) constate que le secteur coopératif a connu une augmentation de 9 % de sa contribution au PIB au Canada. Une autre façon d'évaluer l'impact d'une coopérative consiste à mesurer les coûts supportés et les bénéfices réalisés par les adhérents. Un exemple d'étude empirique est fourni par Harris et Fulton (2000a) fournissent un exemple empirique en montrant que l'adhésion à une CUMA implique une baisse de 35 % des coûts de machinerie comparativement à un producteur non adhérent. De plus, une méthode ignorée le plus souvent concerne les approches qualitatives d'évaluation d'impact. Mojo et al(2017) utilisent cette méthode pour mettre en évidence les défaillances dans les services[15] proposés par les coopératives en Éthiopie qui expliqueraient le faible revenu des membres par rapport aux non-membres.

[14] L'EVI est un index de mesure de performance développé par le département de l'agriculture aux États-Unis (Liebrand, 2008).

[15] Les auteurs montrent que les coopératives dans le contexte de l'étude pratiquent de l'achat latéral via des non-adhérents, ce qui n'améliore pas les revenus des producteurs.

Finalement, certaines études (Mojo et al., 2015; Verhofstadt & Maertens, 2015) utilisent l'approche basée sur l'existence d'un contrefactuel, c'est-à-dire le résultat qui aurait été obtenu par les adhérents s'ils n'avaient pas été membres de la coopérative. Cette approche fait appel des méthodes d'évaluation telles que l'appariement (Rosenbaum & Rubin, 1983) ou celle de la différence en différence. Cette dernière méthode est utilisée par Jardine et al.(2014) pour évaluer l'effet des coopératives de ventes sur la qualité des produits et des prix des produits offerts.

Table 0 2 : Méthodes d'évaluation de la performance appliquées aux coopératives agricoles

Approches méthodologiques	**Description de la méthode**	**Hypothèses**
Modèle de comptage (Deller et al., 2009; Ketilson, 1998)	Méthode ayant pour but d'évaluer la taille d'une coopérative en inventoriant les actifs détenus, les investissements réalisés, les revenus et les profits générés	Fiabilité des dondnées
Matrix de comptabilité de sociale (MCS) (Zeuli & Deller, 2007)	Tableau qui synthétise l'ensemble des flux de transactions dans une économie donnée. Ces données servent de base pour les modèles d'équilibre général calculable	Suppose une uniformité de la technologie dans la production (Keuning & de Ruuter, 1988) Suppose une absence d'avantages non pécuniaires (Rousselière et al., 2020)
Modèle d'équilibre général	Modèle désagrégeant chaque flux de transaction dans la MCS en une composante de prix et de quantité. Ces modèles permettent de faire des simulations à partir d'une série d'équations simultanées à l'équilibre.	Suppose un équilibre sur tous les marchés Aucune transaction n'est réalisée avant l'équilibre (Borges, 2005)
Analyse coût-bénéfice (Borzaga & Depedri, 2013; Harris & Fulton, 2000a)	Méthode permettant d'analyser les coûts et les bénéfices associés à une politique donnée	Suppose la prise en compte de l'ensemble des coûts et de bénéfices et la capacité de les mesurer (Meunier & Marsden, 2009)
Focus group discussion (Mojo et al., 2017)	Méthodes qualitatives basées sur une discussion interactive entre les individus d'un groupe.	
Méthodes à contrefactuel		

Méthode de l'appariement (Mojo et al., 2015; Verhofstadt & Maertens, 2015)	Approche permettant d'estimer un effet causal en appariant les individus ayant des caractéristiques observables semblables	Présence d'un contrefactuel La différence entre les individus traités et non traités est captée uniquement dans les variables observables
Différence en Différence (Jardine et al., 2014)	Mesure les résultats avant et après un programme et compare ces résultats à un contrefactuel	Suppose une tendance équivalente, c'est-à-dire, le fait que le groupe de traitement aurait la même évolution que le groupe de contrôle si aucun traitement n'avait été réalisé (Gertler et al., 2011)

Source : Inspiré de Uzea and Duguid (2015)

0.3.2.2 Limites des méthodes existantes

Bien que s'inscrivant dans des contextes donnés, les différentes approches de modélisation de la performance présentent différentes faiblesses théoriques. Premièrement, comme le montre le Table 0 2, la plupart des méthodes existantes reposent sur des hypothèses restrictives. Par exemple, limiter l'objectif de la coopérative à la maximisation du profit des membres est réducteur puisque les membres poursuivent aussi des objectifs sociaux d'entraide, de partage d'expérience et de solidarité (Lucas et al., 2019). Par ailleurs, bien que les ratios financiers soient couramment utilisés, ils manquent d'une base solide dans la théorie économique, et peuvent être influencés par les politiques publiques de soutien destinées aux coopératives (Sexton et al., 1993). Dans la même logique, ces ratios financiers sont incapables de refléter les activités non comptabilisées pourtant présentes dans les activités de la coopérative. C'est le cas des activités de bénévolat (Leviten-Reid & Campbell, 2016). La MCS ou l'approche d'équilibre général calculable, en plus des hypothèses, peut poser des problèmes empiriques d'accès aux données pertinentes. L'inexistence de base donnée publique sur les coopératives constitue un problème majeur dans les études coopérative (Rousselière et al., 2020). Finalement, l'approche à contrefactuel repose sur l'identification d'un groupe de contrôle, ce qui peut être problématique dans le contexte des coopératives. La raison est que la coopérative peut être exposée à des comportements du type « passager clandestin externe » (Iliopoulos, 2003) permettant aux non-membres d'avoir indirectement accès au service de la coopérative. En raison des limites associées aux approches présentées, cette thèse modélise la performance de la CUMA en utilisant le cadre des frontières. L'intérêt de cette approche est qu'elle permet de construire une frontière permettant de définir l'efficience de la coopérative. Les modèles de frontières n'assument pas nécessairement un comportement économique explicite de minimisation de coût ou de maximisation du profit à la coopérative (Kumbhakar et al., 2015). Dans la section suivante, une brève revue de littérature sur les modèles de frontière est réalisée.

0.3.2.3 Une approche par les frontières de production

Dans cette section, nous utilisons l'annotation **x** et **y** pour désigner un vecteur d'inputs et d'outputs non négatifs ; f désigne une fonction de production.

- **Représentation d'une technologie**

La production est représentée le plus souvent par une technologie (Coelli et al., 2005) :

$$T = \left\{ \left(\mathbf{x}, \mathbf{y} \right) : \mathbf{x} \text{ peut produire } \mathrm{y} \right\} \tag{1}$$

Où : T est un ensemble comprenant tous les vecteurs inputs-outputs tels que **x** peut produire **y**. Une façon équivalente de décrire la technologie est de la présenter en termes d'outputs ou d'inputs. Pour un output, si $P\left(x\right)$ représente l'ensemble des vecteurs **y** que peut produire **x, la** technologie peut être représentée comme suit :

$$P\left(\mathbf{x}\right) = \left\{ \mathbf{y} : \mathbf{x} \text{ peut produire } \mathrm{y} \right\} = \left\{ \mathbf{y} : \left(\mathbf{x}, \mathbf{y} \right) \in T \right\} \tag{2}$$

De même, pour un input, la technologie peut être représentée par :

$$L\left(\mathbf{y}\right) = \left\{ \mathbf{x} : \mathbf{x} \text{ peut produire } \mathbf{y} \right\} = \left\{ \mathbf{x} : \left(\mathbf{x}, \mathbf{y} \right) \in T \right\} \tag{3}$$

Ces représentations de la technologie sont soumises à différentes hypothèses restrictives telles que la convexité, ou le fait qu'il est possible de produire zéro output (Coelli et al., 2005). Cependant, les définitions de la technologie présentée sont utiles pour mesurer l'efficience dans le contexte de modèle non paramétrique. Dans le cas des modèles paramétriques, les fonctions de distance sont utilisées (Shephard, 2012). Ces fonctions permettent de définir une technologie à plusieurs inputs et outputs. Mathématiquement, une fonction de distance en output peut être représentée comme suit :

$$D_o\left(\mathbf{x}, \mathbf{y}\right) = \min \left\{ \theta, \frac{\mathbf{y}}{\theta} \in P\left(\mathbf{x}\right) \right\} \tag{4}$$

Où θ reflète l'expansion maximale d'un vecteur d'outputs tels que ce vecteur atteigne la frontière. Cette fonction est homogène en output (Kumbhakar et al., 2009). Dans le cas d'une fonction de distance en input, la technologie reflète la contraction maximum λ des inputs étant donné un vecteur d'outputs :

$$D_I\left(\mathbf{x},\mathbf{y}\right) = \max\left\{\lambda, \frac{\mathbf{x}}{\lambda} \in L\left(\mathbf{y}\right)\right\} \tag{5}$$

Les fonctions de distance présentées impliquent soit une orientation en input ou en output. Une combinaison des deux orientations impliquent une fonction de distance hyperbolique permettant de prendre en compte de façon simultanée une contraction en input et une expansion en output (Cuesta & Zofío, 2005) :

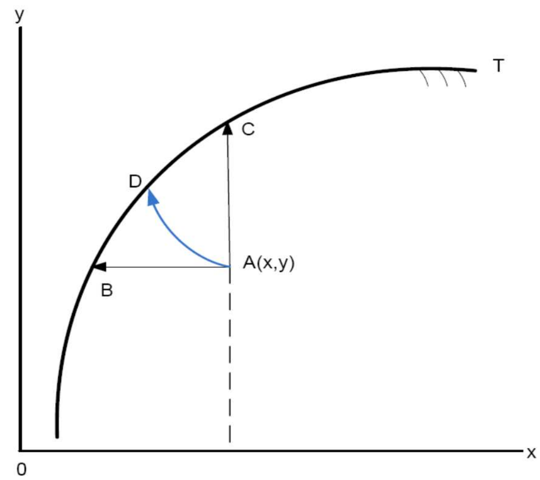
$$D_H\left(\mathbf{x},\mathbf{y}\right) = \inf\left\{b > 0 : \left(\mathbf{x}b, \mathbf{y}b^{-1}\right) \in \mathrm{T}\right\} \tag{6}$$

Cette fonction est homogène de degré 1 en output et de -1 en input. Graphiquement, b représente un scalaire contractant les inputs et les outputs tels que le point A (x,y) soit sur la frontière (Figure 0 3). Une orientation en input correspondrait à la distance $\overline{AB}$ tandis qu'une orientation en output impliquerait une expansion, soit la distance $\overline{AC}$ .Récemment, les fonctions de distance améliorée ont été suggérées pour prendre en compte des mauvais outputs (Cuesta et al., 2009) (pollution par exemple), ou pour introduire l'investissement dans la technologie (Minviel & Sipiläinen, 2018). Une fonction de distance améliorée est une extension de la fonction de distance hyperbolique. Elle peut s'écrire :

$$D_E\left(\mathbf{x},\mathbf{y},I\right) = \inf\left\{b > 0 : \left(\mathbf{x}b, \mathbf{y}b^{-1}, Ib\right) \in \mathrm{T}\right\} \tag{7}$$

Où I désigne l'investissement. La fonction de distance améliorée contracte simultanément les inputs, les investissements et les outputs. Elle est homogène de degré 1 en output et en investissement, et de -1 en input.

Figure 0 3: Fonction de distance hyperbolique



Source : Silva and Stéfanou (1951)

- **Efficience comme mesure de la performance et approches de mesure**

Le concept d'efficience peut remonter jusqu'à Koopman (1951), Farell(1957) . Farell(1957) suggère que le concept d'efficience comprend une efficience technique qui reflète la capacité d'une organisation à obtenir un niveau d'output maximal pour un niveau d'input donné, et une efficience allocative qui est la capacité de l'organisation à utiliser les inputs de façon optimale. Dans le cas particulier d'un seul output et input, la distance $\overline{AC}$ reflète la perte d'efficience liée à une utilisation non optimale de l'input. Une approximation de l'efficience suivant l'orientation en output est donnée par l'expression 1- $\overline{AC}$ (Kumbhakar et al., 2009). Dans un contexte de plusieurs inputs et outputs, l'efficience technique (ET) proposée par Farell (1957) peut s'écrire $ET_I = 1/D_I(x,y)$ pour une fonction distance en input et $ET_o = D_o(x,y)$ pour une fonction de distance en output. Une coopérative est efficiente si ET=1, dans le cas contraire elle est inefficiente. Cette mesure peut être généralisée aux fonctions de distance hyperbolique où $ET_H = 1/D_H(x,y)$. Dans le cas où un comportement économique de minimisation des coûts est supposé, il est possible de mesurer une efficience de coût (EC) telle que $EC(x,y,w) = c(y,w)/w'x$ où c est une fonction de coût et w le prix des inputs. Une efficience locative peut en être déduite en faisant le rapport entre l'efficience de coût et l'efficience technique (Emvalomatis, 2009).

- **Approche de mesure**

La mesure de l'efficience repose sur deux approches à savoir les méthodes non paramétriques et les méthodes paramétriques (Coelli et al., 2005). Les méthodes non paramétriques utilisent des techniques comme la Data Envelopment Analysis (DEA) premièrement introduite par Farell (1957). Les méthodes non paramétriques ne font aucune hypothèse sur la forme fonctionnelle de la fonction de production. Cependant, ces méthodes présentent différentes limites telles que la sensibilité des résultats aux variables extrêmes, ou l'introduction des erreurs de mesure puisqu'elles sont déterministes par nature (Coelli et al., 2005). Contrairement aux modèles non paramétriques, les modèles paramétriques imposent une forme fonctionnelle à la fonction de production et captent à la fois l'aspect déterministe et aléatoire. Dans le cas d'un seul input et output, un modèle paramétrique simple peut s'écrire :

$$\log y = \log f\left(x;\beta\right) + v - u \tag{8}$$

Où β constitue un vecteur de paramètres à estimer ; v un terme d'erreur et u l'inefficience. Les modèles paramétriques reposent sur l'hypothèse de l'exogénéité des inputs et l'indépendance de v et u. Dans cette thèse, nous utilisons à la fois l'approche paramétrique et non paramétrique pour modéliser la performance des CUMA.

0.3.2.4 Application des modèles de frontières stochastiques aux coopératives agricoles

- **Les études existantes**

Différentes études analysent l'efficience des coopératives en utilisant les modèles de frontières. Ces études se diversifient en termes d'hypothèses retenues sur le comportement économique de la coopérative. Certains auteurs (Akridge & Hertel, 1992; Kebede & Schreiner, 1996; Singh et al., 2001) associent à la coopérative un comportement de minimisation des coûts ou de maximisation des profits. D'autres auteurs sont plus flexibles sur le comportement économique de la coopérative en utilisant une fonction de distance (Ariyaratne et al., 2006; Porter & Scully, 1987). Les modèles de frontières appliquées aux coopératives se distinguent aussi par la méthode de mesure de l'efficience. Ces méthodes peuvent être paramétriques ou non paramétriques (Akridge & Hertel, 1992; Kebede & Schreiner, 1996). Finalement, les résultats obtenus par ces études diffèrent. Par exemple, en comparant les coopératives aux entreprises à investissements privés, Porter et Scully(1987) concluent que les coopératives sont inefficientes avec un score d'efficience de 90 %. tandis que les résultats de Kebede et Schreiner (1996) montrent un résultat différent. En suivant la même démarche que Porter et Scully (1987), Soboh et al.(2012) montrent que les coopératives sont techniquement inefficientes avec une efficience moyenne de 42 %. Par contre, les résultats de Singh et al.(2001) suggèrent une efficience en coût des coopératives de commercialisation avec une efficience moyenne de 92 %.

- **Les limites**

Différentes observations peuvent être faites à partir des études existantes. Premièrement, la plupart des études répertoriées s'intéressent aux coopératives de commercialisation. De ce fait, les hypothèses de maximisation de profit ou de minimisation de coûts sont plausibles (Sexton et al., 1989). Cependant, l'hypothèse d'une maximisation est inapplicable dans une CUMA dans la mesure où l'objectif de la CUMA n'est pas associé à la production d'un bien marchand. De même, la minimisation des coûts est davantage une contrainte à satisfaire pour une CUMA qu'un objectif. D'autre part, des défis méthodologiques majeurs se posent dans la mesure de l'efficience. Premièrement, en analysant l'efficience, la plupart des études considèrent un cadre statique, c'est-à-dire, suppose la capacité de la coopérative à ajuster tous ses inputs dans le court terme. Par exemple, Porter et Scully (1987) estiment une efficience statique en considérant que le capital est ajustable dans le court terme. Cependant, cette hypothèse est restrictive dans la mesure où que les inputs quasi fixes ne sont ajustables que dans le long terme (Kumbhakar et al., 2009). Pour une CUMA, il devient difficile d'ajuster dans le court terme la capacité technique d'un équipement une fois l'investissement réalisé. Analyser l'efficience dans un cadre statique alors que les décisions d'ajustements sont réalisables sur le long terme peut biaiser les scores d'efficience (Minviel & Sipiläinen, 2018). De plus, très peu d'études antérieures traitent l'endogénéité. L'endogénéité peut découler d'un problème de simultanéité, le fait que les performances passées de la coopérative affectent la gouvernance qui en retour influence les performances actuelles et futures. Elle peut être liée aussi à un problème de variable omise. Par exemple, la capacité d'investissement d'une coopérative est liée à la présence ou à l'absence d'une contrainte financière qui constitue une variable omise dans la plupart des études antérieures. En cas d'endogénéité, l'estimation des scores d'efficience est biaisée (Mutter et al., 2013). Par conséquent, dans cette thèse, nous considérons que la mesure de la performance des CUMA implique :

- L'utilisation d'une approche moins restrictive concernant le comportement économique de la CUMA via une fonction de distance ;
- La prise en compte du caractère dynamique de la production en CUMA en raison des inputs quasi fixes ;
- La prise en compte du problème d'endogénéité en lien avec les investissements.

0.4 Données de l'étude

0.4.1 Données qualitatives

En utilisant une méthode mixte, nos données sont qualitatives et quantitatives. Les données qualitatives sont collectées via des entretiens semi-dirigés téléphoniques via la plateforme zoom d'une durée de 45 à 120 minutes. Ces données ont été enrichies des documents d'archives ou d'autres documents fournis par les CUMA. Pour une question d'éthique, les CUMA interrogées ont été recrutées par appel téléphonique via un script validé par le comité d'éthique de l'Université Laval (Québec). Un formulaire de consentement approuvé par le Comité d'Éthique de la Recherche avec des êtres humains de l'Université Laval (CERUL) a été signé par les CUMA retenues pour l'étude.

0.4.2 Données quantitatives

Les données quantitatives ont été fournies par la Fédération Nationale des CUMA (FNCUMA) à partir de plusieurs bases de données différentes. Pour obtenir un portait complet des CUMA, nous avons fusionné les bases de données disponibles, ce qui permet d'identifier au total 6572 CUMA sur la période 2010 à 2016. Cependant, nos données posent différents défis statistiques. Premièrement, plusieurs CUMA ne s'identifient pas sur l'ensemble de la période de l'étude comme le montre le Table 0 3. Ce tableau montre la fréquence d'apparition des CUMA sur des années consécutives. Environ 97 % des CUMA sont au moins dans la base de données pour 4 années consécutives. Notre stratégie a été de ne retenir que les CUMA identifiées sur un minimum de 4 années successives.

Table 0 3 : Fréquence d'apparition des CUMA (2010-2016)

Année consécutive	Fréquence d'apparition	Pourcentage d'apparition (%)	Pourcentage cumulé
1	170	0.394	0.394
2	282	0.654	1.048
3	617	1.431	2.479
4	887	2.057	4.535
5	859	1.992	6.527
6	1,464	3.394	9.921
7	38,850	90.079	100.000

Source : Calcul de l'auteur

Ensuite, plusieurs des variables clés de cette étude ont des valeurs manquantes. Le problème des données manquantes constitue l'un des défis dans les études portant sur les coopératives (Uzea & Duguid, 2015). Pour le résoudre, différentes méthodes statistiques incluant la suppression des valeurs manquantes ou l'imputation peuvent être utilisées (Jakobsen et al., 2017). Cependant, pour des variables avec une proportion de valeurs manquantes importantes (plus de 50 % selon Royston (2004), l'imputation n'est pas nécessairement fiable. De plus, la littérature (Royston, 2004) ne converge pas sur le nombre optimal d'imputations. Nous avons donc conservé uniquement les valeurs observées suivant Jakobsen et al.(2017). Précisément, en nous avons conservé les observations identifiées sur l'ensemble des bases de données.

Table 0 4: Description des variables clés de l'étude (2010-2016)

Variable	Données manquantes	Total des Observations	Pourcentage (%)
Investissement environnemental	16,193	43,129	37.546
Taille de la CUMA	7,894	43,129	18.303
Levier financier	1,981	43,129	4.593
Subvention	1,932	43,129	4.480
Nombre de branches	16,193	43,129	37.546
Âge de la CUMA	7,894	43,129	18.303

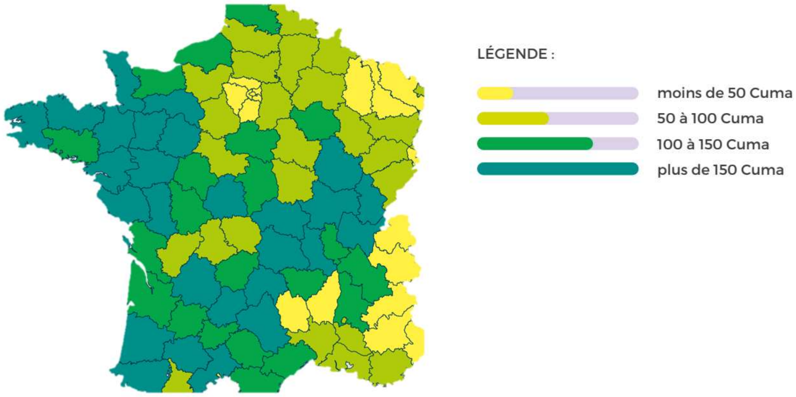
Source : Calcul de l'auteur basé sur les données fournies par la FNCUMA

0.5 Résumé des essais

Dans le premier essai, nous analysons la nature des mécanismes de gouvernance dans le contexte des CUMA au Québec. Nous étudions comment ces mécanismes se combinent pour minimiser différents problèmes de gouvernance. À partir d'une étude de cas multiples, nos résultats montrent que les problèmes de gouvernance des CUMA au Québec concernent à la fois les problèmes de coordination et de motivation. Pour corriger ces défaillances organisationnelles, nous constatons que les CUMA combinent les mécanismes de gouvernance formels et informels (capital social) en mettant toutefois l'accent sur les mécanismes informels. Ces mécanismes incluent, par exemple, l'ajustement mutuel entre les membres, la sélection ex ante, la réputation et la confiance qui caractérisent une forme de capital social relationnel (Nahapiet & Ghoshal, 1998). Précisément, les membres de la CUMA ont principalement recours aux mécanismes informels, en utilisant les mécanismes formels en complément lorsque cela est nécessaire. Ce premier essai permet de mettre en évidence la pertinence des relations interpersonnelles au sein de la coopérative dans un contexte où les mécanismes formels sont défaillants ou inappropriés pour minimiser les problèmes de gouvernance. Dans le deuxième essai, nous analysons théoriquement et empiriquement l'effet du capital social sur la propension et la proportion de l'investissement en actifs environnementaux dans le contexte de la France en utilisant la taille de CUMA comme « proxy » du capital social[16] (Feng et al., 2016). En France, la taille des CUMA (en nombre de membres) reste variable avec des CUMA de plus de 150 membres et des plus petites de moins de 50 membres.

[16] L'utilisation de la taille découle du fait que la confiance entre les membres, leur loyauté envers la coopérative ou même leur satisfaction est liée à la taille de la coopérative (Feng et al., 2016). Nous considérons donc que la taille peur refléter le capital social au sein de la coopérative.

Figure 0 4: Répartition des CUMA par département et par nombre de membres en France



Source : FNCUMA (2021)

L'importance de la taille découle de son effet négatif sur le capital social et positif sur les performances économiques (Feng et al., 2016). Le plus souvent, les coopératives de grande taille bénéficient des économies d'échelle et d'une utilisation efficiente des actifs. Cependant, à un certain point, les problèmes d'interaction (ou de gouvernance) au sein des grands groupes peuvent l'emporter sur les gains des économies d'échelle. Si tel est le cas, il existerait une taille optimale au-delà de laquelle la coopérative attendrait une zone de déséconomie d'échelle. À partir du modèle d'investissement de Fulton et Giannakas (2012), nous générons des hypothèses que nous testons empiriquement sur 2680 CUMA en 2015. Nos résultats montrent que, bien que positif, l'effet de la taille sur la propension à investir dans des actifs environnementaux est non linéaire. Conditionnellement à l'investissement en actifs environnementaux, l'augmentation marginale de la taille de la coopérative affecte négativement la proportion d'investissements en actifs environnementaux. De même, nous constatons que l'augmentation du revenu accroît la probabilité d'un investissement en actifs environnementaux. Cependant, une fois l'investissement réalisé, l'augmentation du revenu moyen des adhérents n'implique pas nécessairement une augmentation de l'investissement en actifs environnementaux. Les effets différenciés des variables sur les probabilités et la proportion de l'investissement en actifs environnementaux suggèrent également le rejet du modèle Tobit par rapport à un modèle de sélection fractionnel (Schwiebert & Wagner, 2015). Dans le troisième essai, nous analysons l'effet des investissements en actifs environnementaux sur la performance des CUMA. Nous modélisons la performance de la coopérative via un modèle stochastique dynamique dans lequel l'investissement est traité comme une variable endogène de la frontière de production. L'intérêt du modèle dynamique réside dans le fait que les CUMA réalisent des investissements communs en input quasi fixe. De même, en traitant l'investissement comme une variable endogène, notre modèle permet de capter l'effet des variables de contrôle affectant l'investissement tout en conservant le caractère dynamique de la production. Nous utilisons une approche en deux étapes qui nous permet, dans la première étape, d'estimer l'effet des pratiques environnementales sur l'efficience de la CUMA. Dans la deuxième étape, nous utilisons une méthode non paramétrique pour générer d'une part un indice de productivité de Malmquist décomposé en un indice de changement technique et technologique et estimer l'effet des investissements en actifs environnementaux sur ces indicateurs. À partir des données de panel des CUMA en France sur la période 2010-2016, nos résultats empiriques montrent qu'une augmentation marginale des investissements environnementaux entraîne une augmentation moyenne de la productivité de 0.121. En ne considérant que l'effet des nouveaux investissements environnementaux, l'augmentation moyenne de la productivité est de 0.129. Cela suggère qu'il est avantageux pour la CUMA de privilégier des équipements environnementaux de premier choix.

0.6 Plan de la thèse

La suite de cette thèse est composée de trois parties. Dans la première partie, nous analysons la gouvernance des CUMA dans le contexte du Québec. Dans la deuxième partie, nous évaluons les déterminants de l'investissement en actifs environnementaux en mettant l'accent sur la taille du groupe. Dans la troisième partie, nous traitons l'implication des pratiques environnementales des CUMA sur leur performance en France. Finalement, la dernière partie est consacrée à la conclusion et à la discussion. Elle résume les principaux résultats, les discutent et propose des recommandations méthodologiques et politiques. Dans cette partie, nous traitons aussi des limites de cette thèse et formulons des suggestions pour les recherches futures.

Chapitre 1 Formal and informal governance mechanism of machinery cooperatives: The case of Québec

https://doi.org/10.1016/j.jcom.2022.100181
Received 27 July 2021; Received in revised form 5 May 2022; Accepted 17 June 2022

1.1 Résumé

Bien qu'intégrées dans un cadre réglementaire, les études suggèrent le rôle important des mécanismes (relationnels) informels dans les coopératives agricoles, principalement considérés comme des compléments aux mécanismes formels. Cependant, l'interaction entre ces deux mécanismes reste incertaine. Pour améliorer notre compréhension de cette interaction, nous étudions les mécanismes de gouvernance dans les coopératives de machines agricoles, en particulier les Coopératives d'Utilisation de Matériel Agricole (CUMA). Les coopératives de machines permettent aux producteurs de partager des machines au sein d'une structure légalement définie, mais les caractéristiques de ces coopératives font qu'elles s'appuient fortement sur des mécanismes informels. Cet article analyse comment l'interaction entre les mécanismes formels et informels minimise les problèmes de coordination et de motivation. Basé sur une approche d'études de cas multiples, le document montre que l'utilisation de mécanismes informels résulte de l'échec des mécanismes formels à minimiser l'opportunisme parmi les membres. En conséquence, les membres de la CUMA auront principalement recours à des mécanismes informels, utilisant des mécanismes formels comme complément en cas de besoin.

MOTS CLÉS
Gouvernance coopérative, gouvernance relationnelle, mécanisme formel, coopératives de machines, mécanisme informel, opportunisme.
Classification JEL : Q130, L640, D860, D23, L14

1.2 Abstract

Although embedded in a regulatory framework, studies suggest the important role of informal (relational) mechanisms in agricultural cooperatives, mostly viewed as complements to formal mechanisms. However, the interaction between these two mechanisms remains unclear. To improve our understanding of this interaction, we investigate governance mechanisms in agricultural machinery cooperatives, especially the "Coopératives d'Utilisation de Matériel Agricole" (CUMA). Machinery cooperatives allow producers to share machinery within a legally defined structure, but the traits of these cooperatives cause to rely heavily on informal mechanisms. This paper analyses how the interaction between formal and informal mechanisms minimizes coordination and motivation problems. Based on a multiple case study approach, the paper shows that the use of informal mechanisms results from the failure of formal mechanisms to minimize opportunism among members. As a result, CUMA members will primarily resort to informal mechanisms, using formal mechanisms as a complement when needed.

KEYWORDS
Cooperative governance, relational governance, formal mechanism, machinery cooperatives, informal mechanism, opportunism
JEL classification: Q130, L640, D860, D23, L14

1.3 Introduction

A vast body of literature has focused on the internal governance of cooperatives(Feng & Hendrikse, 2011; Liang & Hendrikse, 2013). Property rights first attracted the interest of researchers (Cook, 1995). Another aspect mentioned in the cooperative literature is the importance of trust as an organizational strategy (Jensen-Auvermann et al., 2018). Trust would allow the members of the cooperative to maintain a degree of independence from the management but would also promote more flexibility between the members of the cooperative (Borgen, 2011). Most studies on cooperative governance focus on what we could consider "conventional" agricultural cooperatives, that is, cooperatives involved in the upstream or downstream segment of the chain relative to the production segment. In that respect, machinery cooperatives, which are set up to share machinery among a limited number of members, have attracted much less attention thus far. One study identified is by Cornée, Le Guernic, and Rousselière (2020) who adopt a methodology based on a systematic literature review to define the conditions for a successful common-property asset (CPA) organization. Other past studies include Fulton and Harris (2000) and Artz and al.(2010). The particularity of machinery cooperative characteristics lies, among others, in the internal governance structure with "branches of activity" and the sharing of "pooled assets", which is different from that of conventional cooperatives. A branch of activity refers to a piece of agricultural equipment shared by a subgroup of machinery cooperative members and implies frequent and close interactions among members. Similarly, by pooling assets, members benefit from reduced machinery costs while simultaneously exposing themselves to tensions between self-interest and group-interest. In agricultural machinery cooperatives, this tension occurs when, for instance, a specific type of machinery is used only during a very short period due to weather conditions. This particularity induces specific challenges to members of a branch since a failure to use the machinery can result in product quality and economic losses. In addition, the sharing of agricultural machinery is subject to moral hazard, as misuse (not observed) can lead to eventual breakage and costs. When self-interest predominates over the interests of the group, this indicates the potential for opportunistic behaviour (Williamson, 1985).

Given these particularities and given the lack of research on machinery cooperatives, this article explores the governance mechanisms at work in them, specifically the interaction between formal and informal governance mechanisms in the “Coopératives d'Utilisation de Matériel Agricole” (CUMA). Governance mechanisms aim to minimize governance problems, such as coordination and motivation problems[17].While coordination problems refer to the difficulty of coordinating interdependent activities, motivation [18]problems are related to the difficulty of preventing self-interest behaviour due to incomplete contracts (Bijman, 2007) . For this purpose, seven case studies of CUMAs in the province of Quebec in Canada were conducted. We use multiple case studies that can provide more robust results than a single case ((Eisenhardt, 1989). Our research makes several contributions to the existing machinery cooperative literature. First, we further explore the duality of their governance, i.e., formal and informal. Second, we contribute to the broader debate in the cooperative literature regarding formal and informal governance mechanisms. We show that the formal cooperative structure that frames sharing in CUMAs is what distinguishes them from other forms of machinery sharing and simultaneously makes them vulnerable to opportunistic behaviour. Because of opportunistic behaviour and the need for coordination, we identify relational governance as a complementary governance mechanism in CUMAs. Specifically, our results show that the role of formal mechanisms is residual compared to relational mechanisms. This result brings new insight to the debate on more formalization in cooperatives, as suggested by some authors(Cheney et al., 2014). Third, we provide insight into opportunism by members in machinery cooperatives. Opportunism was discussed in relation to the self-interested behaviour of the cooperative managers (Vitaliano, 1983), and Iliopoulos and Valentinov (2012) introduced an opportunism behaviour practised by the board members. Our study shows that in addition to the forms of opportunism mentioned by previous authors, opportunism between cooperative members matters, following the findings of other recent studies.

[17] Charreaux (1996) proposes that governance mechanisms aim to limit conflicts of interest between the organisation's leaders and stakeholders. This approach is more concerned with the control mechanisms of managers.

[18] As one referee pointed out, the motivation problem is often referred to as an agency problem. However, we have retained the terminology "motivation" used by Bijamn(2002). This term is also used by Feng and Hendrikse . (2012)

The paper is organized as follows. Section 2 introduces our theoretical framework on formal and informal governance mechanisms. Section 3 presents the empirical context of the study. Section 4 specifies the methodology, which is based on a multiple case study approach. Section 5 presents the results and various theoretical proposals derived from the empirical results. Section 6 concludes.

1.4 Theoretical background

1.4.1 Formal and relational arrangements in machinery cooperatives and opportunism

Formal mechanisms emanate from a cooperative law (Fici, 2013). In contrast, relational mechanisms are mainly based on social norms such trust. In a machinery cooperative, users share machinery through a formal cooperative arrangement. However, machinery sharing may occur without a formal structure. A simple example is sharing between neighbouring producers based on social norms such as reciprocity (Sutherland & Burton, 2011). In this form of sharing, producers can organize themselves and participate in decision-making processes related to their governance, referring to self-governance (Kooiman, 2003). Machinery cooperatives may also involve self-governance between users but framed by the cooperative arrangement. Because of recognized organizational principles, and social recognition (Eid & Martínez-Carrasco Pleite, 2014), producers can benefit from cooperative arrangements . Legalistic organizations and their formal governance mechanisms have often been criticized in the literature for their propensity to undermine relational governance(Sitkin & Roth, 1993). Another view supported in the literature is the complementarity between formal and relational governance mechanisms. The reasons supporting complementarity are diverse (Lazzarini et al., 2004). One reason is the incompleteness of formal mechanisms, i.e., that a contract or any other formal mechanism is unable to provide for all eventualities (Hart, 1988). Because of the incompleteness of contracts, opportunistic behaviour could occur. Recent studies show that opportunism could be present in cooperatives and practised by cooperatives leaders to the detriment of cooperatives members as well (Garrido, 2019).

In machinery cooperatives, examples of opportunistic behaviour often take the form of ex post behaviour of members, such as carelessness with equipment or failure to meet initial commitments. Producers may be less careful because of the lack of monitoring due to the geographic distance between them. In terms of commitment, Artz and al.(2010) show that in some cases, because of a producer's off-farm occupation, a producer could reduce his or her share hours of the machinery, which would require readjustments within the group. Since machinery cooperatives involve collective action, opportunistic behaviour is detrimental to the whole group and could undermine the coordination of activities.

1.4.2 Governance problems in CUMAs

Bijman (2007) considers two main governance problems in cooperatives: coordination and motivation. In a CUMA, because producers share the same machines, they need to coordinate to do the work on time in each member's field. On the other hand, CUMA producers have a "stronger common property regime", as they are framed by cooperative laws. Common property implies economic benefits related to reduced capital investment. However, by sharing a common resource, members expose each other to risks of opportunism. Opportunism can be active or passive (Wathne & Heide, 2000). Active opportunism occurs when a person engages in explicitly or implicitly forbidden personal behaviour, whereas passive opportunism occurs when a company or individual shirks previously agreed on obligations or refuses to adapt to new circumstances. Artz and al.(2010) show evidence that producers may be passively opportunistic by shirking their obligations due to their personal occupations. Coordination and motivation problems require effective governance mechanism. These mechanisms and their advantages have been widely addressed in the interorganizational literature (Dekker, 2004), while few studies have addressed these in the context of cooperatives. Recently, Hernández-Espallardo et al. (2022) analysed governance mechanisms in the context of marketing cooperatives. However, it is not clear how these mechanisms might affect coordination and motivation problems in the context of a machinery cooperative.

1.4.3 Conceptual model of the CUMA governance mechanism

1.4.3.1 Formal governance mechanism in a CUMA

Formal mechanisms are observable rules from written documents that can be executed via an authority (Zenger et al., 2000). Formal governance mechanisms would also imply delegating authority to a cooperative manager or programming activities that imply deciding in advance how activities may be executed (Gulati et al., 2005). These mechanisms may help mitigate opportunistic behaviour by limiting partners' actions and improve coordination through centralized decision-making. Moreover, since a CUMA is engaged through fixed claims contracts with different stakeholders (financial institutions, supplier), the bylaws and le contrat d'engagement[19] may also function as guarantees for the latter. However, these mechanisms are not very specific or are incomplete (le contrat d'engagement[20]) because of uncertainties arising from the problems of credible commitment (Ostrom, 1990) and the lack of carefulness (moral hazard), among other things. On the other hand, delegating authority to a single cooperative manager may involve control costs arising from agency (Vitaliano, 1983). In addition, recent studies show that centralized decision-making in cooperatives tends to exacerbate conflicts between members (Slade Shantz et al., 2020). Finally, programming activities implies the ability of producers to plan for all eventualities in their production activities, which could be complex due to the uncertainties associated with agricultural activities.

1.4.3.2 Relational governance in a CUMA

Relational governance mechanisms are closely linked to individuals and their relationships (Hoetker & Mellewigt, 2009). Relational norms such as flexibility, honesty, reciprocity, encouraging partners, solidarity, and preservation of the relationship are examples of relational governance (Macneil, 1977). Relational mechanisms also refer to the existence of a pre-established informal authority as a means of mitigating conflict (Slade Shantz et al., 2020). or the development of informal communication between members of a group (Lucas et al., 2019). Flexibility may enhance the capacity of partners to adapt to unforeseeable events (Poppo & Zenger, 2002). Valentinov (2004) suggests that one of the specificities of cooperatives is the

[19] le contrat d'engagement commits members to using a particular piece of equipment through an activity branch

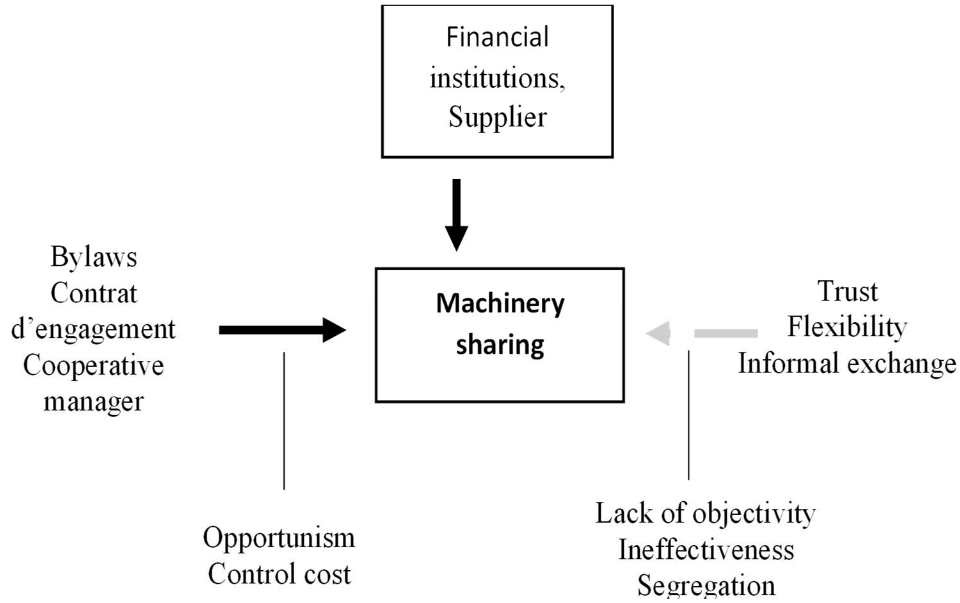
[20] For example, this contract is not explicit regarding control, specifically regarding monitoring behaviour.

importance of interpersonal relations, which makes them social capital-based organizations. The lack of social capital would explain the failure of large cooperatives (Nilsson et al., 2012). Relational governance also has negative aspects, such as the lack of objectivity, ineffectiveness in decision-making, or the recrudescence of opportunistic behaviour (Villena et al., 2011). In machinery sharing, Artz and al.(2010) found that a sense of trust mitigated the moral hazard problem among partners, while flexibility tends to facilitate exchanges between them. The conceptual framework of formal and informal mechanisms of governance within CUMAs is summarized in Figure 1-1. Due to their relations with different stakeholders, such as suppliers and financial institutions[21] and their cooperative legal form, formal mechanisms are necessary in CUMAs. However, because of uncertainties and the possibility of opportunism, formal mechanisms may be limited in their ability to minimize coordination and motivation problems.

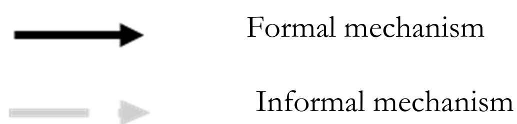
Relational governance could minimize motivation problems because of the trust between the partners and facilitate coordination through informal exchanges and flexibility. At the same time, relational mechanisms are not necessarily a panacea, as they also have their limits. Thus, because of their respective limitations, formal and relational mechanisms could function as complementary mechanisms in CUMAs. However, the net effect of these two mechanisms when they coexist remains ambiguous and depends on several parameters, such as their relative strength in the relation, the features of exchanges, and the outcome of interest (Poppo & Zenger, 2002). We empirically address the interaction of formal and informal mechanisms in the case of CUMAs and show how these mechanisms combine to minimize coordination and motivation problems.

[21] In Québec, some financial institutions such as Caisses populaires (credit cooperatives) have been active in providing credit to new CUMAs. Most of the time, CUMAs finance the capital through members 'investment shares, debt and members fees.

Figure 1-1 : Conceptual framework of CUMA formal and informal governance mechanism



Source : Authors



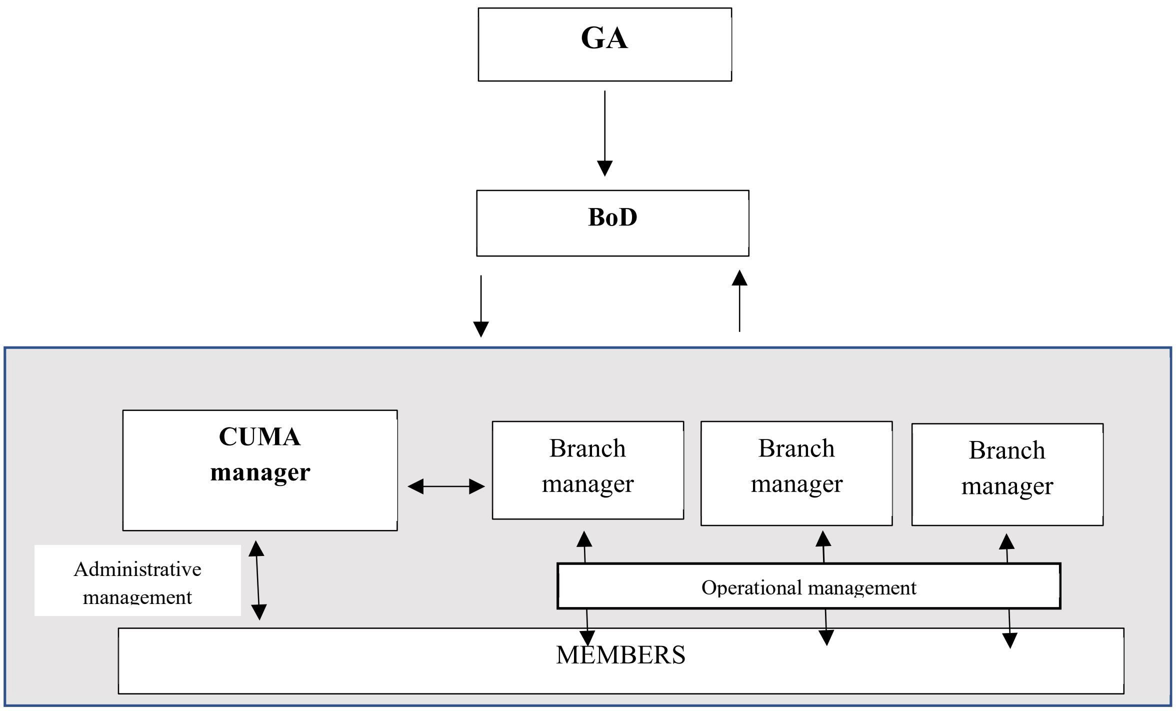
1.5 CUMA in Québec

In the province of Quebec, it was not until 1991 that the first CUMA emerged from 10 producers in the Bas-Saint-Laurent region[22] (Harris & Fulton, 2000b). Today, there are 61 CUMAs operating in the province (Ministère de l'Agriculture, 2018). Figure 1-2 shows a typical CUMA governance structure. CUMAs are democratic member-based organizations with all members forming the general assembly (GA). According to the Quebec Cooperatives Act, the GA adopts the cooperative's bylaws, elects the board of directors (BoD), appoints an auditor, and may adopt any matter relating to the cooperative, such as its affiliation with the cooperative association.
In general, the GA delegates authority to a board of directors whose role may be to oversee the activities of the CUMA. A salaried manager most often manages the administrative affairs of the

[22] The Bas-Saint -Laurent is an administrative region located northeast of Quebec City.

CUMA (compilation of member invoices), while the branch manager is a volunteer producer that is responsible for organizing the use of the machine. There are as many branch managers as there are branches in the CUMA.

Figure 1-2 : CUMA internal governance in Québec (2015)



Source: Adapted from Harris and Fulton (2000)

1.6 Case studies

1.6.1 Data collection

We use multiple case studies that can provide more robust results than a single case (Eisenhardt, 1989). One of the challenges related to the case study is how to define the sample size. The saturation sampling strategy was used in our study. Saturation indicates that adding a new case does not improve the data quality (Eisenhardt, 1989). In total, seven CUMAs were retained in our final sample (Table 1-1). Our sample size is justified theoretically but also pragmatically. Theoretically, 4 or 5 cases are sufficient for a single study (Creswell & Poth, 2016).

On the other hand, given the seven cases' responses, adding more CUMAs would not improve the study's quality following the saturation principle. The data on the CUMAs were collected via seven semi-structured phone interviews or the zoom platform, each lasting between 45 and

120 min. The data collected via seven semi-structured interviews were supplemented by data from archival documents available on the internet and other internal documents provided by the CUMAs. Our questionnaire addressed themes related to the governance of the CUMA, including the governance body and mechanisms (See Appendix A.1) . The interviews were conducted with a member of the CUMA's governance body. In all the CUMAs, we were able to interview the president. In 3 CUMAs, we were also able to talk to another governing body member, such as a board member or the manager, in addition to the president. To protect the privacy of the participants, we used letters A to G to identify the CUMAs. The details[23] of the cases are presented in Table 1-1.

[23] A detailed overview of the evolution of CUMA membership is presented in Appendix A.

Table 1-1 : Details of the cases

CUMA[a]	Date of creation	Active member 2015→ 2020	Estimated Value of Equipment (in Canadian dollars) 2015→ 2020	The dominant type of production	Interviewed
A	1994	25 → 30	1 228 681 → 2 000 000	Dairy production	PRE[b] MCA[c]
B	1999	23 → 23	190 229 →150 000	Dairy production	PRE
C	2003	27 → 27	681 000	Dairy production	PRE PREF[d]
D	1991	36 → 37	561 743	Dairy production Ovine producers	PRE Manager
E	1997	12 → 16	561 086 → 1 000 000	Dairy production Hog production	PRE
F	1999	65 → 70	711 632 →1 850 000	Dairy production	PRE Manager
G	1998	57 → 28	365 955	Dairy production Grain producer	PRE

Note : a To protect the privacy of the participants, we use anonymous names to identify the CUMA
b President of CUMA
c Board members
d Founding president of the CUMA
Source: Based on the information provided by study participants

1.6.2 Data analysis

We conducted an intercase analysis to identify recurrences and differences between cases (Huberman et al., 2014) and performed a content analysis associated with each theme of our questionnaire.

1.7 Results

1.7.1 Governance problem

1.7.1.1 Coordination problem

The challenge of the CUMA members is to organize the activities so that each producer can carry out his activities at the right time (De Toro & Hansson, 2004).

« I have the dethatcher at home, and three of us use it (...), that is why I said we should not have four or five members because it is getting complicated to manage the distribution of the machine, especially since almost everyone needs it at the same time. »(President of F)

To address this problem, CUMAs rely on reducing the number of members in the group depending on the specificity of the machinery. For example, for a stripper, the number of members could reach 15–16 members, while for a mower, the number of members would be limited. Reducing the number of members in the group implies higher individual costs since the individual cost of using the material decreases when the number of members increases.

« We had a maize planter; 8 producers used it; when the loan expired, we split up, (…) then we bought another planter, we have four members for less surface, but, about the same costs; it is a slightly more expensive, but there is much less stress regarding the availability of the machine ». (Board Member of C)

Therefore, the producers in a CUMA could face the following dilemma: save on individual costs by accepting more members or limiting the number of members to minimize the costs of not completing agricultural tasks on time, referred to here as the timeliness cost. Faced with this dilemma, CUMAs must find appropriate coordination mechanisms to strike a balance between reducing machinery costs and timeliness costs.

1.7.1.2 Motivation problem

Motivation problems are related to the difficulty of preventing opportunistic behaviour. An example of passive opportunism in a CUMA is the misuse of equipment in a context that is not suitable for agricultural activities.

«We had a problem with a combine (…) there were three producers using it in the branch, one of them decided in January that he would take the combine to do his corn in the field (…) there were two feet of snow ». (President of B)

The interdependence of the group members means that an individual mistake is paid for collectively. For example, not declaring the units of use would imply fewer costs for the opportunistic producer and a cost of wear not captured by the CUMA since the actual units of use would not correspond to the units declared. In the same way, when a producer changes activity, this implies one fewer person in the group. Therefore, individual costs increase unless the outgoing producer finds a replacement or continues to meet his or her commitment. If the producer cannot meet the contract requirements, the costs fall on the CUMA since it is committed to fixing claims contracts with the supplier or financial institutions.

«All the payments not made by the producer are automatically reimbursed by the CUMA to the financial institution, so this eats into our liquidity, and then reduces our ability to make changes, to make purchases, to do maintenance (...)» (President of D)

Opportunistic behaviour (passive or active) results from the CUMA's inability to anticipate members' intentions, their propensity to behave well, or the lack of an adequate monitoring mechanism. (Table 1-2).

Table 1-2 : Forms of opportunism in CUMA from survey.

Opportunism forms	Empty Cell	A	B	C	D	E	F	G
Passive opportunism	Change of activity	x		x		x		x
	Equipment misuse		x		x		x	
Active opportunism	Undisclosed equipment breakdown				x			x
	Makeshift repair				x			
	Retention of equipment				x			
	Undeclared unit of use		x				x	
	Bad faith						x	

Source: Based on the information provided by study participants

1.7.2 Formal governance mechanism

1.7.2.1 The limited role of governance bodies in CUMAs

Figure 1-2 shows the various governance bodies of the CUMA investigated, the most important of which are the GA, the BoD, and the administrative and operational manager. Traditionally, the GA has decision control (ratification and monitoring) (Bijman et al., 2014). In a CUMA, the ability of the GA to minimize coordination and motivation problems depends on member involvement in collective decision-making. However, our results show the low participation of CUMA members in collective decision-making (Table 1-3) Concerning the BoD, there is a consensus among the presidents on their role, which is mainly to supervise the general activities of the CUMA (relations with suppliers, banks) and to make final decisions, as exemplified by the following quote: «If the members cannot agree among themselves, the Board makes the final decision ». (President of D). This suggests that the BoD's action about motivation problems occurs ex post, which only partly solves the problems faced by producers. In some cases, the fact that the decision-making process in CUMAs is based on the "one member, one vote" principle means that the board may have little room to manoeuvre in its ability to become involved in member control. For example, some CUMAs (A, F) opt for stricter control of member behaviour by using wheel counters. In other CUMAs (B), members have rejected this type of technology.

«(...) Other CUMAs use electronic boxes that measure usage, (...) the members have not accepted it, but I have proposed it (...) there are many things I propose, but they have not necessarily been accepted yet.» (President of B)

Table 1-3: Collective decision making in CUMA[24]

	A	B	C	E	F	G
Participation in collective decision	Strong	Weak	Weak	Strong	Variable	Weak
BoD members	(6)	(5)	(6)	(3)	(6)	(8)
Administrative control	+ +	–	+	–	+ +	+
Formal coordination	+	+	–	–	–	–
CUMA manager	**An salaried employee**					
Branch manager	**A volunteering group Producer**					

Source: Based on the information provided by study participants

Finally, all the CUMAs studied have a governance structure with a double delegation, i.e., administrative and operational. this could imply a double agency problem (Vitaliano, 1983). However, the agency problem would be less important at the operational level than at the administrative level. The rationale behind this statement is simple: the CUMA manager is not a residual claimant, whereas the operational manager, being a member of the group, automatically is. Since the CUMA manager is not a residual claimant, his incentives might differ from those of a CUMA member.

[24] The D has not been included in this table due to lack of specific data.

1.7.2.2 The incompleteness of written contracts

The contractual arrangements in a CUMA are mainly based on the internal rules and le contrat d'engagement. Iliopoulos(2003) suggests that cooperatives should define clauses in their bylaws to constrain opportunistic behaviour. The CUMA bylaws define various general provisions, including the general conditions for forming a branch of activity and handling conflicts. These provisions are usually helpful ex post as a basis for final decisions.

«When, say, a breakage occurs, then the general CUMA rules apply in the sense that, usually when equipment breaks, the cost of repair is shared by all members, unless the breakage is caused by misuse » (President of D).

The fact that the internal regulations only apply to producers who are already members of the CUMA implies that, formally, there is a gap in the CUMA's capacity to anticipate various opportunistic behaviours, particularly regarding the carefulness of the members. In these cases, the CUMA can only intervene when the careless producer's performance has been observed ex post. The mechanism used then, as observed in one CUMA, was to exclude the opportunistic producer at the time of machine renewal.

«Sometimes, during use, we get to know the other person better; when the machine is renewed, when we change the machine, we say, this producer, we put him aside » (President of B).

Le contrat d'engagement is the other side of the formal contractual arrangements in a CUMA. In contrast to bylaws, the contrat d'engagement functions as a specific formal guide that makes explicit how the group members intend to coordinate with each other and meet the requirements of the CUMA. In terms of coordination, the contrat d'engagement specifies that the members define the formal order of equipment use. However, in several of the cases analysed, the systematic use of the contrat d'engagement as an instrument of coordination in machinery sharing remains limited.

«It is written in the contrat d'engagement, the priority list is written there, who's first, who's last (...), it is quite rare that the branch manager has to take out the list, but if there is a conflict, the one who's higher in the list obtains use of the machine » (President of A).

Finally, the contrat d'engagement is based on the strong assumption that group members will respect their promises (careful use of materials, declaration of units of use). The possibility of opportunistic behaviour by group members may make these promises null and void.

1.7.3 Relational governance

1.7.3.1 Mutual adjustment and good understanding

CUMA also relies on relational governance mechanisms. CUMA members will, for example, resort to mutual adjustment, which relies mainly on informal communication (Mintzberg, 1993). By engaging in mutual adjustment, CUMA members can coordinate with each other without strict planning and, thus, have a better ability to adapt to unforeseen circumstances.

> In a branch, especially branches that have been operating for years, we all know each other, we all have a phone in our pockets, we all have our contacts too, so we talk regularly (...). This year, we had a mechanical shovel; normally, the mechanical shovel use is limited to a week maximum; this fall, one producer who is a member of the branch was building a barn, which takes a lot of time (...) the mechanical shovel spent a lot of time at their place, at the same time, no one loses out because as the shovel works more, our hourly rate decreases. (President of C)

An understanding between members may stem from good communication between members. Good understanding introduces flexibility in the relationships of the members and facilitates the organization of machinery sharing. In the presence of a good understanding, members can function autonomously and settle their disputes. In this respect, it is common for CUMAs to initially allow the members themselves to find solutions to their conflicts.

«They try to agree; if they cannot agree, the branch manager will contact the president, the president will contact the board and the board will make a decision; at that point, it becomes the final decision; then the member has to abide by it » (President of A).

1.7.3.2 Selection ex ante

The ability of CUMA members to easily take advantage of unforeseen situations depends on the identities of the group members. Ouchi (1979) identifies two ways for organizations to achieve adequate control, which are selecting people who align with the organization's way of doing things or selecting nonconforming people and placing them under supervision or evaluation. In general, the CUMAs interviewed are selective about new members, and their objective is to select members who correspond to their expectations.

« (…) I will tell you that we all know each other; we all have affinities with each other; it is certain that if there is a producer who would like to join, if there are members who know him, who know that he is not someone who wants to work actively with other producers, we would be more reticent to include him in the CUMA (...) ». (President of C)

In addition, as Table 1-1shows, there is little or no change in the number of members of several CUMAs.

> I do not think that there is any possibility of growing at the moment; I think that we have reached a ceiling, and I would say that, given the size of the farms, it is more inclined to go down, because the bigger the farms are, the more the others do not want to be in CUMA, because the others all want to have their own equipment, because, when it is time, they have to run. (President of F)

When the CUMA presidents are asked if their objective is to expand, the answers are mixed, as several presidents seem to indicate that their CUMA remains open but has not necessarily adopted the idea of expansion. In some cases, the presidents seem to be reluctant to expand; the concept of remaining a small group where good understanding prevails appears to be the ultimate goal of the CUMA. For other CUMAs, the idea of expanding is entirely out of the question.

«We keep our core membership, then we can add branches, but we truly do not want to have more members (...). Sometimes it is necessary to add a new member to a new branch, but if three new members wanted to create a new branch, I think we would refuse them.» (Board member of C)

Membership selection and close memberships are characteristic of hybrid organizations (Iliopoulos, 2003). Although this seems to be a departure from the basic cooperative principles (free membership), CUMA members need to select candidates who are compatible with the group's methods. The issue here is to integrate a member who aligns with the group's organization rather than one who destroys it. The ability of CUMAs or the group member to select candidate members is crucial to their compatibility (Harris & Fulton, 2000b).

1.7.3.3 Reputation

Reputation creates positive incentives to comply with a contract because the present gains from opportunistic behaviour can be quickly offset by the risk of loss in future transactions (Mazé & Ménard, 2010). In CUMAs, the effect of reputation is powerful because the groups are generally very close-knit; thus, bad behaviour is quickly detected and sanctioned. The most common sanction is the removal of the member, who would subsequently have difficulty finding a new partner.

«They (member) do not want to partner with just anyone, because we have 2 or 3 members who we do not want to have; they do not pay attention, it often breaks down when they use it because they are more careless, which undermines the confidence in the system and makes some of the other members of the group lose confidence. »(Manager of F)

When the members' trust is eroded because of a producer with a bad reputation, the consequences can be disastrous for both the offending member and the CUMA. For the CUMA, the result could be the withdrawal of good members, representing a loss for the CUMA in membership.

«There is one who is always breaking everything. Unfortunately, he caused two members to leave; every time there is a renewal, we say, we will not renew if he is there (...). I have one of my best friends who left the branch; he does not' believe in the CUMA, because unfortunately he was involved with three machines, and this guy was also involved with the same three machines.» (President of F)

The fact that a bad reputation can weaken the group's trust and dilute CUMA membership causes CUMAs to be attentive to cases of bad behaviour. The challenge is to maintain a working environment conducive to the achievement of each member's objectives. Even if this mechanism intervenes ex post, that is, after the producer's behaviour has been observed, it still constitutes a credible threat. If a producer is tempted to violate the rules, there is a chance that he will not be discovered, but it is inevitable that if he is found, he will be quickly sanctioned.

1.7.3.4 Trust

Trust is essential because other values flow from it, such as honesty, which in turn reinforces mutual trust. In a CUMA, mutual trust leads the group members to disclose hidden information and, thus, prevents opportunism. Similarly, a lack of trust between members leads to more mistrust and generates a working environment that is not conducive to achieving individual objectives.

«Often, someone who accidentally breaks the machine will say so straight away and even get it fixed straight away, and this wins the trust of others; when someone tries to hide something to save costs, trust is broken. » (President of B)

The value of trust between members also lies in the fact that without mutual trust between members, the sustainability of the branches of activity in a CUMA is limited. Trust will manifest in the ability of the members to renew a given piece of equipment regularly. Thus, members must trust each other to minimize opportunistic situations and hope to continue sharing activities.

«There are members who have been in a branch for ten years and who continue to do so, so you can say that they have confidence. » (President of G)

1.7.4 Relational governance and/or formal governance in a CUMA? theoretical proposition

The formal aspect of CUMAs stems from the fact that a cooperative law governs them. Most often, the presidents of the CUMAs acknowledge the importance of formal governance mechanisms, as the following quote exemplifies: «When things go wrong, when it is not written down, it is more complicated. » (President of B)

Proposition 1

Because of possible opportunistic behaviour and relationships with suppliers and financial institutions, CUMAs use formal governance mechanisms as a basis for decision-making and as a means of coordination with stakeholders.

Even if CUMAs do not seek excessive formalization, they need to comply with the basic formal rules set out in the cooperative law and its internal regulations. According to Fici(2013), cooperative law and rules must take precedence over all other sources of regulation, which should only be applied in a residual way to fill the gaps left by the formal sources. This statement leads to the idea of a possible complementarity between formal and relational governance in cooperatives. Liang et al.(2018) show that informal governance's impact on producers' performance is larger when there is stronger formal governance in the cooperative. CUMAs combine both formal and relational governance mechanisms. The idea of complementarity is therefore also applicable to the CUMA context.

Proposition 2

In a CUMA, formal and relational governance mechanisms function as complementary governance mechanisms. Although complementary to formal mechanisms, relational governance does not seem to play a residual role in a CUMA. In contrast, coordination and motivation in CUMAs seem to rely mainly on intense relational governance mechanisms, while the role of formal governance remains residual.

«We rarely open contracts, (…), you know, the key to a CUMA, and to good branches, is to have members who get along well; in a CUMA, you have to be able to put water in your wine.» (Board member of C)

Thus, interpersonal relationships seem more critical in a CUMA than a relationship based on strict planning of activities defining all possible contingencies.

> «In spring, when everyone is pressing (hay bales), we have machines that run 24 h per day, we know that there is one waiting afterwards; then, they announce rain in 2 days, but we will take turns sometimes, saying, we will not stop the machine; then we talk to each other; then there is another one who will come at night, (...), I am in certain branches that are like that; we found each other; there are four members of the CUMA who have more or less the same philosophy regarding having high-performance machines.» (Board member of C)

Proposition 3

Relational governance does not play a residual role in CUMAs. In fact, its role is essential to the ability of CUMA members to build and maintain trustworthy groups to deal with situations not foreseen by the formal aspect of governance.

1.8 Discussion and conclusion

1.8.1 Relational governance mechanism importance

Although framed by the cooperative law that imposes different formal governance mechanisms, machinery cooperatives rely essentially on relational governance. Bijman et al.(2014) show that cooperatives have made various significant innovations in their internal governance by using professional managers, introducing a voting system based on the importance of the members, integrating non-members in the BoD, etc. But because of the nature of their operations and specific challenges, it becomes necessary for CUMA members to rely on other types of mechanisms. Our findings also reveal the presence of opportunistic behaviour within CUMAs that can undermine the success of the group. Theoretically, our results make it possible to highlight two points of view on governance, namely, that of Williamson(1985) and that of Ostrom (1990). While the first author emphasises the problems of governance linked to the opportunism of individuals, the second shows their capacity to organize themselves via relational governance.

1.8.2 Back to square one?

One of the strengths of CUMAs is their ability to combine formal and relational governance mechanisms. Relational mechanisms minimize coordination and motivation problems while allowing producers to organize themselves through mutual adjustment. However, a large use of relational mechanisms can be detrimental to performance by increasing the occurrence of opportunism (Villena et al., 2011). In the case of CUMAs, one of the problems encountered with the strong socialization between members is the fact that producers tend only to be concerned with patronizing the CUMA without any real involvement in the associative life in the CUMA.

Specifically, in some CUMAs, the presidents remain pessimistic about the continuity of the activities because of the members' lack of interest in becoming involved with the board.

«In our case, there is not much competition (...), when we look for a new director, it is slightly difficult; at the general assembly, it is almost only the board of directors who are there; there are few members who are not directors who are at the general assembly. They are not interested in getting involved; some of them are good users; they are only happy to pay.»(President of B)

In CUMAs, the economic commitment of the members is evident, while from the associative point of view, there seems to be a certain distance between the members and their CUMA. In any case, this distancing implies a form of individualism within cooperatives that contradicts the very nature of agricultural cooperatives. The commitment of members is necessary for the cooperative to be viable. Thus, the lack of commitment could impact the ability of these organizations to continue over time.

This study has several limitations. First, by adopting a multiple case study approach, the generalizability of our study may be limited. Second, this study is based solely on the CUMA board's perspective, which does not exclude desirability bias (Bergen & Labonté, 2020). Moreover, our study may suffer from selection bias because the CUMAs included are mostly small. The size effect could favour more homogeneity, which would facilitate the development of social mechanisms between members (Höhler & Kühl, 2018). At the same time, since CUMAs are organized as several branches of activity, each branch having a limited number of members, the total number of members of the cooperative might not greatly affect the governance mechanisms at work. Future studies could analyse in-depth how the size effect influences governance mechanisms in the context of machinery cooperatives. Finally, we have identified the governance mechanisms at work in CUMAs. Another step would be to link these governance mechanisms to the performance of these organizations following Silva and Morello (2021).

Chapitre 2 What determines investments in environmental assets by agricultural cooperatives (CUMA)? Evidence from France

2.1 Résumé

Sur la base d'une approche théorique et empirique, nous analysons l'effet de la taille de la coopérative sur la propension et la part des investissements environnementaux dans le cas des coopératives utilisatrices de matériel agricole en France (CUMA). Suivant Papke et Wooldridge (1996), nous examinons les données de 2680 CUMA en 2015 et utilisons un modèle fractionnel généralisé en deux parties qui est plus flexible qu'un Tobit et qui résout le problème de sélection. Nos résultats montrent que, bien que positif, l'effet de la taille sur la propension à investir dans des équipements environnementaux est non linéaire (U inverse). Cependant, conditionnellement à l'investissement en actifs environnementaux, l'augmentation marginale de la taille de la coopérative affecte négativement la proportion de l'investissement en actifs environnementaux. De même, nous constatons que l'augmentation des revenus des adhérents augmente la probabilité l'investissement en actifs environnementaux. Cependant, une fois l'investissement réalisé, l'augmentation des revenus n'implique pas nécessairement une augmentation de l'investissement en actifs environnementaux.

2.2 Abstract

Based on a theoretical and empirical approach, we analyse the effect of cooperative size on the propensity and proportion of environmental investment in the case of cooperatives using agricultural equipment in France (CUMAs). Following Papke and Wooldridge(1996), we examine data from 2680 CUMAs in 2015 and use a two-part generalised fractional model that is more flexible than a Tobit and solves the selection problem. Our results show that, although positive, the effect of size on the propensity to invest in environmental equipment is nonlinear (reverse U). However, conditional on the environmental investment, the marginal increase in the size of the cooperative negatively affects the proportion of environmental investment. Similarly, we find that increasing income increases the likelihood of environmental investment. However, once the investment is made, the increase in income does not necessarily imply an increase in environmental investment.

2.3 Introduction

Machinery cooperatives (CUMA) promote collective investment. Driven by their objectives of reducing the cost of mechanisation[25] and improving the social conditions of their members (Fulton & Harris, 2000), these cooperatives are also emphasising the "quality" of their investment, by favouring "environmental type investments". Following Bostian et al.(2016), we define environmental investment as all expenditures on agricultural assets likely to have a positive effect on the environment. In CUMAs, these investments are diversified and encourage collaboration between members for the implementation of environmental practices such as the revaluation of hedges or the collective development of landscapes (Lucas et al., 2019). Although investments in environmental assets represent only a fraction of CUMA investments, they do raise issues for both decision-makers and CUMAs. Indeed, given their potential positive[26] effect on the environment, the challenge for decision-makers would be to identify the factors that could stimulate more environmental investment. For CUMAs, the challenge would be to identify the conditions under which members would be less inclined to make environmental investments. Despite these challenges, little attention has been paid to the factors likely to stimulate or limit CUMAs' investment in environmental assets. Potentially, the factors determining conventional investment by cooperatives, in particular, financial constraint (Chaddad et al., 2005), horizon[27] and portfolio problem (Cook, 1995) could also apply to explain the choice of investment in environmental assets by a CUMA. For example, the propensity of a CUMA to invest in environmental assets may depend on its ability to free itself from financial constraints, as cooperatives are often financially constrained (Musson & Rousselière, 2020a). Furthermore, the size of the cooperative, could also play a role, as shown in the literature on collective action (Olson, 2009). The importance of size stems from its negative effect on social capital (Feng et al., 2016) and its positive effect on economic performance (Pokharel et al., 2020). Social capital

[25]In France, CUMAs can reduce mechanisation costs by up to 50 €per hectare (Durand & Tremblay, 2021) .

[26] Although investment in environmental assets have a positive impact on society, they can also entail irreversible costs (Pindyck, 1990). Irreversibility arises from the fact that some equipment is specific to particular farming practices. For example, a direct seeding drill is specific to direct seeding.

[27] The horizon problem is related to the fact that the period over which a member of the cooperative benefits from the residual return right on an asset is generally shorter than the life of that asset. As for the portfolio problem, it stems from the fact that the investments made in the traditional cooperative do not necessarily correspond to the individual preferences of the members (Cook, 1995).

"refers to the characteristics of social organisation, such as networks, norms and trust, that facilitate coordination and cooperation for mutual benefit" (Putnam, 1993, p. 1). Its value for agricultural cooperatives lies in its ability to not only minimise conflicts between members (Slade Shantz et al., 2020) but also to encourage the adoption of environmental practices in a context of environmental crisis (Lucas et al., 2019). The size of a cooperative is also critical for its economic performance (Pokharel et al., 2020). In most cases, large cooperatives benefit from economies of scale and the efficient use of assets (Gezahegn et al., 2019). However, at some point, interaction problems within large groups can outweigh the gains from economies of scale (Cazzuffi, 2012). Indeed, after a certain threshold, the members are no longer able to converge on the quality of the investment (i.e. its environmental characteristics) for lack of being able to organize an "arena" of exchanges based on democratic principles (i.e. where the preferences of each member can be heard (Cornée et al., 2020). If this is the case, there is an optimal size beyond which the cooperative would reach a zone of diseconomy of scale (membership) because a large CUMA implies more heterogeneity, which could weaken the effect of social mechanisms. Feng et al. (2016) conclude that the smaller a cooperative is, the higher the social capital. Groos et al. (2021) highlight the governance problems that exist within large CUMAs, notably the problem of free riders. However, a large CUMA could also offer more investment in environmental assets given the diversity of member preferences and cost advantages. There is therefore a potential tension between the positive effect of CUMA size on the economic benefits of members and the negative effect on social capital.

The objective of this study is to examine the determinants of investment in environmental assets in agricultural cooperatives with a focus on the effect of the size. Collective action requires a minimum of social capital. Valentinov (2004) shows that there is an optimal number of members. We, therefore, suggest a nonlinear relationship between size and the propensity of investing in environmental assets. Similarly, considering both the economies and diseconomies of scale arguments, one would expect a nonmonotonic relationship between size and investment in environmental assets. The contributions of this study are theoretical and empirical. Theoretically, we extend Fulton and Giannakas' (FG) (2012) model of investment by incorporating social capital. This simple model allows us to highlight the effect of size on investment propensity. Empirically, we analyse the determinants of investment in environmental assets at the CUMA level. Different studies analyse the determinants of the adoption of environmental practices at the producer level (Lee & McCann, 2019; Verhofstadt & Maertens, 2014) or the impact of the cooperative on sustainable investment (Ma et al., 2018). However, to our knowledge, studies that link propensity and investment in environmental assets at the cooperative level are rare. Franken and Cook (2015b) analyse the effect of different determinants related to the horizon problem on investment propensity, but these authors ignore the dimension of investment levels. By focusing on CUMA size, we also empirically test Olson's (2009) hypothesis on the importance of group size. From an empirical point of view, given the diversity of environmental issues, we use the conditional mixed process framework proposed by Roodman (2011), which allows us to estimate a system of simultaneous equations associated with a binary selection equation to resolve potential selection problem (Roodman, 2011). This selection could arise from the fact that after controlling for observable characteristics of CUMAs such as size, unobservable characteristics (e.g. their environmental sensitivity[28]) could influence both the propensity as well as the proportion of investment in environmental assets. Our results show a non-linear relationship between size and investment in environmental assets propensity, while marginal increases in size negatively affect investment in environmental assets without a clear non-linearity effect. Interestingly, marginal increases in average member income and population density also increase the probability of investing in environmental assets.

The remainder of this article is organized as follows. In section 2, we provide our empirical approach. Section 3 presents the theoretical investment model from which we derive hypotheses to be tested followed by the presentation of the data and the variables in section 4. Section 5 presents and discusses the results. Different robustness tests are provided in Section 6 and 7. We draw conclusion in the last section.

[28] The environmental sensitivity of cooperatives can be a lever for the development of environmental innovation (Musson & Rousselière, 2020b)

2.4 Econometric approach

Our objective is to analyse the determinants of the propensity and the level of environmental investment. Analysing these two processes implies estimating a two-part model: the first part determines the factors that impact the decision of the CUMA to invest or not in environmental investment assets, and the second determines the variables impacting the proportion of environmental investment (Cameron & Trivedi, 2009). We use environmental investment proportion to lower heteroskedasticity across CUMAs.

2.4.1 Propensity to invest and the proportion of investment in environmental assets

The propensity to invest in environmental assets is modelled as follows:

$$s_i = 1 \text{ if } \quad U_*^s\left(.,.,S_t\right) > U_*^{s0}\left(.,.,0\right) > 0 \tag{9}$$

Where s is an indicator variable equal to one if the CUMA has a nonzero investment in environmental assets and zero otherwise; U_*^s is a latent variable and S_t represent the environmental function of CUMA. The expression (9) indicates that the CUMA makes an investment in environmental assets when the utility gain is larger than the non-investments A common formulation of the utility is the linear random utility model (Greene, 2003).

$$U_*^s = V_{is}\gamma + u_i > 0 \tag{10}$$

Where V_{is} is a vector of explanatory variables, γ is a vector of unknown parameters to be estimated, and u is the error term. It is assumed that the error term has a standard normal distribution, implying the following:

$$\Pr\left(s_i = 1 \mid \mathrm{v}_{is}\right) = \Phi\left(\mathrm{v}_{is}'\,\gamma\right) \tag{11}$$

where Φ is a normal standard cumulative distribution.

The second part (proportion of investment in environmental assets) is modelling from a fractional model as follows (Papke & Wooldridge, 1996) :

$$E\left(y_i \mid \mathrm{v}_{iy}, \mathrm{v}_{is}, s_i = 1\right) = G\left(\mathrm{v}'_{iy}\,\beta\right), \tag{12}$$

where v_{iy} is a vector of covariables and β is a vector of unknown parameters and $y \in \left[0,1\right]$ representing the proportion of environmental investments. For convenience, we consider G to be a cumulative normal distribution. This fractional model that is valid if the conditional mean is well specified (Papke & Wooldridge, 1996). After controlling for observable characteristics, CUMAs that make investments in environmental assets may be different from CUMAs with zero investment in terms of unobservable factors. For example, the environmental sensitivity of CUMAs could influence both the propensity to invest in an environmental asset and the proportion of that investment. This may pose a selection problem on the unobservable factors (Cameron & Trivedi, 2005). Schwiebert et Wagner (2015) proposed a generalised two parts model for fractional response that consider the selection problem:

$$E\left(y \mid \mathrm{v}_{iy}, \mathrm{v}_{is}, s_i = 1\right) = \frac{\Phi_2\left(\mathrm{v}'_{yi}\,\beta, \mathrm{v}'_{is}\,\gamma; \rho\right)}{\Phi\left(\mathrm{v}'_{is}\,\gamma\right)} \tag{13}$$

where $\Phi_2\left(.;\rho\right)$ denotes the bivariate standard normal distribution, with ρ representing the correlation between the participation and the proportion of environmental investment. If the correlation parameter ρ equals zero, the generalised model reduces to the simpler two parts following Ramalho and Da Silva (2009). In the case of a model with dependence, the likelihood function is:

$$\begin{aligned}\log L\left(\theta\right) = \sum_{i=1}^{n} l_i\theta \equiv \sum_{i=1}^{n} \Big\{\left(1 - s_i\right)\log\left(1 - \Phi\left(\mathrm{v}'_{is}\,\gamma_i\right)\right) + s_i \log\Phi\left(\mathrm{v}'_{is}\right)\Big\} + \\ z_i\left[\left(1 - y_i\right)\log\left(1 - \frac{\Phi_2\left(\mathrm{v}'_{iy}\,\beta, \mathrm{v}'_{is}\,\gamma; \rho\right)}{\Phi\left(\mathrm{v}'_{is}\,\gamma\right)}\right) + y_i \log\left(\frac{\Phi_2\left(\mathrm{v}'_{iy}\,\beta, \mathrm{v}'_{is}\,\gamma; \rho\right)}{\Phi\left(\mathrm{v}'_{is}\,\gamma\right)}\right)\right],\end{aligned} \tag{14}$$

(Schwiebert & Wagner, 2015)

The generalised two-part fractional model is implemented in Stata via the conditional mixed process (Wulff, 2019). Furthermore, the identification of Equations (17) and (18) can be based solely on the nonlinearity of the selection equation. However, for robust estimation, it is recommended to introduce an exclusion variable (Cameron & Trivedi, 2009)

2.4.2 Marginal effect

To better understand the effect of the explanatory variables, it is possible to determine their marginal effects (Schwiebert & Wagner, 2015). Equations (21), (22) and (23) define the marginal probability of positive investments ($y_i > 0$) and the conditional and unconditional means of y_i, respectively:

$$P\left(y_i > 0\right) = \Phi\left(\mathrm{v}_{is}' \gamma\right) \tag{15}$$

$$E\left(y_i \mid y_i > 0\right) = \frac{\Phi_2\left(\mathrm{v}_{iy}' \beta, \mathrm{v}_{is}' \gamma; \rho\right)}{\Phi\left(\mathrm{v}_{is}' \gamma\right)} \tag{16}$$

$$E\left(y_i\right) = \Phi_2\left(\mathrm{var}_{iy}' \beta, \mathrm{var}_{is}' \gamma; \rho\right) \tag{17}$$

By differentiating Equations (15)-(17) with respect to var_{iy}, we obtain the marginal effects on the probability of investment and the conditional and unconditional mean (Wulff, 2019).

2.5 Theoretical model of cooperative environmental investment

We use a simple model inspired by FG (2012). Building on the work of Rey and Tirole (2007), FG (2012) define the conditions under which a cooperative is likely to invest without the horizon problem.

2.5.1 Surplus of the members of the cooperative

Following FG (2012), let us consider a demand function for a service x, e.g. the use of environmental farm equipment, such that:

$$x = ap^{-\eta} \tag{18}$$

where a is a demand shifter, p is the price of the service, and η is the elasticity of demand. We assume that $a'(k) > 0$ where k 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). In addition, k is a function of the number of members z, the investment CI in agricultural equipment's and other factors that could impact the social capital ξ, $\left(k\left(z, CI, \xi\right)\right)$. The link between size and social capital could be found in (Feng et al., 2016). Specifically, increasing size tend[29]s to increase heterogeneity and anonymity which limit the development of social capital. In some cases, CUMAs prefer to remain a small homogeneous group where social mechanisms are easily applicable (Diakité et al., 2022). Similarly, social interactions within the cooperative tend to depend on the technical and economic orientations of members. For example, Lucas (2018) shows that organic producers within CUMAs seemed distant from conventional producers. Thus, social capital would also be a function of the type of investment. ξ captures all the other factors that can determine social capital (Aldridge et al., 2002). We assume that the cooperative maximises the economic surplus of its members by pricing the service at its marginal cost of production *m*. Moreover, members can access the

[29] The increase in size could also promote standardization of procedures within the cooperative.

service using alternative providers[30] at price p_a. If they prefer the services offered by the cooperative, FG (2012) shows that their surplus is :

$$s = \int_{m}^{p_a} ap^{-\eta}dp = \frac{a}{\eta - 1}\left[\frac{1}{m^{\eta-1}} - \frac{1}{p_a^{\eta-1}}\right] \tag{19}$$

FG (2012) states that the cooperative invests if the demand is inelastic. From Equation (9), the net economic surplus of the members after a time horizon T is written as:

$$\Omega_T = \sum_{t}^{T} \delta^t \left(\left(\frac{a(k_t)}{\eta - 1}\left[\frac{1}{m^{\eta-1}} - \frac{1}{p_a^{\eta-1}}\right]\right) - w_{CI} CI_t \right) \tag{20}$$

where t is the time, δ is a discount factor, and w_{CI} is the unit cost of investment. We assume that $w'_{CI}(z) < 0$, i.e., the unit investment cost decreases with the number of members since in a CUMA the cost of the investment being shared among the members using the same machinery.

2.5.2 The objective function of CUMA

Following Szymańska and Jegers (2016) , let us consider S_t to represent the environmental function of CUMA, where S_t depends on the quality of the environment[31] V_t and economic benefits from environmental investment[32] θ:

$$S_t = S(V_t, \theta)$$

where $\partial S / \partial V > 0$ and $S'(\theta) > 0$. It is assumed that as the private benefits from environmental investment increase, more environmental investment can be expected, which in

30 Although the focus is on CUMAs, other forms of organisation, such as informal agreements between producers, provide access to agricultural equipment (Artz et al., 2010).
31 Following European Environment Agency, "environmental quality is a general term which can refer to: varied characteristics such as air and water purity or pollution, noise, access to open space, and the visual effects of buildings, and the potential effects which such characteristics may have on physical and mental health (caused by human activities)". https://www.eea.europa.eu/help/glossary/eea-glossary/environmental-quality
32 For example, authors show that the private benefits to no-till farmers can be higher than those obtained with conventional tillage (Lankoski et al., 2004).

turn improves environmental quality. Therefore, $\partial^2 S / \partial V \partial\theta > 0$. For the quality of the environment V_t, we consider that:

$$V_t = V_0\left(1 - e\left(\sum_{t=1}^{t} E\left(t\right) CI_{t-1}\right)\right)$$

where V_0 represents an initial value of the environment and e is an environmental degradation function. $E\left(t\right) \in \left\{0,1\right\}$ with $E\left(t\right) = 1$ if an environmental investment is made and 0 otherwise. By assumption, degradation decreases with the levels of environmental investment ($e'\left(CI\right) < 0$), environmental value is an increasing function of environmental investment ($V'\left(CI\right) > 0$) and a decreasing function of degradation ($V'\left(e\right) < 0$). Although cooperatives are concerned with member surplus, they also have a social function (Besley & Ghatak, 2017). For example, cooperatives facilitate the adoption of sustainable agricultural practices that have a positive impact on the environment (positive externalities). In the case of CUMAs, environmental commitment may involve the choice of agricultural equipment that is costly but generates positive externalities. The CUMA maximises utility U^s, which is a function of economic surplus Ω_t, social capital[33] k, and environmental function S_t such that $U^S\left(\Omega_t, k\left(z, CI, \xi\right), S_t\right)$ assuming that $U^{S0}\left(.,.,0\right) > 0$ so that it is beneficial for a producer to use the CUMA even if it is not socially committed. The cooperative chooses to make a social commitment if :

$$U^S\left(.,.,S_t\right) > U^{S0}\left(.,.,0\right) > 0 \tag{21}$$

The CUMA maximises utility by maximising the following program:

$$\max_{s/c} U^S\left(\Omega_t, k\left(z, CI, \xi\right), S_t\right) \tag{22}$$

[33] The rationale for the direct link between utility and social capital is that the success of an agricultural cooperative depends on the quality of interpersonal relationships (Valentinov, 2004)

$$\Omega_T = \sum_t^T \delta^t \left(\left(\frac{a(k_t)}{\eta - 1} \left[\frac{1}{m^{\eta-1}} - \frac{1}{p_a^{\eta-1}} \right] \right) - w_{CI} CI_t \right)$$

$$k_t = k(z_t, CI, \xi)$$

$$S_t = S\left(V_t, \theta\right)$$

$$V_t = V_0 \left(1 - e \left(\sum_{\tau=1}^{t} E\left(t\right) CI_{\tau-1} \right) \right)$$

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

$$H = \left[U^s \left\{ \begin{array}{l} \sum_{t=1} \delta^t \left(\frac{a(k)}{\eta - 1} \left[\frac{1}{m^{\eta-1}} - \frac{1}{p_a^{\eta-1}} \right] \right) - w_{CI} CI, k\left(z_t, CI_t, \zeta\right), \\ S\left(V_0 \left(1 - e \left(\sum_{\tau}^{t} E\left(t\right) CI_{\tau-1} \right), \theta \right) \right) \end{array} \right\} \right] \tag{23}$$

2.5.3 The Implications of the objective function of the CUMA

By differentiating Equation (14) with respect to CI, we can identify the factors expected to determine the optimal rate of investment.

$$\frac{\partial H}{\partial CI} = \frac{\partial U^s}{\partial \Omega} \frac{\partial \Omega}{\partial a} \frac{\partial a}{\partial k} \frac{\partial k}{\partial CI} + \frac{\partial U^s}{\partial k} \frac{\partial k}{\partial CI} + \frac{\partial U^s}{\partial S} \frac{\partial S}{\partial V} \frac{\partial V}{\partial e} \frac{\partial e}{\partial CI} \left(E_t\right) - \sum_{t=1}^{T} \delta^t w_{CI} = 0 \tag{24}$$

Equation (24) shows that the optimal investment is realised when the marginal gain from the investment is equal to the marginal cost of the investment. This optimality condition also highlights the importance of the subjective expectation of making an environmental investment $E\left(t_t\right)$. $E\left(t_t\right)$ appears multiplicative with the environmental function; it determines whether an environmental investment is desirable. From Equation (24), different observations can be made.

a) For a given cooperative, in addition to the economic surplus, marginal utility increases with social capital and environmental investment.

b) The third term of Equation (14) on the right is positive, while the sign of the first two is a function of $\partial k / \partial CI$. The marginal increase in investment may imply an increase in social capital or its erosion depending on the role played by the size of the cooperative. Specifically, one can assume that the sign of $\partial k / \partial CI$ is a function of the cross effect between investment and the size of the cooperative. The reason is that increasing the number of members in a cooperative may imply better investment capacity due to economies of scale. Thus, it can be expected that $\frac{\partial}{\partial CI}\left(\frac{\partial k}{\partial z}\right) > 0$.

However, the relationship between size and social capital is nonlinear (Feng et al., 2016; McFadyen & Cannella Jr, 2004) implying that there is an optimal size beyond which any additional member reduces social capital (Also see (Diakité et al., 2022)).

c) If $z \leq z^*$, $\partial k / \partial z > 0$, the marginal increase in members improves social capital. One might therefore expect that $\partial k / \partial CI > 0$. In this case, the marginal gain in expression (14) are positive. It is therefore optimal for the cooperative to invest.

d) If $z > z^*$, $\partial k / \partial z > 0$, the marginal increase in the number of members leads to an erosion of social capital. In this case, $\partial k / \partial CI > 0$, and the first two terms of the marginal gain are negative. In the absence of an environmental investment, the cooperative suffers a disutility. The decision to invest will depend on the net utility between the first two terms and the third term of the marginal gain.

2.5.4 Hypothesis to be tested

This simple model allows us to relate social capital, investment in environmental assets and the size of the cooperative. We make the following hypothesis to be tested :

Hypothesis 1: If a CUMA make an investment in environmental assets, its size affects the propensity and the level of environmental investment nonlinearly (observations c and d).

Hypothesis 2: The propensity and the level of an investment in environmental assets increases with the economic gains linked to this investment (derived from $\left(\partial^2 S \big/ \partial V \partial \theta\right) > 0$).

Based on the two hypothesis, we estimate the following equations:

$$s_i = 1\left(\gamma_1 Size_i + \gamma_2 Size_i * Size + \gamma_3 Income_i + Controls_i + u_i > 0\right) \tag{25}$$

$$y_i^* = \Phi\left(\beta_1 Size_i + \beta_2 Size_i * Size_i + \beta_3 Income_i + Controls_i + \varepsilon_i\right) \tag{26}$$

$$y_i = y_i^* s_i \tag{27}$$

With :

$$\begin{pmatrix} u_i \\ \varepsilon_i \end{pmatrix} \mid v_{iy}, v_{is} \sim \boldsymbol{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right), i = 1, \ldots\ldots, n$$

2.6 Data and variables

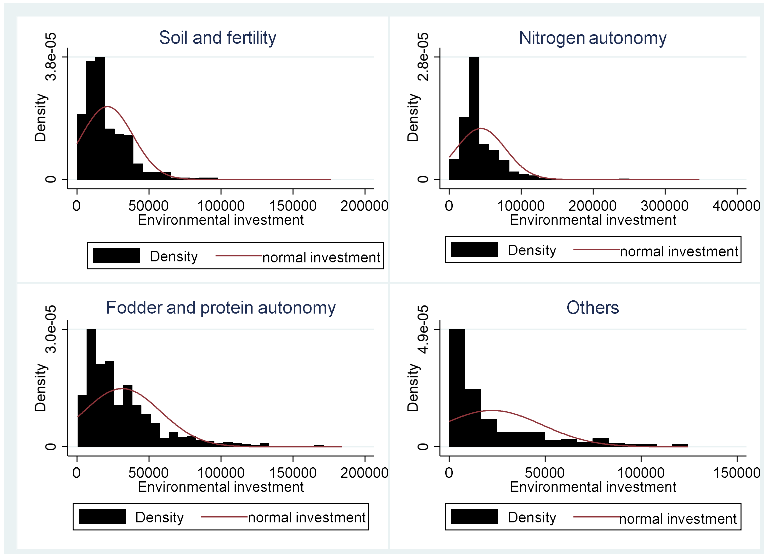
Our data are provided by the national federation of CUMAs. These data concern different financial and organisational characteristics of CUMAs and allow us to characterise the environmental issues associated with each type of environmental equipment. In total, we consider a sample of 2,680 CUMAs for 2015, which we extracted from data provided by the national federation of CUMAs. To capture information on the members, the sample is matched with the data provides by the National department of agricultural Statistics and Prospective analysis in France (AGRESTE) and the National Institute of Statistics and Economic Studies collects (INSEE). We used the 2010 agricultural census data from AGRESTE[34].

Dependent variables

We distinguish two types of dependent variables: one in the selection equation that is binary (invest or not invest) and one designating the proportion of environmental investment y_i. The environmental practices in CUMAs are diverse and depend on the type of agricultural equipment. 6 types of environmental investments are identified in our data. The first three are investments in equipment likely to improve soil health and fertility (SHF), those that promote nitrogen autonomy on farms (NA), and those that facilitate protein autonomy (FPA). An example of an SHF investment is the use of a no-till drill that allows crops to be planted without massive soil degradation. We create a 4th residual category (OTHER) to consider the 3 other types of investments, including improving air quality, reducing the use of plant protection products, and reducing dependence on fossil fuels. Figure 2-1 shows the distribution of environmental investment with a significant asymmetry towards the right. This means that the mass of CUMAs is clustered on low investment values. The shape of the investment distribution justifies the application of a logarithmic transformation.

[34] Due to the release of the 2020 Agricultural Census in July 2022, we have used data from the 2010 Agricultural Census.

Figure 2-1 : Distribution of environmental investment



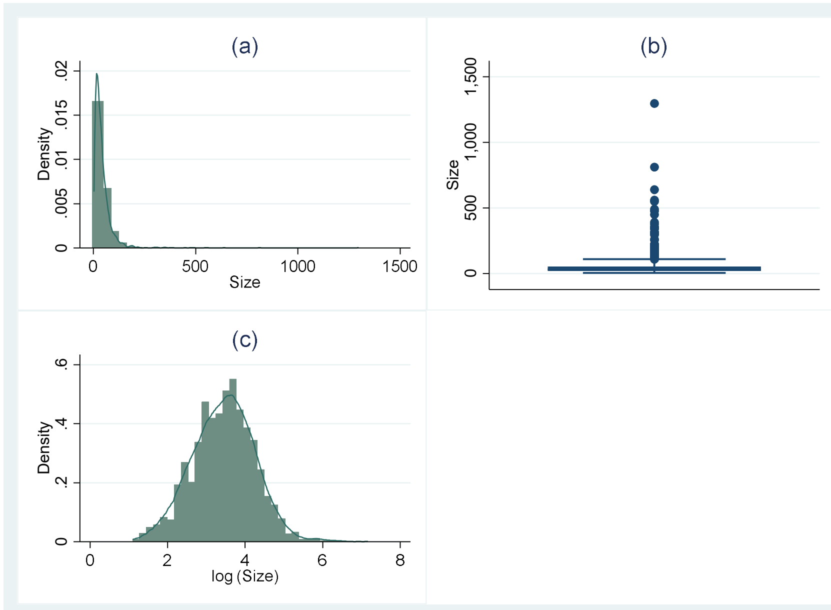
Source: Based on author calculation

Size and income variables

Our independent variable of interest is the size of the CUMA (Size) and member average income following hypothesis 1 and 2. We measure Size by the number of members, following other authors (Cazzuffi, 2012; Grashuis, 2020). In the absence of direct data on CUMA members income, we used the average income at the level of a municipality[35]. These data are provided by INSEE. From the implications of our theoretical model, we assume that the marginal effect of Size and Income is nonlinear on the propensity to invest and investment proportion. Because of the degree of heterogeneity of SIZE (Figure 2-2), this variable is log-transformed.

[35] The data supplied by INSEE provides a territorial division into squares containing households. By adding up the incomes of the household squares contained within a commune, we obtain an aggregated income at the municipality level. We approximate the income of a CUMA by averaging the incomes of the communes in which its members are spread. For more information see :
https://www.insee.fr/en/information/6043143?sommaire=5894773

Figure 2-2 : Distribution of the number of members in the CUMA



Source: Based on author calculation

Control variables

Other variables are likely to influence the propensity and the proportion of environmental investment in a CUMA. First, we include variables capturing the financial performance of the CUMA (leverage, productivity ratio, financial dependence, cash flows ratio)[36]. Leverage is the ratio of total debt to equity (Lerman & Parliament, 1991). This ratio indicates the ability of the CUMA to meet its debt obligations over the long term. In general, a low ratio is preferable as it indicates better investment protection for lenders (Harris & Fulton, 1996). The productivity ratio is a measure of overall efficiency in the use of assets within the cooperative (Parliament et al., 1990). A high ratio would imply a better use of assets. A high rate could also be the result of underinvestment due to horizon problems within the cooperative (Harris & Fulton, 1996). The effect of this ratio on environmental investment is therefore unclear.

[36] The methods for calculating the leverage, productivity ratio and self-financing rate are provided in Appendix B.1

We also include a variable measuring a CUMA's dependence on external financing. In CUMAs, the financing of agricultural equipment depends on external financing.

Some banks simplify loan transactions by putting CUMAs and dealers in direct contact. This type of bank accounts for approximately 60% of the loans in our data. We interpret this ratio as a ratio of financial dependence (Rajan & Zingales, 1996), which may encourage innovation (Acharya & Xu, 2017). We also capture the CUMA's capacity to generate cash from the self-financing rate (Declerck, 2013). Finally, following Russo et al.(2000), we introduce an INTEX variable as a proxy for the cost of debt (see Appendix B.1).

Different socioeconomic variables (proportion of workers, heterogeneity, age of the CUMA, technical-economic orientation[37]) are also included in our model. These variables are often used in the literature on the adoption of environmental practices (Prokopy et al., 2008). For example, the presence of employees in a cooperative may raise agency issues. On the other hand, their presence could also improve the specialisation of tasks at both the governance and operational levels (Becker & Murphy, 1992). Heterogeneity can be a strength for a CUMA insofar as it can encourage the sharing of new experiences between members (Groos et al., 2021). However, more heterogeneity implies more tension and anonymity between members (Nilsson, 2001). As in Höhler and Kühl (2018), we consider different dimensions of heterogeneity, notably the heterogeneity of members and nonmember patrons[38]. Generally, the groups of members differ in CUMAs. For example, there are CUMAs or GAECs (Groupements d'Exploitations Communs) that are members of another CUMA. Nonmember 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 equipment via a member, while the client carries out transactions directly with the CUMA. Nonmembers patrons benefit from cooperative services (Bernard & Spielman, 2009) . As a result, they could potentially encourage specific, expensive investments from CUMAs. We consider the age of the CUMA, which could potentially be correlated with social capital. The intuition is that the longer a CUMA lasts, the more social capital it

[37] In France, farms are classified according to their production and technical specialization.
[38] The patron's role in a cooperative is to buy from the cooperative or sell to it. Thus, a member or a nonmember can patronize the cooperative (Nilsson, 2001).

accumulates. We therefore consider that 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 integrate the square of the age following other authors (Ma et al., 2018). We also control for the technical and economic orientations of members. Franken and Cook (2015b) show that the more members diversify agricultural products, the less they support investment in specialized value-added technology decisions. Furthermore, the model considers the geographical context of the CUMA by considering different variables (region of membership, population density, farm density, proportion of usable agricultural land). For example, high social pressure or high potential area positively affects the environmental investment propensity (Gebremedhin & Swinton, 2003; Hagos & Holden, 2006). Finally, we include the subsidies[39] received by the CUMA. Table 2-1 summarises the main variables of the study.

[39] CUMAs can have access to different subsidies. These subsidies are allocated according to different criteria such as the type of investment made, i.e., environmental investment or not, the renewal of agricultural equipment or the purchase of new equipment. For example, as part of the recovery plan initiated by the French government, CUMAs can benefit from subsidies when their investments promote better environmental protection. More details on the types of subsidies are provided on the website of the federation of CUMAs in France: http://www.cuma.fr/dossiers/subventions-0

Table 2-1 : Descriptive statistics

Variables	Definition	Mean[40]	SD	Observations	Source
Soil health and fertility investment (SHF)	Soil health and fertility (Euros)	21,158	17,776	771	Federation of CUMA
Nitrogen autonomy investment (NA)	Nitrogen autonomy (Euros)	43,981	34,146	627	Federation of CUMA
Fodder and protein autonomy (FPA)	Fodder and protein autonomy (Euros)	31,492	26,782	909	Federation of CUMA
Other investment	Other investment (Euros)	22,291	26,036	236	Federation of CUMA
ISHF=1 (Dummy)	1 if the CUMA invests in SHF	0.287	0.452	771	-
INA=1 (Dummy)	1 if the CUMA Invests in NA	0.233	0.423	627	-
IFPA=1 (Dummy)	1 if the CUMA Invests in FPA	0.339	0.473	909	
IOTHER=1 (Dummy)	1 if the CUMA invests in others investments (air quality, reduction of phytosanitary, fossil energy)	0.088	0.283	236	-
Size	CUMA size (Number)	43.889	52.869	2,680	Federation of CUMA
Leverage	Financial leverage	1.239	1.531	2,680	Federation of CUMA
Dependence	Dependency ratio	0.773	0.418	2,072	Federation of CUMA
Turnover	CUMA productivity ratio	0.154	0.108	2,680	Federation of CUMA
Cash flow ratio	Ratio of cash flow to Turnover	1.274	0.086	2680	Federation of CUMA
Cost of debt	Cost of debt (Euros)	0.046	0.416	2680	Federation of CUMA
Worker[41]	Proportion of worker	0.006	0.082	2,680	Federation of CUMA
Client	Proportion of client non-patrons	0.097	0.10	2,680	Federation of CUMA
Contact	Proportion of contacts non-patron	0.059	0.05	2,680	Federation of CUMA
CUMA=1 (Dummy)	CUMA member	0.506	0.50	1358	-
EARL=1 (Dummy)	EARL member	0.966	0.181	2589	-
GAEC=1 (Dummy)	GAEC member	0.95	0.217	2546	-

[40] The reported averages relate to non-zero data.
[41] Our database makes it possible to distinguish between manual workers who have a more technical role such as driving agricultural machinery and employees who have an administrative role.

Age	Age of the CUMA (years)	39.489	19.340	2,680	Federation of CUMA
Region (Nominal variable)[42]	CUMA geographic region	-	-	2,680	Federation of CUMA
TEOF (Nominal variable)[43]	Technical and economic orientation of farmers	-	-	2,680	AGRESTE 2010
Population density	Population density (habitant per km^2)	2.249	4.183	2,680	AGRESTE 2010
Farms density	Number of farms/usable agricultural area	0.018	0.009	2,680	AGRESTE 2010
Usable agricultural area	Usable agricultural area proportion	0.573	0.162	2,680	AGRESTE 2010
Subsidies	Subsidies received by CUMA (Euros)	740.072	6,793	2,680	Federation of CUMA
Employee	Number of employees	0.092	0.438	2,680	Federation of CUMA
Income	Average income (Euros)	20554.63	9319.349	2680	INSEE 2015

Note : Standard Deviation (SD) ;

[42] Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.

[43] 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. TEOF 1 is the base.

2.7 Results

2.7.1 Estimated coefficients[44]

Fractional models are based on the strong assumption of a correct specification of the conditional mean $E\left(y_i \mid v_{iy}\right)$ (Papke & Wooldridge, 1996). We test the functional form of the selection and level equation using Ramsey's test[45] (1969). The general form of the test is as follows: $E\left(y_i \mid \mathrm{v}_{iy}\right) = G\left(\mathbf{v_{iy}\beta} + \kappa_1\left(\mathbf{v_{iy}\beta}\right)^2 + \kappa_2\left(\mathbf{v_{iy}\beta}\right)^3\right)$

The null hypothesis H0 is that $\kappa_1 = 0$; $\kappa_2 = 0$. Since we are estimating a two-part model, the specification test is performed for both parts. The test results (Table 2-2) indicate that the reset H0 hypothesis cannot be rejected. This result confirms that our functional form is correctly specified.

Table 2-2 : Reset test

Model	Equation	Result
Generalized fractional model	Fractional part	chi2 (2) = 3.33 Prob > chi2 = 0.188
	Binary part	chi2 (2) = 1.36 Prob > chi2 = 0.507

Note : The p-value these are obtained from a chi-square distribution with two degrees-of-freedom

[44] We first estimate a general model where the dependent variable is environmental investment. Appendix B.2 presents the estimated coefficients of the generalised model. Our results suggest a possible dependence between the propensity equation and the level of investment ($\rho > 0$). Thus, a two-part model would not be appropriate.

[45] The Reset test is a general test for functional form misspecification. The test consists of adding the predicted values of dependant variable to the power of 2 and 3 in the estimated equation and then testing the significance of these new variables. If the model is correctly specified, no nonlinear function of the independent variable should be significant when added to the estimated equation (Cameron & Trivedi, 2005)

Table B-2 in Appendix B.2 presents the estimated coefficient of the estimation. The coefficient of the Size variable is positive and significant, while its square is negative and significant when considering environmental proportion and investment propensity. However, the effect of average member income is not significant.

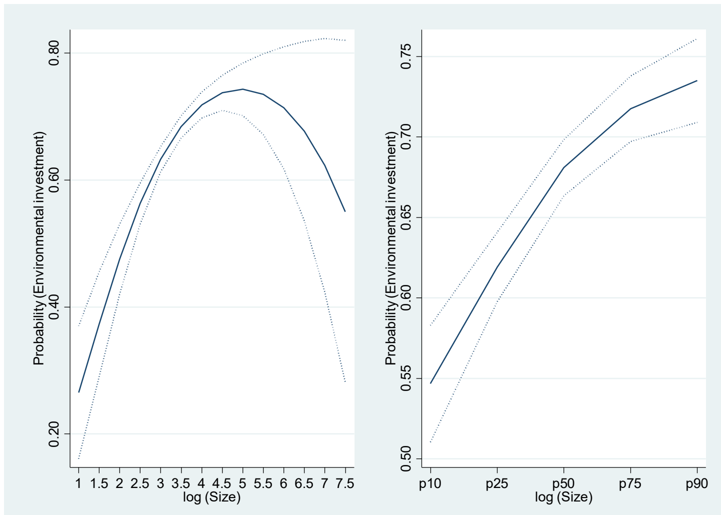
Table 2-3 : Estimated coefficients of Size and Income effect

Variables	Probability	Environmental investment proportion
log (Size)	0.848***	0.484***
	(0.202)	(0.181)
log (Size) × log (Size)	-0.086***	-0.062***
	(0.027)	(0.024)
log (Income)	-0.031	-0.009
	(0.088)	(0.068)

These results confirm hypothesis 1, i.e. the non-linear effect of size on the propensity and proportion of investments in environmental assets, but not hypothesis 2 (The propensity and the level of an environmental investment increases with the economic gains linked to this investment). To confirm the nonlinearity in hypothesis 1, we use the test suggested by Lind and Mehlum (2010), which indicates the presence or absence of a nonmonotonic relationship between two variables. The results (Appendix B.3) support an inverted-U relationship. Figure 2-3 shows the adjusted probabilities at 90% confidence intervals (Williams, 2017). The proportion of environmental investment increases to an optimum of 49 (exp 3.91) before decreasing. Similarly, the propensity to invest increases to an optimum of 141 members (exp4.95) before decreasing. The graph (right) shows that the first quartile of log (member) = 2.39 has an approximately 54% chance of making an environmental investment, while the 4th quartile log (member) = 3.98 has an approximately 71% chance of investing. Furthermore, our exclusion variable[46] (Population density) is not significant as in Gebremedhin and Swinton (Gebremedhin & Swinton, 2003)

[46] Following Yen (2005), the inclusion of an exclusion variable is not essential.

Figure 2-3 : Effect of the size on probability of investment in environmental assets



2.7.2 Marginal effects

2.7.2.1 CUMAs' size marginal effect

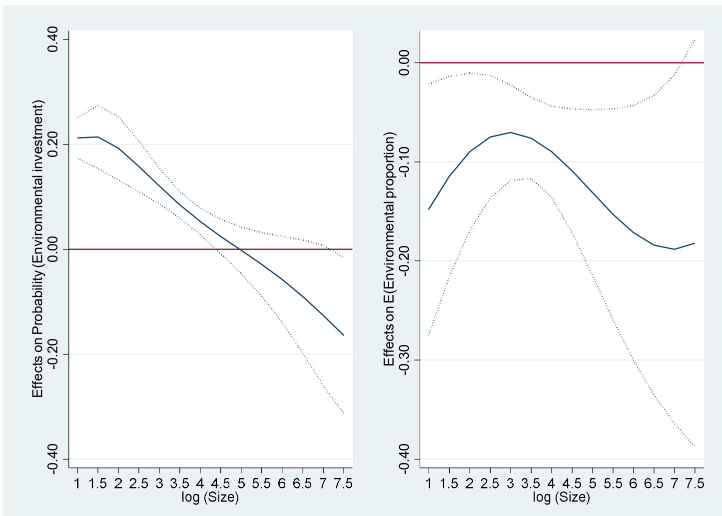
We report in Table 2-4 the net marginal effects of size on the probability of environmental investment, the conditional and unconditional mean of environmental investment. On average, the net effect of the log (Size) on the probability of investment is significant and positive. This implies that a marginal increase in members increases the propensity of environmental investment. Specifically, a 10% increase in size is associated with an increase in the propensity to invest of $0.0953 * \widehat{\beta}$ (Appendix B.4). Thus, when the size of a CUMA increases by 10%, the probability of an environmental investment increases by approximately 0.9%. However, when a CUMA invests, the marginal increase in the number of members tends to decrease the proportion of environmental investment. In other words, increasing size does not necessarily improve the proportion of investments in environmental assets in the population, Size does not have a significant effect on the unconditional environmental proportion since the positive effects on the probability and negative on the conditional proportion compensate each other.

Table 2-4 : Marginal effects of Size

Variable	Probability	Conditional effect	Unconditional effect
log (Size)	0.091***	-0.084***	-0.020
	(0.016)	(0.024)	(0.018)

Figure 2-4 shows the marginal effect on the probability and the conditional effect on different values of size. The probability of investment tends to decrease with the addition of more members while the proportion of environmental investment is nonlinear.

Figure 2-4 : Marginal effect of log (Size) on environmental investment probability and unconditional effect (90% confidence interval)



Graphs of the marginal effects on the percentiles are presented in, **Figure B-1**, Appendix B.5.

2.7.2.2 Marginal effect of control variables

Different control variables are included in the model. The marginal effect of leverage on the propensity to invest is positive. This means that the probability of investment increases when leverage increases. This result is consistent with the notion that borrowing is necessary to develop CUMA activities. However, the negative sign of the square of this variable indicates that beyond a threshold, leverage negatively affects the probability of investment. Excessive leverage can have negative consequences on the cooperative in terms of borrowing capacity or solvency (Moller et al., 1996). As shown in Appendix B.6**,** the marginal effect of leverage on the probability of investment tends to decrease with higher ratios. Similarly, the marginal effect of financial dependence conditional on investment is positive, which confirms previous results (Acharya & Xu, 2017).The results remain mixed regarding heterogeneity. Nonmember patrons affect the probability of investment, but when the CUMA invests, their effect on the environmental investment proportion is negative. At the member-patrons level, the effect remains variable depending on the type of member. For example, the fact that a third CUMA is a member of another CUMA increases the propensity to invest but reduces the environmental investment proportion. This result suggests that heterogeneity is not necessarily a disadvantage for a CUMA, confirming the results of a recent study (Groos et al., 2021). Our results also imply that the older the CUMA, the higher the probability of an environmental investment. This result seems to indicate the absence of a "horizon" problem. Our results also highlight the importance of geographical variables. For brevity, the regional fixed effects have been reported in Appendix B.2. Interestingly, the proportion of environmental investment decreases with high debt costs. Finally, contrary to the results obtained by Gebremedhin and Swinton (2003), the marginal effect of agricultural area density is negative, implying that the propensity for environmental investment tends to decrease with the agricultural potential of the area. Detailed results are provided in **Table B-3**.

Table 2-5 : Marginal effects of control variables

Variables	Probability	Conditional effect	Unconditional effect
Leverage	0.065***	-0.132***	-0.063***
	(0.013)	(0.021)	(0.015)
Dependence	0.013	0.090***	0.063***
	(0.021)	(0.034)	(0.024)
Worker	-0.082	-0.372**	-0.275**
	(0.119)	(0.166)	(0.119)
Client	0.545***	-0.460***	-0.102
	(0.102)	(0.162)	(0.113)
Contact	-0.028	-0.038	-0.035
	(0.206)	(0.327)	(0.249)
Employee	-0.027	-0.002	-0.011
	(0.023)	(0.042)	(0.028)
CUMA	0.046**	-0.100***	-0.049**
	(0.021)	(0.030)	(0.022)
EARL	0.014	-0.071	-0.041
	(0.053)	(0.078)	(0.066)
GAEC	0.082*	0.034	0.049
	(0.046)	(0.069)	(0.048)
Age (log)	0.029*	0.023	0.028
	(0.017)	(0.027)	(0.021)
Farms density	-3.897***	-2.426	-3.034
	(1.316)	(2.603)	(1.915)
Usable agricultural area	-0.058	0.037	0.003
	(0.060)	(0.092)	(0.069)
Subsidy	-0.000	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)
Cash flow ratio	0.007	-0.048	-0.029
	(0.012)	(0.034)	(0.024)
Turnover	-0.203	-0.282	-0.261
	(0.141)	(0.216)	(0.177)
Cost of debt	-0.190	-1.397***	-0.990***
	(0.141)	(0.420)	(0.287)
Population density	-0.001	0.002	0.000
	(0.002)	(0.003)	(0.001)
Observations	2,680	2,679	2,679

2.8 Robustness tests

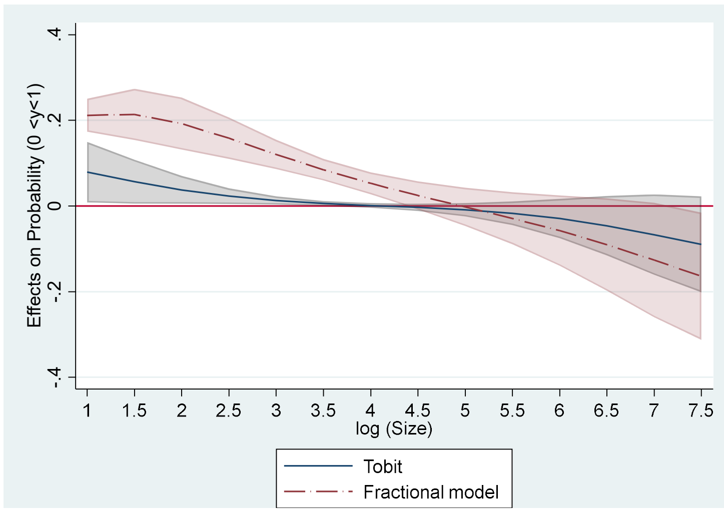
2.8.1 Tobit model estimation

The fractional selection model assumes that zero and nonzero investments are generated by different mechanisms. We assess the robustness of this assumption by estimating a Tobit[47] model with two limits (Cameron & Trivedi, 2009). The results of the Tobit model are reported in Appendix B.7. The specification test does not reject null hypothesis of the specification test, which implies that the Tobit model is potentially well specified $\left(\Pr ob > F = 0.458\right)$. We tested the normality and homoscedasticity hypothesis using the generalised residuals test (Cameron & Trivedi, 2009, p. 534) . Due to the violation of these two assumptions, the Tobit results are not necessarily reliable.

On the other hand, the generalised fractional model assumes a bivariate normal distribution for the error terms of the selection and share equation, which can be restrictive. An alternative is to estimate a two-stage selection model that relies on a univariate normality assumption (Cameron & Trivedi, 2009). This approach compares a Heckman model where the main equation is estimated via an OLS. The results of the model are reported in Appendix B.7. The Reset test indicates a good specification of the binary part of the Heckman model $\left(prob > chi2 = 0.7210\right)$, which is to be expected since both the fractional and Heckman models assume that the selection equation is a probit type. On the other hand, there is evidence $\left(prob > chi2 = 0.07\right)$against the specification of the value equation as opposed to the fractional model. Figure 2-5 presents the marginal effect of size on the probability of environmental investment for the fractional model and Tobit. Overall, the predicted values look the same, although Tobit seems to underestimate the marginal effect.

[47] See Wulff and Villadsen (2020), Ramalho et al.(2011) for a detailed comparison between the Tobit model and the fractional model.

Figure 2-5 : Marginal effect of the size on the probability to invest (90 % Confidence interval)



2.8.2 Multiple exclusion variables

We include additional exclusion variables in our selection equation to test whether adding new variables would been appropriate. Specifically, we include a quadratic term for population density and different interaction terms between population density and the proportion of poor households. The model with additional exclusion variables can be considered an unrestricted model that we compare to the restrictive model with only one exclusion variable. A likelihood ratio test can be used to compare the two types of models, where Hypothesis H0 implies that the restrictive model is valid. With: $LR = 2\left[\ell_{unrestricted} - \ell_{restricted}\right]$, where ℓ is the logarithm of the maximum likelihood (Wooldridge, 2002).

We estimate only the environmental investment propensity. The results are reported in Appendix B.8, **Table B-6**. The p value (0.11) of the test is well above 5%, which suggests that the H0 hypothesis of the LR test cannot be rejected. In other words, our model is robust to the addition of an additional exclusion variable.

2.9 Assessing some heterogeneity

2.9.1 Environmental issues

We re-estimate the fractional model when considering separately the different environmental issues including Soil health and fertility (SFS), Nitrogen autonomy (AAE) and Fodder and protein autonomy (AFP). Appendix B.9 summarises the estimation results without the OTHER category. Overall, considering the heterogeneity of environmental issues does not drastically change our results. As shown in Table 2-6, hypothesis 1 is partially confirmed. Indeed, the effect of size on the probability of environmental investment is non-linear while its effect on the proportion of environmental investment is unclear. Interestingly, increasing income improves the probability of environmental investment but negatively affects the proportion of environmental investment. This result also does not completely confirm hypothesis 2.

Table 2-6 : Estimated coefficients of Size and Income

	Probability	Environmental investment proportion	Probability	Environmental investment proportion	Probability	Environmental investment proportion
Variables	ISHF	SHF	INA	NA	IFPA	FPA
Size (log)	0.613***	-0.077	0.906***	0.598	0.363	-0.568**
	(0.231)	(2.295)	(0.243)	(0.382)	(0.227)	(0.272)
Size (log)*Size (log)	-0.052*	0.003	-0.072**	-0.055	-0.028	0.022
	(0.030)	(0.217)	(0.032)	(0.046)	(0.030)	(0.034)
Income (log)	0.017	-0.049	0.190*	0.140	0.076	-0.148*
	(0.248)	(0.121)	(0.107)	(0.102)	(0.123)	(0.076)
Constant	-3.084	0.429	-4.906***	-3.585***	-2.735**	4.576***
	(2.431)	(10.984)	(1.232)	(1.354)	(1.353)	(1.397)
atanhrho_12		1.220		2.605		-0.064
		(5.805)		(1.620)		(0.424)
Observations	2,680	2,680	2,680	2,680	2,680	2,680

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1 ; SFS: Soil health and fertility ; AAE : Nitrogen autonomy; AFP :Fodder and protein autonomy

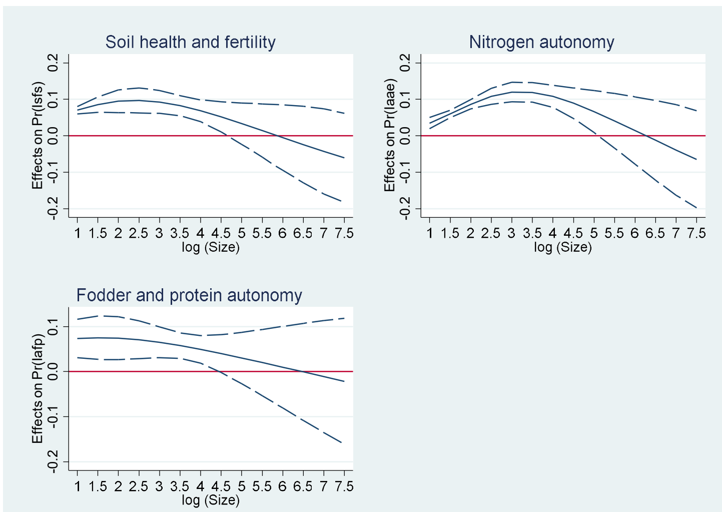
The net marginal effects are reported in Table 2-7. Indeed, the net marginal effect of size on the probability of an environmental investment is positive. However, this effect is non-linear (Figure 2-6). Moreover, when the CUMA invests, the marginal increase in size tends to negatively affect the proportion of environmental investment. These results partially confirm hypothesis 1. Interestingly, we find that the probability of investing in equipment related to nitrogen autonomy increases with an increase in income, which confirms hypothesis 2. However, once the investment is made, the increase in income does not necessarily imply more environmental investment. The detailed results of the marginal effects are provided in Appendix B.9, **Table B-8**.

Table 2-7 : Marginal effects of the explanatory variables

	Probability			Conditional effect			Unconditional effect		
Variables	SHF	NA	FPA	SHF	NA	FPA	SHF	NA	FPA
Size (log)	0.080***	0.111***	0.056***	-0.216	-0.095	-0.408***	-0.071	-0.002	-0.138***
	(0.016)	(0.014)	(0.016)	(0.803)	(0.079)	(0.067)	(0.103)	(0.012)	(0.021)
Income (log)	0.006	0.054*	0.026	-0.060	-0.005	-0.145*	-0.018	0.008	-0.052**
	(0.080)	(0.030)	(0.042)	(0.127)	(0.070)	(0.077)	(0.054)	(0.017)	(0.025)

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 2-6 : Marginal effects of size on the probability of environmental investment (90% confidence interval)

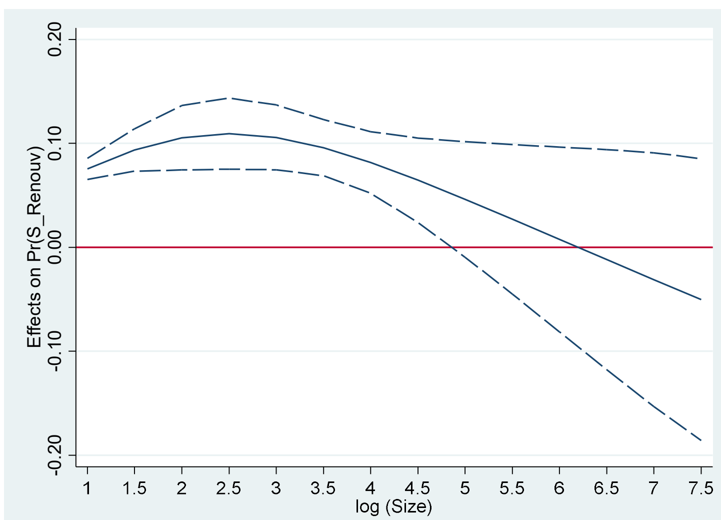


We include several variables in the selection equation, including the quadratic term for population density, an interaction term between density and the agricultural potential of the area, average income at the community level and the interaction between income and density. The estimation results are reported in Appendix B.10, **Table B-9**. We have omitted the FPA and OTHER categories. Overall, there is no significant change in the marginal effect of the variable size. However, on average, the marginal effect of population density is significant. Similarly, the propensity to invest tends to increase with income levels.

2.9.2 Renewal of equipment

We re-estimate the general fractional model on different subsamples. We consider the case where the investment is made in the context of the renewal of environmental equipment. In CUMA, the ability of a branch of activity to renew equipment indicates a presence of trust between members (Diakité et al., 2022). Approximately 31% of environmental investments are made in the context of renewal. Appendix B.11 summarises the estimation results. On average, the marginal net effect of size on the propensity to renewal is positive. This result suggests that the chances of renewed environmental investment increase with the size of the CUMA. However, the effect is not linear. In addition, there is no evidence of a size effect on the proportion of environmental investment, which partially confirms hypothesis 1. Similarly, our results do not confirm hypothesis 2. The detailed marginal effects are reported in **Table B-12**

Figure 2-7 : Marginal effect of log (size) on the probability of renewed environmental investment (90% confidence interval)



Discussion and conclusion

The main objective of this study is to investigate the effect of size on the propensity and proportion of investment in environmental assets. We find that the marginal effect of size on the rate of investment is nonlinear, which confirms hypothesis 1. This result is robust to the different specifications tested in this study. On the other hand, conditional on investment, our results suggest that an increase in the marginal size decreases the environmental investment proportion without a clear nonlinearity effect. We also find that increases in CUMA member average income tend to increase the likelihood of environmental investment which partially confirms hypothesis 2. However, once the investment is made, the increase in income does not necessarily imply more environmental investment. These results have different implications. Firstly, the growth indicators often mentioned in statistics (i.e the number of agricultural producers who are members: in France 3 out of 4 farmers are members of a cooperative) must be interpreted with caution. Although it is desirable that more producers join cooperatives, the absolute increase in the number of members does not necessarily influence their environmental incentives. On the other hand, the promotion of CUMAs must be encouraged to the extent that the increase in the number of members promotes the sharing of risk associated with investments in environmental assets, which increases the probability of an investment.

Our results also allow us to highlight different determinants of investment in CUMAs. Existing studies highlight different investment problems within agricultural cooperatives. The horizon problem is often mentioned as a determinant (Cook, 1995). In the case of CUMAs, the horizon problem does not appear to be a significant factor. In contrast, our results suggest an increase in the environmental investment proportion with the age of the CUMA. More precisely, an increase in age of 10% would imply an increase in the propensity to invest of 0.29 %. The justification for this result is partly based on the importance of interpersonal relationships (Chapter 1) that may exist between members of an elderly CUMA. Financial constraint is also mentioned as a hindrance to the ability of cooperatives to invest (Chaddad et al., 2005). Although we do not test for the presence of financial constraints, the introduction of the leverage ratio allows us to capture the capacity of the CUMA to meet its financial obligations. This ratio has a positive marginal effect, implying that investments increase when financial leverage increases. This result is consistent with the notion that borrowing is necessary to develop CUMA activities. However, the effect of leverage is nonlinear, indicating that excessive leverage can negatively affect the propensity to invest. An interesting finding is the sensitivity of CUMAs' financing capacity rate to environmental investments, which suggests a potential financial constraint[48]. Future studies could analyse the existence or absence of a financial constraint in the context of CUMAs due to the high dependence of these cooperatives on external financing (approximately 65% of investment [49]). Furthermore, our results find no evidence of a significant effect of subsidies on the probability of investment in environmental assets. This result could be justified by the fact that the subsidies are associated with predefined agricultural equipment which would not necessarily reflect the choice of the members.

This study has weaknesses and limitations that need to be discussed. First, because we consider cross-sectional data, our analysis does not capture the dynamic nature of financial performance variables. Indeed, the financial leverage or debt ratio of a cooperative is likely to evolve over time. Second, although this study is based on the theoretical negative effect of the size of cooperatives on social capital, our model does not explicitly include a variable capturing this effect. The reasons for this are related to the difficulty of measuring social capital (Nilsson et al., 2012).

[48]The sensitivity of investments to financing capacity is not necessarily seen as evidence of a financial constraint (Kaplan & Zingales, 1997).

[49] See http://www.cuma.fr/france/actualites/la-dynamique-des-cuma-en-chiffres.

Chapitre 3 Investment in environmental assets and cooperatives performance: Evidence from agricultural machinery cooperatives in France

3.1 Résumé

Nous analysons la relation entre l'investissement environnemental et la performance économique des coopératives de machinerie agricole (CUMA) à l'aide de données de panel de 2010 à 2016. Nos estimations sont basées sur une fonction de distance stochastique dynamique améliorée qui inclut l'investissement comme variable déterminant la frontière et contracte de manière asymétrique les inputs et les outputs. Nous traitons l'investissement comme une variable endogène et l'approche des variables instrumentales est utilisée pour corriger cette endogénéité. Une méthode non paramétrique a été utilisée pour générer différentes mesures de performance, y compris le changement de productivité, le changement technologique et le changement d'efficacité. Nous utilisons l'approche du panel dynamique pour saisir l'effet de l'investissement environnemental sur les mesures de performance. Nos résultats empiriques montrent que les CUMA peuvent améliorer leur performance productive en réduisant les intrants de plus de 50 % tout en doublant leur investissement. De plus, nous constatons que l'investissement environnemental est bénéfique pour les CUMA. En effet, nos résultats montrent qu'une augmentation marginale des investissements environnementaux conduit à une augmentation moyenne de la productivité de 0,214. Si l'on considère uniquement l'effet des nouveaux investissements environnementaux, l'augmentation moyenne de la productivité est de 0,217. Ceci suggère qu'il est avantageux pour la CUMA d'investir dans des équipements environnementaux de premier choix. Cependant, les performances passées ont un impact négatif sur les performances actuelles de la CUMA.

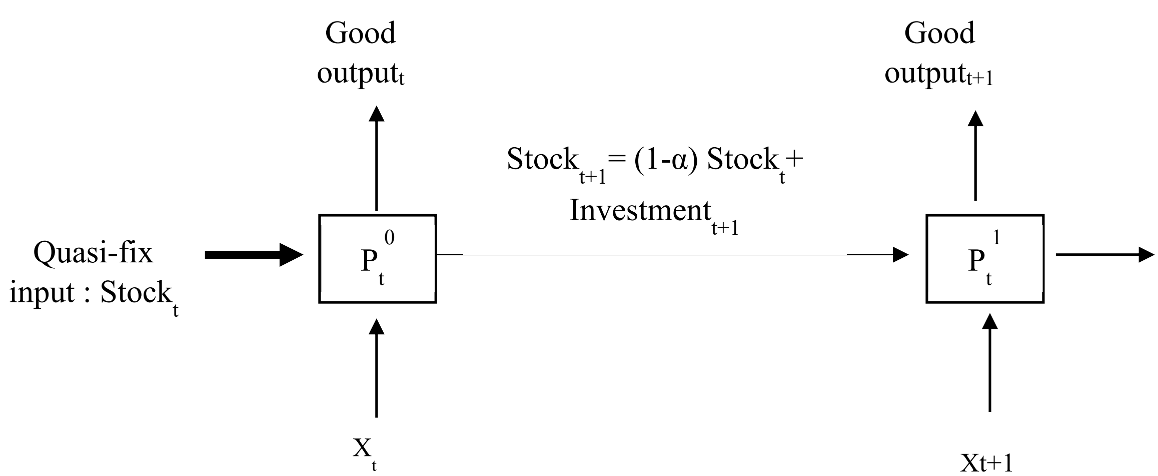
3.2 Abstract

We analyse the relationship between investments in environmental assets and economic performance of agricultural machinery cooperatives (CUMAs) using panel data from 2010 to 2016. Our estimates are based on an enhanced dynamic stochastic distance function that includes investment as a frontier variable and asymmetrically contracts inputs and outputs. We treat investment as an endogenous variable and the instrumental variables approach is used to correct for this endogeneity. A non-parametric method was used to generate different performance measures including productivity change, technological change and efficiency change. We use the dynamic panel approach to capture the effect of investment in environmental assets on the performance measures. Our empirical results show that CUMAs can improve their productive performance by reducing inputs by more than 50% while doubling their investment. Furthermore, we find that investing in environmental assets is beneficial for CUMAs. Indeed, our empirical results show that a marginal increase in environmental investment leads to an average increase in productivity by 0.214. Considering only the effect of new investment in environmental assets, the average increase in productivity is 0.217. This suggests that it is advantageous for the CUMA to invest in first choice environmental equipment.

3.3 Introduction

Investment in environmental equipment have the potential to induce technological change, which is one of the main sources of productivity in agricultural cooperatives(Pokharel & Featherstone, 2021). Following Bostian et al.(2016), we could define environmental investment as all expenditures on agricultural assets likely to have a positive effect on the environment. In addition, investment in environmental equipment can also lead to an improvement in overall firm productivity through cost and differentiation advantages. Cost advantages result from the organisation's ability to introduce best practices and processes that improve its efficiency while reducing its environmental impact (Dechant & Altman, 1994). In the same vein, differentiation advantages result from environmental practices that emphasise product characteristics and product markets. Although scarce, some studies suggest a positive relationship between investment in environmental equipment and cooperative performance. For example, Galdeano-Gómez et al.(2008) shows that investment in environmental equipment allows horticultural cooperatives to benefit from competitive advantage. Generally, CUMAs are recognised for their ability to minimise the machinery costs of their members through the pooling of investments. In addition to the cost advantages, these cooperatives are committed to the dissemination of good agricultural practices through investments in equipment that can have a positive environmental impact (Allaire & Assens, 2002). Despite a recognised environmental commitment, the effect of investment in environmental equipment on the economic performance of CUMAs is missing from the cooperative literature. The objective of this study is to investigate the relationship between the investment in environmental equipment of CUMAs and their economic performance. To capture the performance of CUMAs, we use the dynamic stochastic frontier framework, which allows us to estimate CUMA dynamic technical efficiency. We use a non-parametric approach to generate a Malmquist index which we decompose into an index of technical and technological change. The interest of frontier models is to provide not only a measure of the performance of cooperatives with respect to an optimal frontier (efficiency) but also the evolution of productivity change. Technical efficiency refers to the capacity of the CUMA to operate on an optimal production frontier by maximising its output for a given level of input, by minimising its inputs for a level of output or by simultaneously maximising its output and by minimising its inputs (Cuesta et al., 2009). A large body of literature has focused on the technical efficiency of agricultural cooperatives (Singh et al., 2001). Although these studies are of interest, they generally use a static framework that ignores the intertemporal nature of production and assumes the ability of firms to quickly adjust inputs to improve their efficiency. Specifically, static models ignore investment decisions and assume that the capital stock is adjustable in the short run. Galdeano-Gómez et al.(2008) uses a static stochastic frontier framework by considering efficiency as fixed. This approach is restrictive in that no other time-invariant variable can be included in frontier inputs because it would imply multicollinearity with the inefficiency term (Kumbhakar et al., 2015). Recent studies show that in the presence of quasi-fixed inputs, static models overestimate inefficiency scores since these inputs do not instantly adjust to their optimal level(Alem, 2020). Therefore, we model the performance of CUMAs by adopting the dynamic production process framework. One of the advantages of this framework is to introduce investment into the production function and to account for the accumulation of capital stock, which depreciates over time. Variable inputs and quasi-fixed inputs of period t are transformed by the production process to obtain a level of output, a new stock of quasi-fixed input.

Figure 3-1 : Dynamic production process



Source : Minviel and Sipiläinen (2018)

Moreover, contrary to previous studies, we consider investment in environmental assets to be endogenous. The reason is that agricultural cooperatives are often financially constrained, which potentially affects their investment capacity (Chaddad et al., 2005). In addition, the characteristics of the cooperative such as age, size or interpersonal relationships between members are likely to influence investment (Diakité et al., 2022). Our data allow us to obtain relevant information on different dimensions of the CUMA, in particular the financial dimension, the investment in environmental assets made, the financial partners of the CUMA and the governance dimension. The empirical results show that CUMAs can improve their performance by reducing inputs by more than 50% while doubling their investment. Furthermore, we find that investment in environmental assets is beneficial for CUMAs. Indeed, our empirical results show that an increase in investment in environmental assets leads to an average increase in productivity of 0.214. However, considering only the effect of new investment in environmental assets, the average increase in productivity is 0.217. This suggests that it is advantageous for the CUMA to invest in new environmental equipment.

The rest of the paper is structured as follow. Section 2 reviews the existing literature on cooperative performance and the relation between cooperative performance and investment in environmental assets. Section 3 presents our methodology followed by the presentation of the results methodology in Section 4. Different robustness tests are provided in Section 5. We draw conclusion in the last section.

3.4 Related literature

3.4.1 Cooperative performance and investment in environmental equipment

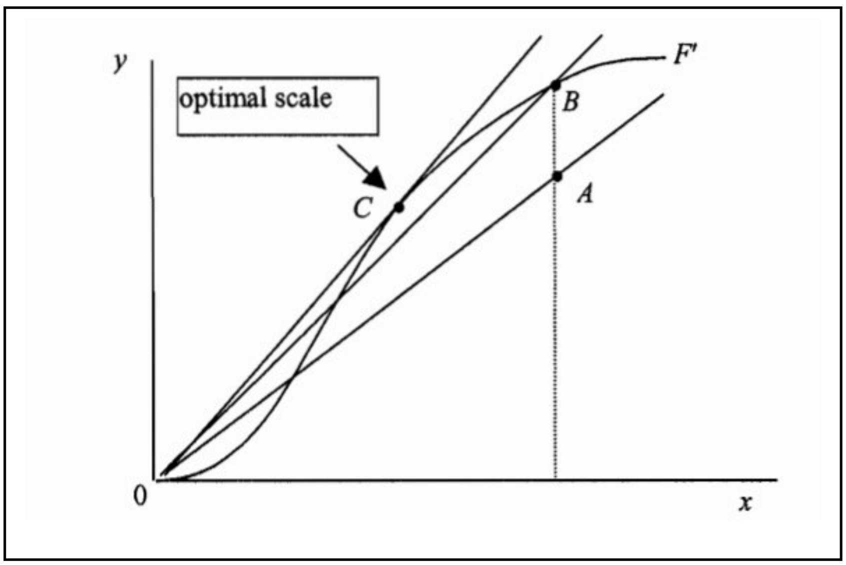
There is a lack of empirical evidence on the impact of investment in environmental equipment on performance in the context of agricultural cooperatives. One of the only studies identified is that of Galdeano-Gómez et al.(2008) . Their results show a positive relationship between investment in environmental assets and productivity improvement in horticultural cooperatives. Horticultural cooperatives are different from CUMAs in that the first are market-oriented cooperatives while CUMAs focus on investment in agricultural equipment for their members. However, investment in environmental equipment could also have a positive effect on CUMAs performance. First, investment in environmental equipment can positively influence technological change, i.e., the capacity of the CUMA to enhance its production technology through innovative equipment. In the cooperative literature, technological change is essential as it is one of the primary sources of productivity for cooperatives (Pokharel & Featherstone, 2021). At the same time, the absence of technological change is likely to limit the adaptability of agricultural cooperatives in a context of strict environmental regulation or may imply their disappearance. Second, the interest of investment in environmental equipment for a CUMA lies in the fact that the replacement of obsolete equipment by newer and more environmental equipment would imply less energy use (Bostian et al., 2016). Using less energy, the CUMA improves its efficiency by reducing the quantity of its inputs while being able to maintain the same level of output. Thus, we expect a positive effect of investment in environmental equipment on the performance of CUMAs.

3.4.2 Empirical issues

3.4.2.1 Cooperative performance measure

The concept of cooperative performance is complex, as it depends on the objectives of the cooperatives, which are defined in different ways in the literature. Soboh et al. (2009) review the literature on agricultural marketing cooperatives. Their study shows that when a single objective is assigned to the cooperative, profitability is most often used as the performance criterion. However, the profitability objective is not common to all agricultural cooperatives. Other performance measures such as financial ratios, i.e., liquidity and productivity, may be used when the cooperative has multiple objectives (Harris & Fulton, 1996). Although financial ratios are a common tool in performance measurement, they lack of a solid foundation in economic theory (Sexton et al., 1993). In the same vein, because of cooperative objective complexity, Franken and Cook (2015a) suggest conceptualizing cooperative performance as a latent construct. Other performance measures include economic efficiency when it is assumed that several objectives are assigned to the cooperative. A large body of literature has focused on the technical efficiency of agricultural cooperatives (Porter & Scully, 1987). Cooperatives' performance measures may also depend on the interest group. Indeed, the performance indicators for owners would be different from those of directors (Hind, 1999). Similarly, the performance criteria for global society would be different from the criteria for cooperative members. For example, based on frontier models, Galdeano et al. (2006) use the environmental total factor productivity as a social performance indicator. In summary, measuring the performance of a cooperative is complex. The performance indicator should depend on both the objectives of the cooperative and the interest groups. In CUMAs, the main objective is to minimise members' costs (Harris & Fulton, 2000a). Thus, minimising members' costs can be a performance criterion. However, this criterion is limited since these cooperatives also have social and environmental objectives (Lucas et al., 2019). In this study, we analyse the performance of cooperatives using the stochastic frontier framework. The interest of frontier models is to provide not only a measure of the performance of cooperatives with respect to an optimal frontier (efficiency) but also the evolution of productivity change. The consideration of these two measures is important insofar as a cooperative could be efficient while being able to improve its productivity. For example, as shown in Figure 3-2, if Cooperative A were to move to point B, it would be efficient. However, moving from point B to point C, the line from the origin is tangent to the production frontier and therefore defines the maximum possible production. The interest of the stochastic frontier framework also lies in the fact that our performance measure is derived from the production technology. Analyses of efficiency and productivity have been used in the cooperative literature as performance measures.

Figure 3-2 : Efficiency and productivity concept



Source : Coelli et al. (2005, p. 5)

3.4.2.2 Parametric or non-parametric model

We can find contributions on dynamic efficiency and productivity change modelling using the parametric or non-parametric approach[50]. The advantage of the non-parametric approach such as Data Envelopment Analysis (DEA), is that it makes no assumptions about the functional form of the frontier apart from the regularity axioms (concavity, monotonicity)(Ramanathan, 2003). However, the efficiency scores from DEA method are generated deterministically, which

[50] Nemoto and Goto (1999), Ouellette and Yan (2008) as also use non-parametric dynamic models.

is one of the major criticisms in the literature. Performance measures can also be derived from a parametric approach. Parametric dynamic approach is carried out using either reduced form and or structural models(Emvalomatis, 2009). The reduced forms are an extension of the standard stochastic models through an autoregressive process of order 1 for the inefficiency component. The interest of these models is to capture the persistence of inefficiency, i.e., the transmission of inefficiency from one period to another (Minviel & Sipiläinen, 2018). Although the reduced form allows some dynamic aspects of the production process to be modelled, it does not allow the dynamic structure to be explicitly modelled. While some studies use the reduced form, the structural approach have been scarce (Serra et al., 2011). The structural approach is mainly based on two methods i.e. shadow cost method (Rungsuriyawiboon & Hockmann, 2015) and distance function (Serra et al., 2011). Serra et al.(2011) argue that the shadow cost method does not model the technology of production directly. These authors suggest a dynamic input distance function derived from a cost function since there is a duality between the input distance function and the cost function. Since the distance function allows a complete characterisation of the production technology and does not require price data or behavioral assumptions, in this article we follow the distance function approach. However, since the parametric approach can be sensitive to the functional form, we also use a non-parametric approach to measure the performance of the CUMA following previous authors (Murillo-Zamorano & Vega-Cervera, 2001)

3.4.2.3 Endogeneity problem in dynamic stochastic frontier models

When using frontier models, endogeneity remains an issue to be considered. In agricultural cooperatives, endogeneity can arise from a simultaneity problem. For example, the past performance of the cooperative is likely to influence its current organisation which in turn may have an impact on future performance (Franken & Cook, 2013). Endogeneity can also be linked to an omitted variable problem. Indeed, some frontier variables may be correlated with omitted variable which violates the assumptions of stochastic frontier analysis (Mutter et al., 2013). For the CUMAs, investment is correlated to their ability to access finance. In the presence of a financial constraint, a CUMA may be limited in its ability to make long-term investment (Li et al., 2015). Several approaches are proposed to deal with endogeneity issue (Kumbhakar & Lai, 2022). Some authors (Coelli, 2000; Cuesta & Zofío, 2005) argue that the regressors in the frontier equation can be considered exogenous due to the imposition of the quasi-homogeneity condition. Other authors (Tran & Tsionas, 2015) suggest methods based on the copula function that allows to directly model the correlation between endogenous variables and the symmetric error. However, this method can be computationally intensive and requires an appropriate copula. Recently, Karakaplan and Kutlu (2019) suggest a flexible instrumental variable-based approach that allows testing the endogeneity assumption of the potentially endogenous variable. In this paper we use Karakaplan and Kutlu's (2017) approach which allows us to capture the effect of a possible financial constraint on the investment capacity of the CUMA.

3.5 Methodology

3.5.1 Theoretical concept of the dynamic distance function

As in Minviel & Sipiläinen (2018), a dynamic enhanced hyperbolic distance model is used to model the production technology in CUMAs. The interest of enhanced hyperbolic model lies in the simultaneous contraction of investment, output and variable inputs. Formally, the dynamic enhanced hyperbolic distance function is written as:

$$D_{H_t}\left(y_{t,} I_t, K_t, x_t, z_t\right) = \inf\left\{\theta_t > 0 : \left(x_t \theta_t, I\theta^{-1}{}_t\right) \in \mathrm{V}\left(y_t : K_t, z_t\right)\right\} \quad (28)$$

where y_t is a desirable output.

I_t is a vector of gross investment $I_t\left(I_t \in R_+{}^H\right)$;

K_t is a vector of quasi fixed input $K_t\left(K_t \in R_+{}^P\right)$;

x_t is a vector of variables input $x_t\left(x_t \in R_+{}^N\right)$;

$\mathrm{V}\left(y_t : K_t, z_t\right)$ is a set of minimum inputs needed to produce y_t given K_t. Following O'Donnell (2018), z characterises the physical variables involved in production process that are not controlled by CUMAs.

θ_t is a scalar giving the value of the contraction of investment and variable inputs; and

t measures time.

If the technology satisfies the usual axioms, then the enhanced distance function verifies satisfies the following properties (Cuesta et al., 2009) :

$$D_H\left(\mu y, \mu I, K, \mu^{-1} x, z\right) = \mu D_H\left(y, I, K, x, z\right), \mu > 0, \quad (29)$$

$$D_H\left(\lambda y, I, K, x, z\right) \leq D_H\left(y, I, K, x, z\right), \lambda \in \left[0,1\right], \quad (30)$$

$$D_H\left(y, \lambda I, K, x, z\right) \leq D_H\left(y, I, K, x, z\right), \lambda \in \left[0,1\right], \quad (31)$$

$$D_H\left(y, I, K, \lambda x, z\right) \leq D_H\left(y, I, K, x, z\right), \lambda \geq 1. \quad (32)$$

Where μ and λ are nonnegative scalar. The enhanced hyperbolic distance function is nondecreasing in investment and output (30) and (31) and nonincreasing in inputs (32), and it exhibits a degree of homogeneity corresponding to (29). Property (29) is essential because it implies that if desirable outputs and investment increase by the same amount and variable inputs decrease by the same amount, the enhanced distance function increases by the same amount (see (Cuesta & Zofío, 2005). An estimable (parametric) form for the Equation (24) can be derived by setting $\mu = 1/y$ see Cuesta and Zofio(2005)

3.5.2 Empirical approach

An enhanced hyperbolic function specification is used by various authors in static models (Adenuga et al., 2019) and in dynamic models (Minviel & Sipiläinen, 2018). Several studies in the agricultural context using stochastic frontiers employ translog functions to approximate the technology (Adenuga et al., 2019). However, if outputs are strongly disposable, as we assume in this study, then a functional form that incorporates cross-products and square terms of the conventional inputs introduces a functional form error into the analysis because curvature properties implied by economic theory are violated (O'Donnell, 2014). Thus, the empirical technology can be approximated by a translog function excluding the cross-products and the squared terms for the conventional inputs. Since we treat z as a non-conventional input (not controlled by the CUMA), we introduce the quadratic terms of this variable following other authors (Njuki et al., 2019).

$$
\begin{aligned}
&\ln D_{H_{it}}\left(y, I, K, z, x\right) = \gamma_0 + \sum_g \alpha_g \ln y_{git} + \sum_h \beta_h \ln I_{hit} + \sum_p \beta_p \ln K_{pit} + \\
&\sum_j \beta_j \ln z_{jit} + \sum_j \sum_{j'} \beta_{jj'} \ln z_{jit} \ln z_{j'it} + \sum_n \beta_n \ln x_{nit} + \\
&+\sum_r \Upsilon_r + \varsigma Dum + \zeta\tau + Dum * \sum_h \beta'_h \ln I_{hit} + Dum * \sum_p \beta'_p \ln K_{pit} + \\
&+Dum * \sum_j \beta'_j \ln z_{jit} + Dum * \sum_j \sum_{j'} \beta'_{jj'} \ln z_{jit} \ln z_{j'it} \\
&+Dum * \sum_n \beta'_n \ln x_{nit} + v_{it}
\end{aligned} \tag{33}
$$

where v_{it} is the usual two-sided error with:

$v \sim N\left(0, \sigma_v^2\right)$ and Υ captures the geographical region of the cooperative.

Dum is a dummy variable taking value 1 for a CUMA with positive environment investment and 0 otherwise. The interest of this dummy is to determine if there is a difference in technology between CUMAs with positive investment in environmental assets value and CUMAs with zero investment in environmental assets. A similar strategy is found in Maietta and Sena (2008);

τ a smooth time trend that accounts for technological change.

The enhanced hyperbolic distance function is homogeneous by degree 1 in output and investment and by degree -1 in variable inputs. Following Cuesta and Zofio (2005), the homogeneity condition is written as:

$$
-\sum_n \beta_n + \sum_g \alpha_g + \sum_h \beta_h = 1 \quad \text{(Appendix C.1)} \tag{34}
$$

To impose homogeneity conditions, it is sufficient to normalise the inputs and outputs in Equation 33 by any input or output. Normalising Equation 33 by y, we obtain Equation 35 :

$$
\begin{aligned}
&-\ln y_{git} = \gamma_0 + \sum_h \beta_h \ln I^*_{hit} + \sum_p \beta_p \ln K_{pit} + \\
&\sum_j \beta_j \ln z_{jit} + \sum_j \sum_{j'} \beta_{jj'} \ln z_{jit} \ln z_{j'it} + \sum_n \beta_n \ln x^*_{nit} + \sum_r \Upsilon_r + \varsigma Dum + \xi\tau \\
&Dum * \sum_h \beta'_h \ln I^*_{hit} + Dum * \sum_p \beta'_p \ln K_{pit} + Dum * \sum_j \beta'_j \ln z_{jit} + Dum * \sum_j \sum_{j'} \beta'_{jj'} \ln z_{jit} \ln z_{j'it} + \\
&Dum * \sum_n \beta'_n \ln x^*_{nit} + u_{it} + v_{it}
\end{aligned}
$$

(35)

Where:

$I^* = I/y_g$ and $x^* = x * y_g$; $u_{it} = -\ln D_{H_{it}}$; $u_{it} \sim h(\boldsymbol{r}_{it}, \boldsymbol{\delta}) u^*_i$; $u^*_i \sim N^+(\mu, \sigma^2_u)$

u_{it} is a one-sided error capturing inefficiency not correlated with v_{it}. The distribution of u_{it} allows the coefficient $\boldsymbol{\delta}$ to be interpreted as semi elasticity, where h is a scaling function (Kumbhakar et al., 2015); u^*_i is CUMAs specific random component.

r_{it} represents the variables that influence inefficiency. A negative coefficient $\boldsymbol{\delta}$, which reduces inefficiency loss, indicates a positive effect on efficiency. A single-step procedure is used to account for the exogenous influences on inefficiency term (Wang & Schmidt, 2002). The capital stock variables K and z are not handled as standard input but as a technology shifter following Minviel and Sipiläinen (2021). Hence, these variables are not normalised.

3.5.3 Endogeneity problems in dynamic stochastic frontier models

We treat investment as an endogenous variable. Recently, Karakaplan and Kutlu (2017) suggest a flexible instrumental variable-based approach that allows testing the endogeneity assumption of the potentially endogenous variable. We adopt this approach. The model of Karakaplan and Kutlu (2017) is detailed in Appendix C.2. For brevity, we present the general model:

$$
\begin{aligned}
&y^*_{it} = \mathbf{x}^* \mathbf{1}'_{it} \boldsymbol{\beta} + v_{it} - u_{it} \\
&u_{it} = \boldsymbol{h}(\boldsymbol{r}'_{it}\boldsymbol{\delta}) \boldsymbol{u}^*_i \\
&\mathbf{x}^* \mathbf{3}_{it} = \boldsymbol{R}_{it} \boldsymbol{\gamma} + \boldsymbol{\varepsilon}_{it}
\end{aligned} \qquad (36)
$$

Where y^{*}_{it} is the logarithm of the normalized output ; $\mathrm{x}^{*}1_{it}$ is a vector of normalized exogenous and endogenous explanatory variables in the frontier equation ; ε_{it} is a two side error; $\mathrm{x}^{*}3_{it}$ a column vector of normalized endogenous variables; R_{it} a vector of instruments and other variables.

With :

$$\begin{bmatrix} \tilde{\boldsymbol{\varepsilon}}_{\boldsymbol{it}} \\ v_{it} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\Omega}^{-1/2}\boldsymbol{\varepsilon}_{\boldsymbol{it}} \\ v_{it} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} I_m & \sigma_v \boldsymbol{\rho} \\ \sigma_v \boldsymbol{\rho}' & \sigma_v^2 \end{bmatrix} \right),$$

where Ω is the covariance -variance matrix of ε_{it} ; ρ the correlation between $\tilde{\varepsilon}_{it}$ and v_{it}; σ^{2}_{v} the variance of v_{it} and $\tilde{\varepsilon}_{it} \sim N(0,1)$

Karakaplan and Kutlu (2017) shows that that equation 36 can be written as :

$$\begin{aligned} y^{*}_{it} &= \mathrm{x}^{*}1'_{it}\beta + \sigma_v \rho' \tilde{\varepsilon}_{it} + w_{it} - u_{it} \\ y^{*}_{it} &= \mathrm{x}^{*}1'_{it}\beta + \left(\mathrm{x}^{*}3_{it} - R_{it}\gamma\right)' \eta + e_{it} \end{aligned} \tag{37}$$

Where: $e_{it} = w_{it} - u_{it}; w_{it} = \sigma_v \sqrt{1-\rho'\rho}\,\tilde{w}_{it}$ and $\eta = \sigma_w \Omega^{\frac{-1}{2}} \rho \Big/ \sqrt{1-\rho\rho'}$. The term $\left(\mathrm{x}^{*}3_{it} - R_{it}\gamma\right)' \eta$ represents the bias correction. If η is significant, the correction term is necessary. Otherwise, the model can be treated as exogenous. The xtsfkk package under Stata (Karakaplan, 2022)allows the estimation Equation 35. We use financial leverage as an instrument for financial constraints, as in Egger and Kesina (2014). Following Guariglia (2008), leverage can be considered a proxy for the external financing constraint insofar as it can influence the cooperative's ability to access external financing. To verify the strength of an instrument, a commonly used rule of thumb is to have its z value greater than $\sqrt{10} \approx 3.16$ (Staiger & Stock, 1997).

3.5.4 Cooperative Performance measure

- *Efficiency score*

The interest of stochastic functions is to determine an efficiency score. This score is estimated following The Karakaplan and Kutlu (2017) :

$$EFF_{it} = \exp(-u_{it}) = \exp\left(-E\left[u_{it} \mid e_i\right]\right) = \exp\left(-h_{it}\left(\mu_{i^*} + \frac{\sigma_{i^*}\phi\left(\frac{\mu_{i^*}}{\sigma_{i^*}}\right)}{\Phi\left(\frac{\mu_{i^*}}{\sigma_{i^*}}\right)}\right)\right)$$

Where:

$$\mu_{i^*} = \frac{\sigma_w^2\mu - \sigma_u^2 \boldsymbol{e_i'h_i}}{\sigma_u^2 \boldsymbol{h_i'h_i} + \sigma_w^2}; \sigma_{i^*}^2 = \frac{\sigma_w^2}{\sigma_u^2 \boldsymbol{h_i'h_i} + \sigma_w^2}$$

$$\boldsymbol{e_{it}} = y^*_{it} - \boldsymbol{x1'_{it}}\beta - \varepsilon_{it}{}'\eta; \varepsilon_{it} = x^*3_{it} - R_{it}\gamma$$

- *Malmquist index*

We also use various productivity indicators as performance measures. As shown in Figure 3-2 , an efficient CUMA can still improve its productivity. Productivity can be decomposed into different factors, and different approaches for doing so exist in the literature (Färe et al., 1994; Pastor et al., 2011) In this study, we use a biennial Malmquist index. Specifically, the biennial Malmquist index (BMI. is the ratio of the distance function. A performance value below 1 indicates a decline in productivity, while a value above 1 suggests an increase in productivity.

We introduce quasi-fixed inputs as in Ouellette and Vierstraete (2010) :

$$M_0^B\left(y^{*\,t+1}_i, x^{*\,t+1}_i, k^{*\,t+1}_i, I^{*\,t+1}_i\right) = \left[\frac{D^B{}_o\left(x^{*t+1}_i, y^{*t+1}_i, I^{*t+1}_i, k^{t+1}_i\right)}{D^B{}_o\left(x^{*t}_i, y^{*t}_i, I^{*t}_i, k^t_i\right)}\right]$$

where:

M_o^B is the BMI, and D_o^B is a biennial distance function. The base t period biennial technology is defined as the convex hull of period t and period t+1 technology:

$$T_c^{B,t} = convex\left(T_c^t, T_c^{t+1}\right)$$

The BMI is decomposed into efficiency change and technical change.

$$EC_o^B = \left[\frac{D_0^{t+1}\left(x^{*t+1}, y^{*t+1}, I^{*t+1}, k^{t+1}\right)}{D_o^t\left(x^{*t}, y^{*t}, I^{*t}, k^t\right)}\right]$$ where EC_o^B is the efficiency change and

$$TC_o^B = \left[\frac{D_0^B\left(x^{*t+1}, y^{*t+1}, I^{*t+1}, k^{t+1}\right)}{D_0^B\left(x^{*t}, y^{*t}, I^{*t}, k^t\right)} \frac{D_0^t\left(x^{*t}, y^{*t}, I^{*t}, k^t\right)}{D_0^{t+1}\left(x^{*t+1}, y^{*t+1}, I^{*t+1}, k^{t+1}\right)}\right]$$ where TC_o^B is the technical change.

Although our basic model uses an enhanced hyperbolic frontier, the productivity indicators are determined via an output distance function. The malmquist index and its components can be calculated via a parametric approach as in Fuentes (2001) and Pantzios et al.(2011). The parametric approach would involve introducing into the equation (35) , the time and second degree polynomial of time to capture the technological change (Fuentes et al., 2001). However, this specification is rejected by our model. Furthermore, we estimate the BMI using the DEA method, as it does not impose any specific functional form on technology. We used the malmq2 package in Stata to obtain the BMI decomposition (Du, 2021).

3.5.5 Impact of investment in environmental assets on performances

Our objective is to analyse the effect of investment in environmental assets on the performance of the CUMA. Following Lanoie et al.(2008) and Broberg et al. (2013), we use the proportion in investment in environmental assets as a proxy for investment in environmental assets. However, we acknowledge that this proxy may be biased since it is likely to incorporate investment in second-hand equipment. Since our data allow us to distinguish between investment in new and second-hand equipment, we also test the effect of this type of investment on CUMA performance. Our performance measures include BMI, EC_o^B and TC_o^B. We analyse the effect of investing in environmental assets on performance indicators using a dynamic panel model.

Our basic specification can be written as:

$$p^{p}{}_{it} = j_{it}' \beta_{x}^{\;p} + \alpha_{i} + \varepsilon_{it} \tag{38}$$

where:

p_{it}^{p} is a CUMA performance variable; j_{it} column vector, α_{i} captures the fixed effects, and ε_{it} is the error term. The fixed effect (FE) and first difference (FD) estimators provide consistent estimates of the coefficients of the time-varying regressors when the regressors are uncorrelated with the time-varying error term. However, this assumption is restrictive. It could be that time-varying regressors are correlated with time-varying error. In this case, the instrumental variable estimator is consistent (Cameron & Trivedi, 2009). This assumption is appropriate in our context because investment may be correlated with unobservable variables such as financial constraints, which are not static. An extension of model 38 is to include a lag variable of the dependent variable. A basic specification can be written as (Roodman, 2009):

$$p^{p}{}_{it} = \beta_{y}^{\;p} p^{p}{}_{it-1} + j_{it}' \beta_{x}^{\;p} + \alpha_{i} + \varepsilon_{it} \tag{39}$$

The Equation (39) suggests that CUMA past performance may influence present performance. Following others authors (Biagini et al., 2020), β_{x}^{p} may be interpreted as the short-run effect of regressors. We use GMM (generalised method of moments) to estimate Equation 39. The interest of this method lies in its capacity to account for the endogeneity of the regressors and unobserved heterogeneity. The GMM system estimator (Arellano & Bond, 1991) may be more flexible than the classical GMM difference model since it allows the fixed variables to be integrated only in the level equation. However, the Andrews and Lu (2001) test can be used to compare the models.

3.5.6 Data and variables definition

3.5.6.1 Data

The data are provided by the federation of CUMAs in France. Our data allow us to obtain relevant information on different dimensions of the CUMA, in particular the financial dimension, the investment in environmental assets made, the financial partners of the CUMA and the governance dimension. We consider data between 2010 and 2016. However, due to the many gaps in our data, our strategy was to retain only the CUMAs identified over a 4-year period (Table 3-1) shows the distribution of CUMAs according to their frequency of occurrence. To capture information on the members, our sample is merged with the data provides by the National department of agricultural Statistics and Prospective analysis in France (AGRESTE) and the National Institute of Statistics and Economic Studies collects (INSEE) 2010 data, which identify various characteristics of the members in particular: the technical and economic orientation of the members' farms, the number of communes in which these members are spread, the agricultural area and the total population at the commune level.

Table 3-1 : Frequency of successive occurrence of CUMA (2010-2016)

Consecutive year	Frequency	Percentage	Cumulative percentage
1	170	0.394%	0.394%
2	282	0.654%	1.048%
3	617	1.431%	2.479%
4	887	2.057%	4.536%
5	859	1.992%	6.528%
6	1,464	3.395%	9.923%
7	38,850	90.097%	100%

Source: Authors calculation

3.5.6.2 Variable definitions

Table 3-2 summarises the main variables in this study.

- *Output*

Identifying the output of a cooperative is complex, as the output depends on the objectives and type of cooperative. For example, in the case of marketing cooperatives, it is common to use production volume or turnover as output (Maietta & Sena, 2008; Singh et al., 2001). The choice of this type of output is based on the underlying assumption of an objective function intended to maximise the welfare of the members of the cooperative. However, this approach may be restrictive, as the literature indicates that these organisations are potentially capable of taking on more global social missions (Besley & Ghatak, 2017). In addition, an efficient cooperative could be far from the frontier because of the effect of the difference in prices charged to members. Since CUMAs offer services to their members, the quantity of services can be a good output. However, CUMAs use different units (kilogram, hectare, tonne, euro minute, hour) to quantify the service offered. As a result, it becomes complex to obtain a single aggregate indicator that reflects the diversity of members' activities. In this study, we use the added value (Turnover minus intermediary consumption) as in Galdeano et al. (2006). The added value could reflect the CUMA's ability to promote better use of equipment. To mitigate price effects, we deflated the monetary value of the added value by the producer price index[51], which allows us to obtain an implicit quantity (O'Donnell, 2018).

- *Investment in environmental equipment as a determinant of performances*

Our main variable of interest is investment in environmental equipment. We consider investment in environmental assets as all the expenditure on agricultural equipment likely to have a positive environmental impact. Six types of investment in environmental assets are identified in our data. The first three are investments in equipment likely to improve soil health and fertility (SHF), those that promote nitrogen autonomy on farms (NA), and those that facilitate protein autonomy (FPA). An example of an SHF investment is the use of a no-till drill that allows crops to be planted without massive soil degradation. The 3 other types of investments, include improving air quality, reducing the use of plant protection products, and reducing dependence on fossil fuels. These equipment's has been identified through qualitative work carried out by

[51] We use the annual producer price indices based on 2015 by the Institute of National Statistics in France (INSEE)

the FNCUMA. According to Porter and Van der linde (1995)the effect of investment in environmental assets is dynamic. To take this dynamic into account, we integrate lag variables for the investment in environmental equipment variable following other authors(Broberg et al., 2013) The intuition is that an environmental measure taken at time t-2 may have effects at time t.

- *Frontier variable*

We use three inputs (Investment, Energy, Employee) and contextual variables (Stock, Subsidies). Following the literature on dynamic efficiency (Boussemart et al., 2019; Minviel & Sipiläinen, 2021), dynamics in production decisions are modelled using gross investment in agricultural equipment. We also use expenditures on energy and a dummy for employees as a frontier input variable. In France, there are approximately 4,800 employees for 10,322 CUMAs, i.e. less than one employee per CUMA (FNCUMA, 2021), which implies zero for this variable in our data. Because of the multicollinearity between the employee variable and the other variables of the frontier, we introduced it as a dummy. For other inputs with zeros, we used the procedure proposed by Battese (1997), namely:

$$x_i^n = \max\left(x_i^n, D_i^n\right) \tag{40}$$

where $D_i^n = 1$ if $x_i^n = 0$ and $D_i^n = 0$ if $x_i^n > 0$

Land, buildings and equipment are reported as stock variables. To capture the depreciation effect, we adopted Fazzari et al.'s (1987) equation to determine the capital stock accumulation:

$$k_t = \left(1 - \upsilon\right) k_{t-1} + I_t \tag{41}$$

where:

k_t is a stock of capital; υ is the depreciation rate. We use 3% for land and buildings and 10% for equipment following Silva and Stefanou (2007).Furthermore, all inputs in monetary values have been deflated using input price indices from the French National Institute of Statistics and Economic Studies (INSEE) as deflators. However, as suggested by Sipiläinen and Oude Lansink (2005), this procedure does not convert them to quantities. The descriptive statistics of the main variables of the study are reported in Table 3-2. To avoid a convergence problem, all variables have been divided by their geometric mean (Cuesta & Zofío, 2005).

Table 3-2 : Variables definition

Variable	Parameter	Unity	Definition
Added Value		Euros	Output of CUMA
Frontier variables			
Investment	β_1	Euros	Gross investment in agricultural equipment
Stock	β_2	Euros	Capital stock (buildings, land, equipment)
Subsidy	β_3	Euros	Equipment Subsidy
Energy	β_4	Euros	Total energy expenditure
$^{+}$Region	Υ_r	-	Region to which the CUMA belongs (11 categories)
D (Dummy)	ς		1 for CUMA with environmental investment, 0 otherwise
DSalary (Dummy)	β_5	-	1 for CUMA with employee, 0 otherwise
Time	τ	Year	(2010…2016)
Variables of the endogeneity equation			
Leverage	γ_1	Ratio	CUMA financial leverage
Subsidy	γ_2	Euros	Equipment Subsidy
Size	γ_3	-	Total number of members
Age	γ_4	year	Age of CUMA
Debt Cost	γ_5	Euros	Debt cost
Otex^{++}	γ_6	-	Technical orientation of producers

Salary	γ_7	-	Total number of employees
Variables of inefficiency term			
Environment	r_1	Euros	investment in environmental assets proportion
Subsidy	r_2	Euros	Equipment Subsidy
Branch	r_3	-	Number of branches of activity
Diversity	r_4	-	Shanon index
Time	τ	Year	(2010…2016)
DEmployee (Dummy)	r_5	-	1 for CUMA with employee, 0 otherwise

Note : Region includes 11 categories ; Region 1 = Auvergne-Rhône-Alpes ; Région 2= Bourgogne-Franche-Comté ; Région 3= Bretagne ; Région 4 = Centre-Val de Loire ; Région 5 =Nord-Pas-de-Calais-Picardie ; région 6 = Normandie ; Région 7 = Nouvelle Aquitaine ; Région 8 = Occitanie ; Région 9 = Pays de la Loire ; Région 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.

++OTEX 1 = Cattle, sheep and goats; OTEX 2 = Arable crops; OTEX 3 = Vegetable growing and horticulture; OTEX 4 = Fruit and other permanent crops; OTEX 5 = Pigs and poultry; OTEX 6 = Mixed farming; OTEX 7 = Wine growing. OTEX 1 is the basic category.

- *Variables in the endogeneity equation*

We treat the investment variable as an endogenous variable. The reason is that in the case of financial constraints, a cooperative may be limited in its investment capacity (Chaddad et al., 2005). To correct for potential endogeneity, we use financial leverage as an instrument for financial constraints. Following Guariglia (2008), leverage can be considered a proxy for the external financing constraint insofar as it can influence the cooperative's ability to access external financing. Based on the literature (Maietta & Sena, 2010), we also include the subsidies received, CUMA size, age, debt cost and technical orientation of members as additional variables. Following Russo et al. (2000), the cost of debt is proxied by the ratio of interest expenses over total assets minus equity. These variables are likely to have an impact on the CUMA's ability to access external resources.

- *Determinants of performance*

To take this dynamic into account, we integrate lag variables for the investment in environmental assets variable following other authors (Broberg et al., 2013; Lanoie et al., 2008). The intuition is that an environmental measure taken at time t-2 may have effects at time t. We also include a subsidy variable that can affect the performance of the cooperative. We include lagged effects for this variable. We account for the heterogeneity within the CUMA. The effect of heterogeneity is captured via the diversity of activities in the CUMA (Branch) and the diversity of members proxied by the Shannon index H (Hernández-Nicolás et al., 2019).

$$H = -\sum (p_i) * \ln(p_i) \tag{42}$$

where p_i is the proportion of member patrons and nonmember patrons. The nonmember 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 equipment via a member, while the client carries out transactions directly with the CUMA. The diversity indicator could reflect also the quality of the CUMA's social network (Deng et al., 2021). A high index value would indicate a diverse social network. Finally, we also include a time variable to capture a trend in the inefficiency term and whether the CUMA has employees.

Table 3-3 : Summary of the statistics of the main variable

	Without investment in environmental equipment			*With investment in environmental equipment*		
	Mean	Std.Dev	N	Mean	Std.Dev	N
Added value	87,548	75,998	2,493	114,638	94,352	7,741
Investment	65,750	84,475	2,493	111,463	116,322	7,741
Stock	524,593	466,519	2,493	731,291	589,770	7,741
Subsidy	1,060	6,369	2,493	1,039	5,889	7,741
Energy	2,383	9,014	2,493	3,257	11,737	7,741
Salary	0.0609	0.378	2,493	0.065	0.344	7,741
Size	45.97	53.42	2,493	52.52	50.91	7,741
leverage	1.195	1.662	2,493	1.349	0.964	7,741
Branch	2.014	1.179	2,493	3.918	2.423	7,741
Age	38.530	18.91	2,493	38.42	18.40	7,741
Diversity	0.478	0.225	2,493	0.481	0.221	7,741
Environment	-	-		0.568	0.321	7,741
New investment				0.538	0.329	7,741
Debt cost	0.025	0.030	2,493	0.031	0.037	7,741

3.6 Results

Before commenting on the estimation results, we conduct various tests. First, as we consider our stochastic model to be endogenous, we tested whether a correction is necessary using the Durbin-Wu-Hausman test. This test allows us to verify that η is significant (Karakaplan & Kutlu, 2017). In our case, the test indicates that there is endogeneity and correction is necessary (see Table 3-5). As seen in Appendix C.3, the z value of our instrument is higher than 3.16. We can reject the hypothesis of a weak instrument. We also tested the validity of a stochastic model using the Schmidt and Lin residual test (Schmidt & Lin, 1984). The null hypothesis is the absence of left-handed skewness. The *p value* is less than 0.01, which confirms the stochastic model (existence of one-sided error). Second, we tested the simple endogenous model against the augmented model, which accounts for the difference in technology between a CUMA with zero and nonzero investment in environmental assets value. The LR test[52] value is 539.58 with a restriction number equal to 6. At the 5% significance level, the augmented model cannot be rejected. We also test the validity of the stochastic model in the case of the endogenous augmented model. Again, the null hypothesis is rejected. In addition, as our model is dynamic, we tested whether a static model would be appropriate. At a degree of freedom of 1, the null hypothesis is rejected at 5%. We tested an endogenous Cobb Douglas specification against an endogenous augmented model. The LR test value (254.69) indicates that our specification fits the data better than the Cobb Douglas with a restriction number equal to 6. Finally, to introduce more flexibility into the technology, we tested a translog function by integrating all quadratic and interaction terms. The LR value of 1453.29 indicates that the restricted model is preferable with a restriction number of 19. The dynamic endogeneity-corrected augmented model is therefore preferable. Table 3-4 summarises the main hypothesis.

[52] LR test is computed as follows: $\Lambda = -2\left[\ell_{\text{restricted}} - \ell_{\text{unrestricted}}\right]$ where l is a loglikelihood value (Wooldridge, 2002)

Table 3-4 : Hypothesis test on the parameters

Null hypothesis	Λ	Critical value (5 %)	P-value (skewness)	Decision
No inefficiency	-	-	0.000	Reject null
Endogenous model vs Enhanced endogenous model $\sum\beta' = 0$	539.586	12.592		Reject null
No inefficiency in enhanced endogenous model	-	-	0.000	Reject null
Enhanced dynamic model Vs Enhanced Static model $\sum \beta_1 = 0$	402.682	5.991		Reject null
Cobb Douglas vs Restricted translog $\beta_{33} = 0$ and $\sum\beta' = 0$	254.692	12.592	-	Reject null
Translog Vs Restricted translog	1453.813	30.144		Reject null

Source: Authors calculation

The detailed results of the estimation are presented in Appendix C.3., **Table C-2**. For brevity, Table 3-5 presents the main variables of the frontier. Model (1) corresponds to the endogeneity corrected model without the interaction terms with dummy Dum. Model 2 corrects for endogeneity and considers the interaction terms with Dum. Model 3 is static and considers the interaction with Dum.

Table 3-5 : Estimation results[53]

	Dynamic endogeneity - corrected model (1)	Augmented dynamic endogeneity-corrected model (2)	Augmented Static model (3)
Investment	0.043***	0.047***	
	(0.004)	(0.006)	
Stock	-0.247***	-0.250***	-0.171***
	(0.01)	(0.011)	(0.009)
Subsidy	0.001	-0.007	-0.008
	(0.007)	(0.01)	(0.01)
Subsidy $\times$ Subsidy	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)
Energy	-0.014***	-0.021***	-0.020***
	(0.001)	(0.002)	(0.002)
Dum	-0.017*	-0.039**	0.007
	(0.007)	(0.012)	(0.012)
Salary (dummy)	-0.108**	-0.126**	-0.105*
	(0.04)	(0.039)	(0.041)
Time	-0.054***	-0.046***	-0.056***
	(0.004)	(0.004)	(0.004)
Dum $\times$ Investment		0.033***	
		(0.005)	
Dum $\times$ Stock		-0.123***	-0.107***
		(0.009)	(0.008)
Dum $\times$ Subsidy		0.004	0.006
		(0.009)	(0.009)
Dum $\times$ Energy		0.010***	0.008***
		(0.001)	(0.001)
Dum $\times$ Subsidy2		0.000	-0.001
		(0.001)	(0.001)
Constant	1.412***	1.243***	1.428***
	(0.045)	(0.044)	(0.046)
η Endogeneity test $X^2 = 5.48$	$p > Chi2 = 0.01$		
η Endogeneity test $X^2 = 9.48$		$p > Chi2 = 0.002$	
Mean efficiency	0.384	0.426	0.366
+,*,**,*** means the estimated coefficient is statistically significant at p<0.10, p<0.05, p<0.01, p<0.001			

53 Although the output considered is the added value, we have also estimated our models by considering the turnover as output. The results are broadly similar with an average efficiency of 0.38 for the dynamic endogeneity corrected model. The estimation results can be provided upon request.

3.6.1 Input elasticities

Elasticities are estimated from model 2. Following Cuesta and Zofio (2005), first-order coefficients can be interpreted as distance elasticities evaluated at the sample means. Overall, the sign of the coefficients is consistent with the expected signs. The positive sign of the investment coefficient indicates that as investment increases, the CUMA moves closer to the frontier. Similarly, the negative sign of the stock suggests that CUMAs with a high level of stock are moving away from the frontier. Interestingly, the increase in the energy cost seems to move CUMAs with zero investment in environmental assets away from the frontier (coef. = -0.021), while CUMAs with investment in environmental assets are moving closer to it (coef. = 0.010). This could suggest that energy consumption is not an issue for this type of CUMA. Furthermore, the subsidy does not seem to affect the technology. Thus, the finding suggests that our specification satisfies the monotonicity property (nonincreasing in input by increasing in investment). The elasticities are reported in Table 3-6 for the significant variables. On average and considering conventional input, the energy variable seems to be less important in CUMAs with investment in environmental assets than CUMAs without investment in environmental assets.

Table 3-6 : Input elasticities[54]

	Investment	Stock	Energy
CUMA with zero environmental investment	0.047***	-0.25***	-0.020***
CUMA with environmental investment	0.08***	-0.037***	-0.012***

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

[54] For CUMAs with zero investment value, the coefficients of the estimation correspond to the elasticity. However, for CUMAs with non-zero values, the net elasticity of Investment is calculated as follows: $\beta_1 + \beta_1'$

3.6.2 Returns to scale and technical change

Based on the homogeneity condition (Equation 4), constant returns to scale are exhibited at the sample mean when (Cuesta & Zofío, 2005):

$$-\sum \beta_n = \frac{1}{2} \tag{43}$$

From Table 3-5, the estimated value of the term $-\sum \beta_n$ is inferior to 0.5, meaning that CUMAs are operated under decreasing returns to scale. Despite the declining returns, over the period 2010-2016, the coefficient corresponding to the time variable intended to capture neutral technical change presents a negative sign and is statistically significant in all specifications. Its value reflects the existence of an upward shift in the frontier by a value of 4.6% on average.

3.6.3 Efficiency score

Our estimates also allow us to obtain an efficiency score from the corrected model (model 2). The average efficiency is 0.42 with a minimum efficiency of 0.08 (Table 3-7). This result suggests that, overall, CUMAs can improve their performance by reducing inputs by 58 % (1-0.42) while doubling their investment (1/0.42). Table 3-7 also shows that the exogenous and model tends to underestimate efficiency, which differs from the results of Karakaplan and Kutlu (2019) and are similar to those of Xu et al. (2022). Furthermore, as in Minviel and Sipiläinen (2018), we found that static models overestimate the inefficiency score (and therefore underestimate efficiency). The difference in technical efficiency between the corrected and uncorrected models varies from 0.05 to 0.16.

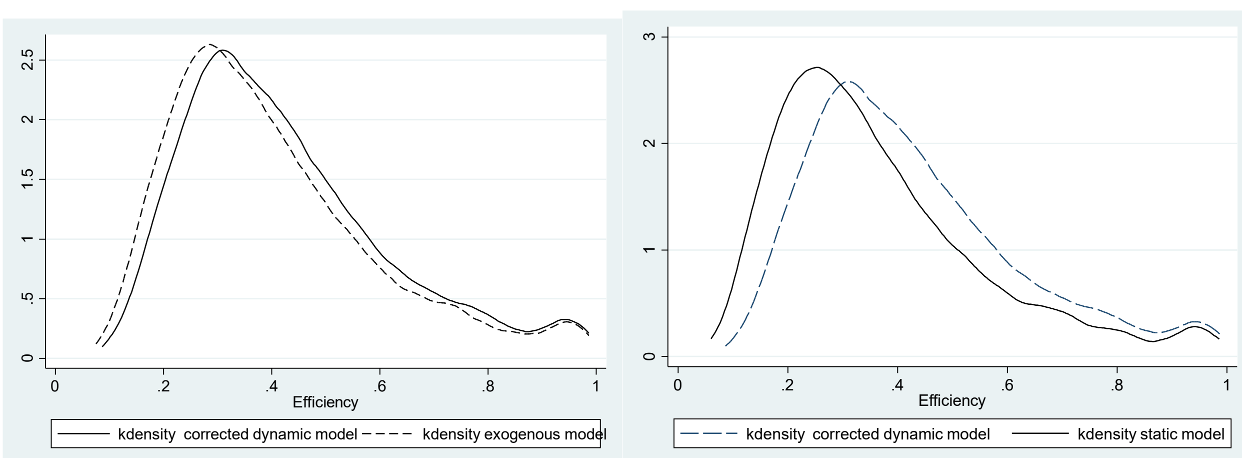
Table 3-7 : Descriptive statistics of efficiency score

	Mean	Std.Dev.	Min	Max	t-test
Corrected dynamic Efficiency	0.426	0.189	0.086	0.986	
Dynamic Exogenous model	0.401	0.19	0.075	0.986	
Difference	*0.062*				*185.207****
Corrected dynamic Efficiency	0.426	0.189	0.086	0.986	
Static model	0.366	0.191	0.060	0.986	
Difference	*0.163*				*212.364****
	Mean	Std.Dev.	Min	Max	t-test
Corrected dynamic Efficiency	0.426	0.189	0.086	0.986	
Dynamic Exogenous model	0.401	0.19	0.075	0.986	
Difference	*0.062*				*185.207****
Corrected dynamic Efficiency	0.426	0.189	0.086	0.986	
Static model	0.366	0.191	0.060	0.986	
Difference	*0.163*				*212.364****

*Note : .*** means the estimated coefficient is statistically significant at $p < 0.001$*
Source: Author calculation

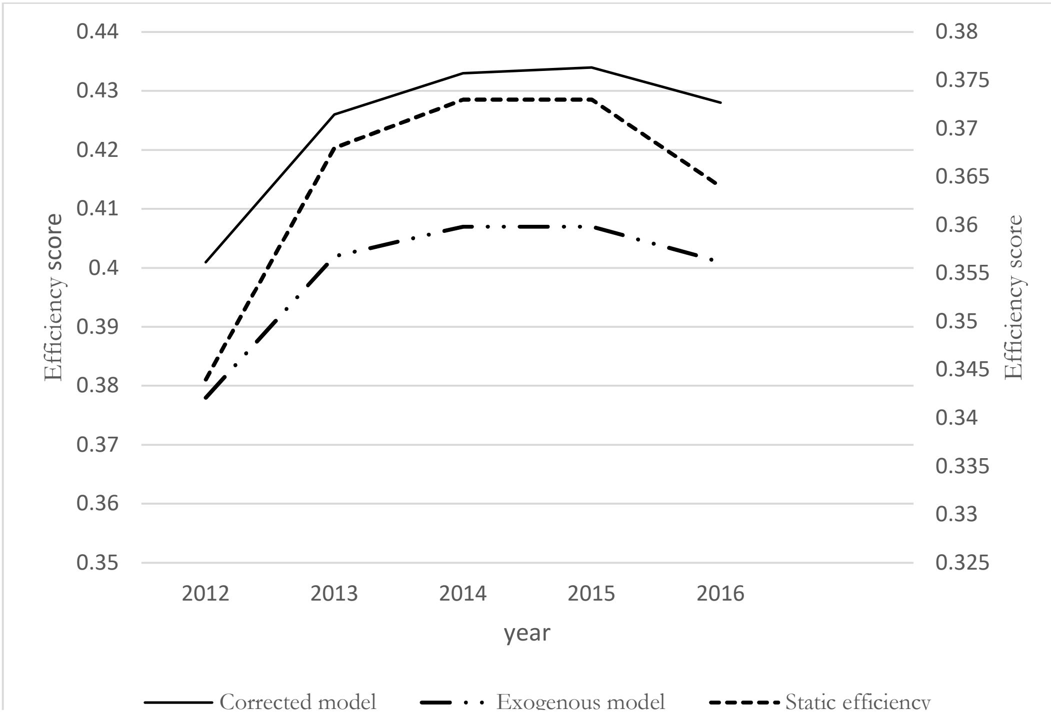
The Figure 3-3 clearly indicates that the exogenous model and static model underestimates the efficiency, which confirms the previous authors' findings.

Figure 3-3 : Corrected model and non corrected efficiency score



The differences in scores between the corrected dynamic model, the exogenous dynamic and the static model can also be seen by examining the evolution of the efficiency score on average (Figure 3-4)

Figure 3-4 : **Average yearly efficiency score based on model (2)**



3.6.4 Factors influencing technical efficiency

The estimation of the one-step stochastic model allows us to estimate the effects of the determinants of the inefficiency term. Following Kumbhakar and Wang (2005), the sign of the coefficient of the inefficiency term provides the direction of the impact of the exogenous variables. Table 3-8 summarises the results. The contemporaneous environmental variables are significant. However, the lagged variables introduced in our model do not capture the dynamic effect. Interestingly, since the squared term of the environmental variable is significant, this suggests that the environmental regulation effect is nonlinear. These results should be treated with caution, as the environmental variable is potentially endogenous. It is possible that CUMAs that have made investment in environmental assets differ in their characteristics from CUMAs with no investment in environmental assets. Moreover, the absence of the dynamic effect of investment in environmental assets could be because our proxy (environmental investment) mainly incorporates investment in second-hand equipment. In addition to the environmental variable, our model captures the effect of different variables. The contemporaneous variable of subsidy variable is not significant. However, the lagged effect (lag2) is significant, indicating that the effect of the subsidy on CUMA performance is dynamic. The effect is positive, indicating a negative impact on efficiency. This may be because subsidies may encourage investment in equipment that is not appropriate for members who may not use it in the long term. In addition, the sign of our proxy for activity heterogeneity (Branch) indicates that heterogeneity negatively affects the efficiency of CUMAs, which confirms previous study (Diakité et al., 2022). We note that the time trend in the inefficiency term included to allow for time-varying inefficiency is negative and statistically significant at the 1% level. This indicates that over the period 2010-2016, CUMAs on average experienced a decrease in technical inefficiency.

Table 3-8 : Determinants of inefficiency term

	Dynamic Endogenous model (4)	Enhanced Dynamic Endogenous model (5)	Enhanced Static model (6)
Environment	-0.187***	-0.496***	-0.214***
	(0.051)	(0.067)	(0.051)
Environment × Environment	0.130**	0.352***	0.201***
	(0.047)	(0.06)	(0.047)
Environment (lag1)	0.001	-0.008	-0.006
	(0.011)	(0.013)	(0.011)
Environment (lag2)	-0.012	-0.017	-0.016
	(0.011)	(0.013)	(0.011)
Subsidy	0.003	0.000	0.001
	(0.007)	(0.008)	(0.007)
Subsidy (lag1)	0.001	0.001	-0.001
	(0.003)	(0.003)	(0.003)
Subsidy (lag2)	0.007*	0.008*	0.007**
	(0.003)	(0.003)	(0.003)
Branch	0.014***	0.015***	-0.003
	(0.002)	(0.002)	(0.002)
Diversity	0.009	-0.01	-0.005
	(0.158)	(0.158)	(0.158)
Time	-0.036***	-0.044***	-0.038***
	(0.006)	(0.007	(0.006)
Time × Subsidy	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)
Salary (Dummy)	-0.123*	-0.167**	-0.107*
	(0.051)	(0.06)	(0.051)
Constant	0.467***	0.309**	0.622***
	(0.094)	(0.099)	(0.093)

Note : +,,**,*** means the estimated coefficient is statistically significant at p<0.10, p<0.05, p<0.01, p<0.001*

3.6.5 Dynamic panel estimates of investing in environmental assets effect on CUMA productivity

3.6.5.1 Biennal Malmquist index result[55]

The descriptive statistics of the performance variables are reported in Table 3-9. On average, over the period 2010-2016, there is a productivity gain for CUMAs driven by efficiency progress. The productivity gains of agricultural cooperatives are often linked to technological progress (Pokharel & Featherstone, 2021). In the case of CUMAs, productivity gains seem to be more related to efficiency progress, as in Kondo et al.(2008)

Table 3-9 : Summary of CUMA performance

Variable	Mean	Std. Dev.
BMI	1.038	0.307
Efficiency change	1.152	0.438
Technical change	0.956	0.231

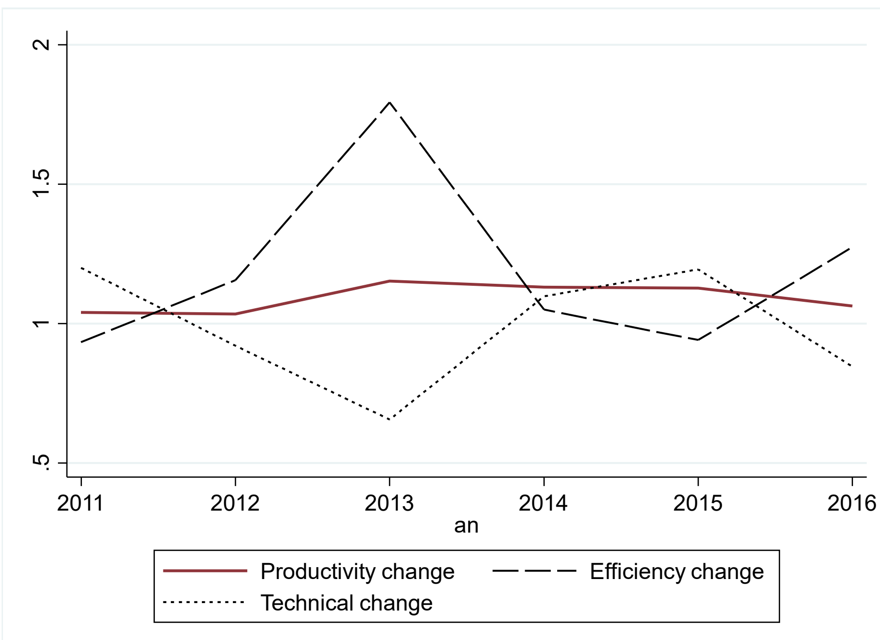
Table 3-10 reports a detailed summary of the BMI from 2010 to 2016. Overall, there is a gain in CUMA productivity over the period considered. For example, between 2011 and 2012, the productivity gain is 2%, while over the period 2013-2014, it is at its highest with a gain of 11%. There was also a decline in productivity between 2012 and 2013 of approximately 2%. Detailed results of efficiency and technical change are presented in Appendix C.4

[55] Due to the extreme values, only the observations between the first and 99th percentiles have been retained.

Table 3-10 : Biennal Malmquist Index (BMI)

Period	Mean	Std. Dev.	Median
2010-2011	1.017	0.32	0.973
2011-2012	1.022	0.27	0.987
2012-2013	0.979	0.249	0.967
2013-2014	1.114	0.352	1.061
2014-2015	1.076	0.331	1.027
2015-2016	1.037	0.326	0.985

Figure 3-5 : Average Productivity, efficiency and technical change



3.6.5.2 Effect of investment in environmental assets

We first estimated a fixed effect model. A random effect model could also have been estimated. However, we discarded this estimator after performing a robust[56] version of the Hausman test (Cameron & Trivedi, 2009). In the fixed effect model, our variable of interest is significant for productivity. This would imply that investing in environmental assets affects CUMA productivity. Specifically, the effect appears to be nonlinear with a U-shaped form. Productivity decreases with investment in environmental assets until a minimum of 41% (=0.152/ (2*0.181)) (Table 3-11). This indicates that the effect of investments in environmental assets is not linear.

Second, we relax the fixed effect assumption by estimating a panel model with instrumental variables. Specifically, the Environment variable is instrumented by leverage. We conduct statistical tests to ascertain whether the instruments are underidentified, redundant, weak, or valid and whether the environmental variable is endogenous. For the underidentification and weak instrument tests, we use the Kleibergen and Paap (2006) approach, which is valid in the presence of non-i.i.d. errors. Under the null hypothesis, the model is underidentified. For each of the productivity indices, we reject the null hypothesis at 5%, which implies that our instruments are relevant. Similarly, our instruments are not redundant since the null hypothesis of redundancy is rejected. However, the values of the Kleibergen–Paap rk Wald statistic seem to indicate that our instruments are weak. As we just have one instrument for one endogenous variable (just-identified model), we cannot test the validity of our instrument. In contrast, in the first two models with instrumental variables, the endogeneity test confirms that the proportion of investment in environmental assets is endogenous. Overall, investment in environmental assets has a positive effect on productivity. For brevity, the detailed results are given in the Appendix C.5

[56] A standard Hausman test requires the random effect estimator to be efficient, i.e., the error term and α_i are i.i.d. A bootstrapped robust Hausman test is implemented in Stata (Kaiser, 2014).

Furthermore, we also tested a first-difference estimator. The results indicate that the effect of the environmental variable always remains positive (Appendix C.6,**Table C-5**)

Table 3-11 : Fixed effect and Instrumental Variable (IV) model

	Fixed effect (7)			Panel IV-Fixed effect (8)		
	Productivity	Technical change	Efficiency change	Productivity	Technical change	Efficiency change
Environment	-0.152*	-0.059	-0.038	1.139+	0.549	0.402
	(0.073)	(0.059)	(0.107)	(0.623)	(0.369)	(0.54)
Environment2	0.181*	0.021	0.135			
	(0.072)	(0.059)	(0.106)			
Environment (lag1)	-0.028	-0.014	-0.001			
	(0.019)	(0.016)	(0.028)			
Environment (lag2)	0.005	0.017	-0.011			
	(0.019)	(0.014)	(0.028)			
Constant	1.244***	0.821***	1.580***			
	(0.042)	(0.024)	(0.053)			
Robust Hausman test	102.25***	41.37***	41.10***			
Kleibergen-Paap rk LM Statisitic				5.470*	5.470*	5.470*
IV redundancy test				5.470*	5.470*	5.470*
Kleibergen-Paap rk Wald F-Statistic				5.545	5.545	5.545
Endogeneity test				7.307**	5.098*	0.333

*Note : :+ $p<0.10$, * $p<0.05$, ** $p<0.01$, *** $p<0.001$ Coeff / Std. Err We use 200 bootstrap repetitions for Robust Hausman test. The Kleibergen-Paap rk LM Statisitic is compare to χ^2 value of 1 degree freedom. For Panel IV, errors are clusterd at the CUMA level and instrumental variables are Leverage and debt cost. For Kleibergen-Paap rk Wald we use Cragg-Donald critical value.*

We estimated a first-difference Arellano and Bond (1991) (AB) robust two-step standard errors model with all variables considered to be endogenous (c) and subsidy considered to be exogenous (d). Globally, the test of Andrews and Lu (2001) confirms that the endogenous model is better than the exogenous model (Appendix C.7). For consistent estimation, the dynamic panel model requires the time-varying error to be serially uncorrelated at lag 2, and the null hypothesis of overidentifying restring cannot be rejected (Cameron & Trivedi, 2009). The tests confirm only the validity of model (c) on productivity. The results show that investment in environmental assets positively affects CUMA productivity. Specifically, a marginal increase in investment in environmental assets increases the productivity by 0.378 points. Using the investment in environmental assets proportion mean in Table 3-3 (0.568) and multiplying it for the estimate's parameter (0.378), we obtain 0.214, that is the increasing average effect of productivity growth linked to investment in environmental assets. This result implies also in the short term that an increase of one unit of investment in environmental assets leads to an increase in productivity of 0.378. For brevity, the detailed results are given in Appendix C.8. **Table 3-12** summarises the main results.

Table 3-12 : First difference model (Arellano & Bond, 1991)

	AB-Endogenous model (c)			AB-Endogenous model / Subsidy exogenous (d)		
	Productivity	Technical change	Efficiency change	Productivity	Technical change	Efficiency change
Productivity (lag 1)	-0.260***			-0.270***		
	(0.047)			(0.045)		
Technical change (lag 1)		0.175+			0.163+	
		(0.104)			(0.096)	
Efficiency change (lag 1)			-0.188***			-0.207***
			(0.046)			(0.041)
Environment	0.378**	-0.068	0.464*	0.379*	-0.049	0.510*
	(0.142)	(0.092)	(0.213)	(0.178)	(0.084)	(0.234)
Environment (lag 1)	0.01	-0.001	0.053	-0.01	-0.003	0.031
	(0.065)	(0.03)	(0.092)	(0.067)	(0.024)	(0.083)
Environment (lag 2)	0.047	-0.002	0.053	0.039	-0.002	0.032
	(0.05)	(0.026)	(0.067)	(0.05)	(0.02)	(0.06)
AR1 (p-value)	0.000	0.046	0.43	0.000	0.002	0.000
AR2 (p-value)	0.565	0.001	0.10	0.68	0.00	0.30
Sargan-Hansen Test	0.691	0.000	0.879	0.375	0.000	0.55
Observation	1756	1756	1756	1756	1756	1756

Note : +,,**,*** means the estimated coefficient is significant at $p<0.10$, $p<0.05$, $p<0.01$, $p<0.001$ .The fixed variables were dropped because of the first difference in Arellano and Bond (1991). Furthermore, as we use first difference model, endogenous variables are valid instruments with AR (2) (Kripfganz, 2019).In the first model, all variables are treated as endogenous while in the second, the subsidy variable is exogenous.*

3.7 Robustness check

First, we introduced the number of employees as a shifter of the stochastic frontier. In other words, we do not impose any homogeneity condition on this variable. The results of the estimation are reported in Appendix C.9, **Table C-8**. We do not find any substantial difference from our basic model.

We modified the estimation presented in Table 3-12 by integrating quadratic terms following the recommendation of Kiviet (2020). The results are presented in Appendix C.9, **Table C-9**. Overall, none of the specifications passed the validity tests. Second, we also tested a GMM system (Arellano & Bover, 1995) against the first-difference model. The test of Andrews and Lu (2001) suggests that Arellano and Bond's model performs better (Appendix C.9, **Table C-10**)

Secondly, we have added other covariates to the Arellano and Bond (1991) model only for productivity variable. We treat these variables as endogenous. We do not find a significant effect for the size and age of the CUMA. On the other hand, the effect of investment in environmental assets remains positive.

Furthermore, CUMAs may invest in unproductive equipment (approximately 73% of CUMAs have a nonzero value). Such investment would be expected to lead to a negative impact on productivity. Thus, we consider only the proportion of investment in new equipment (Table 3-13). Our results confirm the positive effect of investment in environmental assets on the productivity of CUMAs. Specifically, we obtain an average productivity increase of 0.217 (using the new investment in environmental equipment proportion mean in Table 3-3 (0.538) and multiplying it for the estimate's parameter (0.404), we obtain 0.217). In other words, the effect of investment in environmental assets is underestimated when new equipment and unproductive equipment are mixed.

Table 3-13 : First difference model with new equipment investment (Arellano & Bond, 1991)

	Model with additional covariates	New investment
	Productivity	Productivity
Productivity (lag)	-0.278***	-0.261***
	(0.049)	(0.048)
Environment	0.244+	
	(0.128)	
Environment (lag 1)	-0.009	
	(0.065)	
Environment (lag 2)	0.045	
	(0.047)	
Environment (new equipment)		0.404*
		(0.16)
Environment (new equipment lag 1)		0.017
		(0.067)
Environment (mew equipment lag 2)		0.04
		(0.05)
Age (log)	0.199	
	(0.156)	
Age (log)	-0.029	
	(0.173)	
Size (log)	216.956	
	(246.432)	
Size × Size (log)	-27.791	
	(32.957)	
AR1 (p-value)	0.000	0.000
AR2 (p-value)	0.476	0.45
Sargan-Hansen Test	0.642	0.649
Observation	1756	1756

Note : +,,**,*** means the estimated coefficient is significant at $p<0.10$, $p<0.05$, $p<0.01$, $p<0.001$. The first model introduces new variables while in the second we take into account the new investments made by the CUMA*

Conclusion and discussion

Using the endogenous dynamic stochastic frontier framework, we analysed the efficiency of CUMAs and investigated whether the investment in environmental assets of CUMAs influences their economic performance. First, our results show the importance of methodological aspects. In fact, static and exogenous models tend to underestimate the efficiency of CUMAs. Overall, our results show that CUMAs have room for improvement in terms of endogenous investment (capacity to double their investment) while reducing their inputs by more than 50% compared to energy expenditure. Regarding the effect of investment in environmental assets, we find that there is a correlation between the proportion of investment in environmental assets and CUMA inefficiency. Specifically, we find that the effect is nonlinear (U-shaped) with a minimum in investment in environmental assets of 70%. We also analysed the effect of investment in environmental assets on productivity change by accounting for the endogeneity of investment in environmental assets. Considering that all our regressors are endogenous, we found that a marginal increase in investment in environmental assets implies an average productivity growth by 0.214. Moreover, considering only investment in environmental assets in new equipment, we see an increase in average productivity by 0.217. Thus, investing in quality environmental equipment seems more beneficial to CUMAs. Interestingly, our results highlight a form of persistence of the CUMA's past performance. Precisely, past performance tends to negatively affect the current performance of CUMA. The positive effect of investment in environmental assets on CUMA performance is in line with a previous study (Pokharel & Featherstone, 2021). Contrary to previous studies (Pokharel & Featherstone, 2021), productivity change tends to be more driven by improvements in efficiency than by technical progress. This implies that CUMAs need to focus on the efficient use of inputs, which underlines the importance of the quality of management but also the ability of CUMA members to coordinate effectively through formal and informal mechanisms as shown chapter 1. Improving the quality of management would involve, for example, an appropriate level of investment, communication and planning (Harris & Fulton, 2000b). This would have the effect of minimising the persistence of past performance. This study also has limitations. First among them is the fact that the instruments used are weak may affect the efficiency of our estimates, especially in the panel IV model. Moreover, our non-parametric model relies on constant returns to scale, which does not allow for direct comparison of these results with the parametric model (Cuesta & Zofío, 2005). Moreover, by analysing only technical efficiency, our model assumes an allocative efficiency of CUMAs, i.e. their capacity to efficiently combine inputs. In terms of perspectives, future studies could improve our decomposition of productivity by integrating the role of management and assessing the effect of investments in environmental assets on management quality in CUMAs (Grifell-Tatjé & Lovell, 1997).

Conclusion générale

Les coopératives agricoles constituent des organisations singulières. Traditionnellement, ces organisations font l'objet de critiques sur leur capacité à être performantes (Cook, 1995) Cependant, l'évolution des formes coopératives ainsi que leur implication dans les questions environnementales relance le débat sur leur performance. Cette thèse s'intéresse aux CUMA que nous traitons comme des coopératives non traditionnelles, c'est-à-dire des coopératives n'appliquant pas de façon stricte les principes coopératifs traditionnels. Les CUMA sont aussi particulières dans la mesure où les transactions (partage de matériel) entre adhérents doivent se faire dans une même fenêtre de temps compte tenu de la saisonnalité des activités agricoles. De ce fait, dans le premier chapitre, nous cherchons à comprendre, la nature des mécanismes de gouvernance en CUMA et comment ces coopératives parviennent à minimiser les problèmes de coordination et de motivation. Nos résultats montrent que les CUMA combinent les mécanismes de gouvernance formels et informels (capital social) en mettant toutefois l'accent sur les mécanismes informels pour minimiser les problèmes de gouvernance. Ces mécanismes informels incluent, par exemple, l'ajustement mutuel entre les membres, la sélection ex ante, la réputation et la confiance qui caractérisent une forme de capital social relationnelle (Nahapiet & Ghoshal, 1998). Précisément, les membres de la CUMA ont principalement recours aux mécanismes informels, en utilisant les mécanismes formels en complément lorsque cela est nécessaire. Ce premier essai permet de mettre en évidence la pertinence des relations interpersonnelles au sein de la coopérative dans un contexte où les mécanismes formels sont défaillants ou inappropriés pour minimiser les problèmes de gouvernance. Dans le deuxième essai, nous analysons les déterminants des investissements en actifs environnementaux. Nous analysons théoriquement et empiriquement l'effet du capital social sur la propension et la proportion de l'investissement environnemental dans le contexte de la France en utilisant la taille de CUMA, i.e, le nombre de membres comme « proxy » du capital social. En utilisant un modèle fractionnel sur des données de coupes transversales, nos résultats montrent que la relation entre la taille de la CUMA et la probabilité d'un investissement en actifs environnementaux est non linéaire. Cependant, lorsqu'un investissement est réalisé, l'augmentation de la taille du groupe affecte négativement la proportion d'un investissement en actifs environnementaux. Ce résultat confirme la volonté des CUMA à préserver l'homogénéité des groupes (Diakité et al., 2022).

Dans le troisième essai, nous analysons l'implication des investissements en actifs environnementaux sur la performance économique des CUMA. Nous modélisons la performance via un modèle de frontière paramétrique et non paramétrique, traitons l'investissement comme une variable endogène. Nos résultats montrent que l'investissement en actifs environnementaux est bénéfique pour les CUMA. Plus précisément, il est avantageux pour la CUMA d'investir dans des équipements environnementaux de premier choix. Cependant, les performances passées ont tendance aussi à influencer les performances actuelles de la CUMA

Implications méthodologiques et politiques des essais

- *Promouvoir l'action collective volontaire pour la promotion des pratiques durables*

Les CUMA sont un exemple de coopération volontaire où des agriculteurs s'associent pour le partage d'un bien commun (le matériel agricole). La gouvernance d'un bien commun est complexe car elle implique des interactions continuelles dans un temps limité (Agarwal, 2014), notamment dans le cas des CUMA, les transactions sont saisonnières. Malgré cette complexité, comme l'a montré le chapitre 1, les CUMA parviennent à gérer efficacement les défis de gouvernance auxquels elles font face tout en étant en mesure d'adopter des pratiques durables. De ce fait, la capacité des CUMA à traiter des problèmes de gouvernance font d'elles des organisations fiables pour la promotion des pratiques durables. Il est donc nécessaire de promouvoir ces coopératives surtout dans le contexte du Québec où leur croissance connait un ralentissement ces dernières années[57]. À l'image des CUMA, d'autres formes de coopération volontaire telles que les Groupements d'Exploitation en Commun (GAEC) doivent aussi être encouragés. Une façon de promouvoir les CUMA et les formes de coopérations connexes serait de les soutenir financièrement via des subventions. En même temps, comme le montrent les résultats du chapitre 3, les subventions octroyées aux CUMA n'impliquent pas nécessairement un changement technologique. L'une des explications est que ces subventions concernent à la fois du matériel en renouvellement ou en création d'activité. Pour un meilleur impact, les subventions octroyées aux CUMA devraient cibler davantage du matériel innovant, impliquant la mise en place de pratiques environnementales nouvelles. En même temps, il est possible que les subventions incitent les CUMA à investir dans du matériel non approprié ce qui affecte leur

[57] Les raisons de ce ralentissement sont diverses. Nos entretiens avec les responsables de CUMA ont révélé par exemple qu'une des raisons est l'augmentation des exploitations agricoles de grandes tailles. Le plus souvent, les producteurs de ces exploitations sont moins intéressés par une mutualisation du matériel agricole.

efficience. A ce niveau, une piste serait de proposer des contrats d'essais pour tester les matériels proposés par les constructeurs ou les concessionnaires aux CUMA.

- *Relativiser l'importance de l'accroissement de la coopérative*

Comme le montrent les résultats du chapitre 2, il est nécessaire de nuancer l'importance de l'accroissement de la taille. Certaines coopératives poursuivent une stratégie de niche qui leur permet de rester petites en taille tandis que d'autres visent l'expansion horizontale et verticale. La première expansion se construit via des fusions et acquisitions (Van der Krogt et al., 2007), alors que la seconde concerne la diversifications des stratégies d'affaires de la coopérative. Dans un contexte de forte compétition, les coopératives sont amenées à fusionner ou à se restructurer afin de répondre aux exigences du marché (Valiorgue, 2021). Cependant, comme le montre nos résultats, l'accroissement de la taille n'implique pas nécessairement de meilleures incitations environnementales ou une amélioration de la performance économique (Melia-Marti & Martinez-Garcia, 2015). En effet, l'accroissement de la taille de la CUMA est susceptible d'augmenter les chances d'un investissement en actifs environnementaux tout en influençant négativement la proportion de ces investissements au-delà d'un seuil critique. Par conséquent, bien que le contexte économique mondial favorise un glissement des coopératives vers des structures organisationnelles plus complexes, la recherche d'un équilibre entre les avantages économiques associés aux grands groupes et le maintien des relations interpersonnelles est nécessaire. De plus, l'importance des relations interpersonnelles invitent à interpréter certains indicateurs avec précaution notamment le nombre d'agriculteur par coopérative (FNCUMA, 2021)

L'importance de la prise en compte du caractère dynamique de la production et de l'endogénéité

Du point de vue méthodologique, le chapitre 3 montre la nécessité d'une prise en compte du caractère dynamique de la production et de l'endogénéité. Les coopératives, notamment les CUMA mobilisent des inputs quasi fixes qui ne peuvent pas être traités comme des inputs variables ordinaires. En ignorant la spécificité des inputs, les scores d'efficience peuvent souffrir d'un biais. Par exemple, les modèles statiques et les modèles exogènes tendent à sous-estimer le score d'efficience comme le montrent les résultats du chapitre 3. L'analyse de l'efficience dans le contexte des coopératives agricoles nécessitent donc une prise en compte de la spécificité des inputs en présence.

Limites

Différentes limites empiriques et théoriques peuvent être soulignées.

- Premièrement, dans le chapitre 1, la généralisation de nos résultats peut être limitée dans la mesure où notre méthodologie s'appuie sur une étude de cas. Bien que l'étude de cas multiples soit avantageuse et que l'objectif n'est pas tant la généralisation des résultats (Yin, 2018), nous reconnaissons qu'elle reste encastrée dans un contexte géographique. De ce fait, des recherches futures pourraient tester les hypothèses du chapitre dans des contextes différents autre que celui du Québec.
- Deuxièmement, dans le chapitre 2, bien que différents auteurs (Deng et al., 2021) utilisent le nombre de membres comme une mesure de la taille de coopérative, utiliser ce proxy dans le contexte des CUMA peut être limité dans la mesure où dans ces coopératives, l'accent est mis sur les branches d'activités. Ces branches bien que régit par les règles générales de la CUMA sont autonomes dans la gestion de leurs transactions. Cependant, nos données ne nous ont pas permis de capter le nombre de membres par branche d'activités.
- Troisièmement, toujours dans le chapitre 2, nous utilisons la taille pour approximer le capital social. Cependant, d'autres variables telles que le contexte historique et social de la CUMA pourraient aussi déterminer le capital social. Le plus souvent, l'émergence d'une action collective repose sur l'existence d'un capital social préexistant que nous ne captons pas dans le chapitre 2. Par exemple, nos entretiens avec certaines CUMA au Québec a révélé que les membres fondateurs de leurs CUMA étaient déjà engagés dans des activités de partage informelles,
- Quatrièmement, le modèle non paramétrique utilisé pour décomposer la performance des CUMA dans le chapitre 3 suppose des rendements constants alors que l'approche paramétrique suggère que les CUMA fonctionnent sous des rendements décroissants. De ce fait, les résultats issus des deux approches ne sont pas directement comparables.

Pistes pour les recherches futures

À partir des limites identifiées, différentes pistes de recherches peuvent être proposées.

- Premièrement, une extension de l'étude qualitative sur les mécanismes de gouvernance dans le contexte européen serait souhaitable à des fins de comparaison avec le contexte nord-américain. Par exemple, il serait intéressant d'analyser si les CUMA en Europe sont soumises à la même logique que les CUMA au Québec en privilégiant des groupes de petites tailles où les mécanismes informels sont mis en avant.
- Une autre extension au niveau du chapitre 2, serait d'intégrer différentes dimensions du capital social. Notre étude s'est limitée à la taille de la CUMA. Cependant, comme le montre la section des limites, d'autres variables mériteraient d'être prises en compte ainsi que différentes dimensions du capital social notamment l'importance des réseaux (fédération, réseau de producteur), les représentations des adhérents de la CUMA.
- Dans le chapitre 3, nous avons inclus une variable binaire *Dum,* pour capter les différences de technologie entre les CUMA ayant réalisé un investissement environnemental et celles à zéro investissement environnemental. Bien que cette approche soit valide dans la littérature (Maietta & Sena, 2008), une autre approche serait de réaliser une étude d'impact avec contrefactuel. L'objectif serait d'estimer un effet causal de l'investissement environnemental sur la performance en corrigeant pour la sélection sur les observables et les inobservables. De plus, bien que nous corrigions pour l'endogénéité de l'investissement dans l'équation de la frontière, les futures recherches pourraient prendre en compte l'endogénéité de cette variable dans l'équation de l'efficience. Cela impliquerait une double correction pouvant être réalisée via une approche par variables instrumentales (Karakaplan, 2022).
- Finalement, une extension du chapitre 3 serait de modéliser les coûts d'ajustement. En effet, les modèles stochastiques dynamiques reposent sur l'hypothèse des coûts d'ajustements qui font en sorte qu'une organisation est susceptible d'accepter d'être inefficiente dans le court terme lorsque les coûts d'ajustements sont importants (Stefanou, 2009). Puisque notre étude ne fait aucune hypothèse explicite sur le comportement économique des CUMA, une extension serait d'introduire une analyse de coût. Cette analyse permettrait de modéliser de façon explicite les coûts d'ajustement, surtout que l'augmentation du stock tend à éloigner la CUMA de la frontière.

Bibliographie générale

Acharya, V., & Xu, Z. (2017). Financial dependence and innovation: The case of public versus private firms. *Journal of Financial Economics*, *124*(2), 223–243. https://www.sciencedirect.com/science/article/pii/S0304405X16300101

Adenuga, A. H., Davis, J., Hutchinson, G., Patton, M., & Donnellan, T. (2019). *Environmental technical efficiency and phosphorus pollution abatement cost in dairy farms: A parametric hyperbolic distance function approach*.

Agarwal, B. (2014). Food sovereignty, food security and democratic choice: Critical contradictions, difficult conciliations. *Journal of Peasant Studies*, *41*(6), 1247–1268.

Akridge, J. T., & Hertel, T. W. (1992). Cooperative and investor-oriented firm efficiency: A multiproduct analysis. *Journal of Agricultural Cooperation*, *7*(1141-2016–92515), 1–14. https://ageconsearch.umn.edu/record/46280/files/Volume%207%20Article%201.pdf

Aldridge, S., Halpern, D., & Fitzpatrick, S. (2002). Social Capital: A Discussion Paper London: Performance and Innovation Unit. *Available at Www. Social-Capital. Net/Docs/PIU*, *20*, 121–130.

Alem, H. (2020). Performance of the Norwegian dairy farms: A dynamic stochastic approach. *Research in Economics*, *74*(3), 263–271. https://www.sciencedirect.com/science/article/pii/S109094432030274X

Alho, E. (2015). The effect of social bonding and identity on the decision to invest in food production. *Journal of Behavioral and Experimental Economics*, *59*, 47–55. https://www.sciencedirect.com/science/article/pii/S2214804315001226?casa_token=S-vQNyODsCkAAAAA:rSlQ8CJzcZD9Kwb4nYhyTzQqKCggblUUPkquA5yMGkPRCIXc-IT46DtjjZssywURZ88eq1v56v9q

Allaire, G., & Assens, P. (2002). *Coopération et territoire. Le cas des coopératives d'utilisation de matériel agricole*. 16–18. https://www.researchgate.net/profile/Gilles-Allaire/publication/278964997_Cooperation_et_territoire_Le_cas_des_Cooperatives_d'Utilisation_de_Materiel_Agricole/links/5588380e08aeb716bccfe749/Cooperation-et-territoire-Le-cas-des-Cooperatives-dUtilisation-de-Materiel-Agricole.pdf

Andrews, D. W. K., & Lu, B. (2001). Consistent model and moment selection procedures for GMM estimation with application to dynamic panel data models. *Journal of Econometrics*, *101*(1), 123–164. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.940.1266&rep=rep1&type=pdf

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277–297. https://academic.oup.com/restud/article-abstract/58/2/277/1563354

Ariyaratne, C. B., Featherstone, A. M., & Langemeier, M. R. (2006). What determines productivity growth of agricultural cooperatives? *Journal of Agricultural and Applied Economics*, *38*(1), 47–59. https://ageconsearch.umn.edu/record/43748/files/47.pdf

Artz, G. M., Colson, G., & Ginder, R. G. (2010). A return of the threshing ring? A case study of machinery and labor-sharing in Midwestern farms. *Journal of Agricultural and Applied Economics*, *42*(1379-2016–113645), 805–819. https://ageconsearch.umn.edu/record/100515/files/jaae264.pdf

Bagnoli, L., & Megali, C. (2011). Performance measuring in social enterprises. *Nonprofit Volunt. Sect. Q*, *40*(1), 149–165. https://flore.unifi.it/retrieve/handle/2158/362994/360527/EMES%20-%20Measuring%20performance%20in%20social%20enterprises%20-%20LUCA%20BAGNOLI.pdf

Battese, G. E. (1997). A note on the estimation of Cobb-Douglas production functions when some explanatory variables have zero values. *Journal of Agricultural Economics*, *48*(1–3), 250–252. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1477-9552.1997.tb01149.x?casa_token=OcuMyioNbLYAAAAA:5D2H8Di29tKzdxM3UxO4MLmJXdeKKAjmR9zuIEzsdodtm5R2gA9px6vNR6ar3YIUzmqihVvpLv6rcngq

Becker, G. S., & Murphy, K. M. (1992). The division of labor, coordination costs, and knowledge. *The Quarterly Journal of Economics*, *107*(4), 1137–1160. https://www.nber.org/system/files/chapters/c11238/c11238.pdf

Benoit, K. (2011). Linear regression models with logarithmic transformations. *London School of Economics, London*, *22*(1), 23–36. https://links.sharezomics.com/assets/uploads/files/1600247928973-from_slack_logmodels2.pdf

Bergen, N., & Labonté, R. (2020). "Everything Is Perfect, and We Have No Problems": Detecting and Limiting Social Desirability Bias in Qualitative Research. *Qualitative Health Research*, *30*(5), 783–792. https://journals.sagepub.com/doi/abs/10.1177/1049732319889354

Bernard, T., & Spielman, D. J. (2009). Reaching the rural poor through rural producer organizations? A study of agricultural marketing cooperatives in Ethiopia. *Food Policy*, *34*(1), 60–69.

Besley, T., & Ghatak, M. (2017). Profit with purpose? A theory of social enterprise. *American Economic Journal: Economic Policy*, *9*(3), 19–58. https://www.jstor.org/stable/pdf/26598161.pdf

Bhuiyan, M. B. U., Huang, H. J., & de Villiers, C. (2021). Determinants of environmental investment: evidence from Europe. *Journal of Cleaner Production*, *292*, 125990. https://www.sciencedirect.com/science/article/pii/S0959652621002109

Biagini, L., Antonioli, F., & Severini, S. (2020). The role of the common agricultural policy in enhancing farm income: a dynamic panel analysis accounting for farm size in Italy. *Journal of Agricultural Economics*, *71*(3), 652–675.

Bijman, J. (2002). Essays on Agricultural Co-operatives. *Governance Structure in Fruit and Vegetable Chains(Ph. D. Dissertation). Erasmus University Rotterdam, Rotterdam, The Netherlands*.

Bijman, J. (2007). The role of producer organisations in quality-oriented agro-food chains; an economic organisation perspective. *Governance for Quality in Tropical Food Chains*, 257–278.

Bijman, J., Hanisch, M., & van der sangen, G. (2014). Shifting control? The changes of internal governance in agricultural cooperatives in the EU. *Annals of Public and Cooperative Economics*, *85*(4), 641–661.

Borgen, S. O. (2011). Product differentiation and cooperative governance. *The Journal of Socio-Economics*, *40*(3), 327–333. https://www.sciencedirect.com/science/article/pii/S1053535710001551

Borges, A. M. (2005). *Applied genral equilibrium models : An assessment of their usefulness for policy analysis*. 35. https://www.oecd.org/economy/outlook/35567467.pdf

Borzaga, C., & Depedri, S. (2013). When social enterprises do it better: efficiency and efficacy of work integration in Italian social cooperatives. In *Social enterprise* (pp. 101–117). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9780203102916-16/social-enterprise-critical-appreciative-lens-1-suzanne-grant

Bostian, M., Färe, R., Grosskopf, S., & Lundgren, T. (2016). Environmental investment and firm performance: A network approach. *Energy Economics*, *57*, 243–255. https://www.sciencedirect.com/science/article/pii/S0140988316301311

Boussemart, J.-P., Lefer, H.-B., Leleu, H., & Parvulescu, R. (2019). Technical catching-up and decoupled payments in a selection of French farms. *European Review of Agricultural Economics*, *46*(2), 215–235. https://academic.oup.com/erae/article-abstract/46/2/215/5067603

Broberg, T., Marklund, P.-O., Samakovlis, E., & Hammar, H. (2013). Testing the Porter hypothesis: the effects of environmental investments on efficiency in Swedish industry. *Journal of Productivity Analysis*, *40*(1), 43–56. https://link.springer.com/article/10.1007/s11123-012-0335-6

Cameron, A. C., & Trivedi, P. K. (2005). *Microeconometrics: methods and applications*. Cambridge university press.

Cameron, A. C., & Trivedi, P. K. (2009). *Microeconometrics using Stata*. Stata Press.

Cazzuffi, C. (2012). Membership size and co-operative performance: evidence from Ghanaian cocoa producers' societies, 1930-36. *Economic History of Developing Regions*, *27*(1), 67–92. https://journals.co.za/doi/abs/10.10520/EJC126761

Chaddad, F. R., & Cook, M. L. (2003). *The emergence of non-traditional cooperative structures: public and private policy issues*.

Chaddad, F. R., & Cook, M. L. (2004). Understanding new cooperative models: an ownership–control rights typology. *Applied Economic Perspectives and Policy*, *26*(3), 348–360. http://www.academia.edu/download/50115910/RAE04.pdf

Chaddad, F. R., Cook, M. L., & Heckelei, T. (2005). Testing for the presence of financial constraints in US agricultural cooperatives: an investment behaviour approach. *Journal of Agricultural Economics*, *56*(3), 385–397.

Charreaux, G. (1996). Vers une théorie du gouvernement des entreprises. Chapitre 15. *Le Gouvernement Des Entreprises, Économica*.

Charreaux, G. (1997). *Le gouvernement des entreprises: Corporate Governance, théories et faits*. Economica Paris. https://catalogue-bu.u-bourgogne.fr/discovery/fulldisplay/alma991004626079706659/33UB_INST:33UB_INST

Cheney, G., Santa Cruz, I., Peredo, A. M., & Nazareno, E. (2014). Worker cooperatives as an organizational alternative: Challenges, achievements and promise in business governance and ownership. *Organization*, *21*(5), 591–603.

Chomel, C. (2006). *Agricultural co-operatives in the EU–15, Comparisons of legal systems*. *18*, 19.

Coelli, T. (2000). *On the econometric estimation of the distance function representation of a production technology*. Université Catholique de Louvain. Center for Operations Research and …. http://webdoc.sub.gwdg.de/ebook/serien/e/CORE/dp2000-42.pdf

Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. springer science & business media. https://books.google.ca/books?hl=en&lr=&id=V2Rpu8M6RhwC&oi=fnd&pg=PA1&dq=an+introduction+to+efficiency+and+productivity+analysis+&ots=E3ydffv_9Q&sig=FHytqp1vkF0aafqFwFO3DC7asJs#v=onepage&q=an%20introduction%20to%20efficiency%20and%20productivity%20analysis&f=false

Coen, R. M., Eisner, R., Rondina, F., & Durlauf, S. N. (2008). Investment (neoclassical). *The New Palgrave Dictionary of Economics Online. Basingstoke: Palgrave Macmillan*.

Condon, A. M. (1990). *Property rights and the investment behavior of US agricultural cooperatives*. Virginia Polytechnic Institute and State University. https://vtechworks.lib.vt.edu/bitstream/handle/10919/39375/LD5655.V856_1990.C657.pdf?sequence=1

Cook, M. L. (1995). The future of US agricultural cooperatives: A neo-institutional approach. *American Journal of Agricultural Economics*, *77*(5), 1153–1159. https://www.jstor.org/stable/pdf/1243338.pdf?casa_token=RIaeCyQbVCgAAAAA:ROE47Kzc8gBHPqJxSPBTnSA6ayOSwnWLikicuT7lYYBV6XWWwSjEQDqv9tVttgNIdmugWvMOixQVxsAdpiLcW2diQ2pXSIokh17m2Hq6dwxa8kQnyqoB

Cook, M. L. (2018). A life cycle explanation of cooperative longevity. *Sustainability*, *10*(5), 1586. https://www.mdpi.com/2071-1050/10/5/1586/pdf

Cornée, S., Le Guernic, M., & Rousselière, D. (2020). Governing Common-Property Assets: Theory and Evidence from Agriculture. *Journal of Business Ethics*, 1–20. https://link.springer.com/article/10.1007/s10551-020-04579-1

Cotterill, R. W. (1987). Agricultural cooperatives: A unified theory of pricing, finance, and investment. *Cooperative Theory: New Approaches*, 171–258. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.200.308&rep=rep1&type=pdf

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications. https://www.academia.edu/download/55010759/creswell_Qualitative_Inquiry_2nd_edition.pdf

Cuesta, R. A., Lovell, C. A. K., & Zofío, J. L. (2009). Environmental efficiency measurement with translog distance functions: A parametric approach. *Ecological Economics*, *68*(8–9), 2232–2242.

Cuesta, R. A., & Zofío, J. L. (2005). Hyperbolic efficiency and parametric distance functions: with application to Spanish savings banks. *Journal of Productivity Analysis*, *24*, 31–48.

De Toro, A., & Hansson, P.-A. (2004). Machinery co-operatives—a case study in Sweden. *Biosystems Engineering*, *87*(1), 13–25. https://www.researchgate.net/profile/Alfredo_De_Toro/publication/303895560_Machinery_Cooperative/data/575b0a0108ae9a9c95519568/Machinery-Cooperative.pdf

Dechant, K., & Altman, B. (1994). Environmental leadership: from compliance to competitive advantage. *Academy of Management Perspectives*, *8*(3), 7–20. https://journals.aom.org/doi/abs/10.5465/AME.1994.9503101163

Declerck, F. (2013). L'approche financière des coopératives agricoles. In *Les coopératives agricoles: identité, gouvernance et stratégies* (Larcier).

Dekker, H. C. (2004). Control of inter-organizational relationships: evidence on appropriation concerns and coordination requirements. *Accounting, Organizations and Society*, *29*(1), 27–49. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.335.9536&rep=rep1&type=pdf

Deller, S., Hoyt, A., Hueth, B., & Sundaram-Stukel, R. (2009). Research on the economic impact of cooperatives. *University of Wisconsin Center for Cooperatives*, *231*(2209), 232–233. http://staging.community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-deller-et-al.pdf

Deng, W., Hendrikse, G., & Liang, Q. (2021). Internal social capital and the life cycle of agricultural cooperatives. *Journal of Evolutionary Economics*, *31*(1), 301–323. https://repub.eur.nl/pub/128129/Repub_128129.pdf

Diakité, D., Royer, A., Rousselière, D., & Tamini, L. D. (2022). Formal and informal governance mechanisms of machinery cooperatives: The case of Quebec. *Journal of Co-Operative Organization and Management*, *10*(2), 100181. https://www.sciencedirect.com/science/article/pii/S2213297X22000179?casa_token=r6t8kr7aUxIAAAAA:DWPLXq4LiR1LDm_m51Uzp0Gk_AULCYytf_8vOuqGfEO3svNklr0Y5Nx5f2opHtvSbu47SVd1srA

Draperi, J.-F. (2018). L'environnement, nouvel horizon coopératif? *RECMA*, *1*, 4–5. https://www.cairn.info/revue-recma-2018-1-page-4.htm

Du, K. (2021). *MALMQ2: Stata module to compute Malmquist Productivity Index*. https://econpapers.repec.org/software/bocbocode/s458716.htm

Dunn, J. R. (1988). Basic cooperative principles and their relationship to selected practices. *Journal of Agricultural Cooperation*, *3*(1141-2016–92562), 83–93. https://ageconsearch.umn.edu/record/46212/files/Volume%203%20Article%207.pdf

Durand, H., & Tremblay, D. (2021). *La charge de mécanisation des exploitations agricoles*.

Dyer, J. H., & Singh, H. (1998). The relational view: Cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review*, *23*(4), 660–679. https://journals.aom.org/doi/abs/10.5465/amr.1998.1255632

Egger, P. H., & Kesina, M. (2014). Financial Constraints and the Extensive and Intensive Margin of Firm Exports: Panel Data Evidence from C hina. *Review of Development Economics*, *18*(4), 625–639.

Eid, M., & Martínez-Carrasco Pleite, F. (2014). *The International Year of Cooperatives and the 2020 vision*. https://www.euricse.eu/wp-content/uploads/2015/03/1414508630_n2589.pdf

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550. http://euroac.ffri.hr/wp-content/uploads/2010/06/Eisenhardt_1989_Building-Theories-from-Case.pdf

Emvalomatis, G. (2009). *Parametric models for dynamic efficiency measurement*. The Pennsylvania State University. https://etda.libraries.psu.edu/files/final_submissions/2086

Fahlbeck, E. (2007). *The Horizon Problem in Agricultural Co-operatives. Vertical Markets and Co-operative Hierarchies. The role of Co-operatives in the Agri-food Industry*. Springer Academic Publishers.

Färe, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review*, 66–83. https://www.jstor.org/stable/pdf/2117971.pdf

Farrell, M. J. (1957). *The Measurement of Productive EfficiencyJournal of the Royal Statistical Society. Series A (General), 1957*.

Fazzari, S., Hubbard, R. G., & Petersen, B. C. (1987). *Financing constraints and corporate investment*. National Bureau of Economic Research Cambridge, Mass., USA. https://www.nber.org/system/files/working_papers/w2387/w2387.pdf

Feng, L., Friis, A., & Nilsson, J. (2016). Social capital among members in grain marketing cooperatives of different sizes. *Agribusiness*, *32*(1), 113–126. https://onlinelibrary.wiley.com/doi/full/10.1002/agr.21427?casa_token=B9MHjCiZ2cAAAAAA%3AVG8-zoSwnEg475VSvtWjNkJIVzR3BLyHGDQhF8SXhTm2alhF2sYmq98fRjYgIgXG1L_q_jzqV9FvXyoL

Feng, L., & Hendrikse, G. (2008). On the nature of a cooperative: a system of attributes perspective. In *Strategy and Governance of Networks* (pp. 13–26). Springer. https://repub.eur.nl/pub/10886/ERS-2007-093-ORG.pdf

Feng, L., & Hendrikse, G. W. J. (2011). *Coordination and governance: The case of cooperatives versus IOFs*. https://ageconsearch.umn.edu/record/114359/files/Feng_Li_326.pdf

Feng, L., & Hendrikse, G. W. J. (2012). Chain interdependencies, measurement problems and efficient governance structure: cooperatives versus publicly listed firms. *European Review of Agricultural Economics*, *39*(2), 241–255.

Fici, A. (2013). An introduction to cooperative law. In *International handbook of cooperative law* (pp. 3–62). Springer. https://link.springer.com/chapter/10.1007/978-3-642-30129-2_1

Filippi, M. (2014). Using regional advantage : French agricultural cooperative' economic and governance tool. *Annals of Public and Cooperative Economics*, *85*(4), 597–615. https://onlinelibrary.wiley.com/doi/full/10.1111/apce.12053

Filippi, M. (2020). Do French agrifood co-ops have a head start in Corporate Social Responsibility? An initial examination of French co-ops and their practices. *Review of Agricultural, Food and Environmental Studies*, *101*(4), 489–506.

FNCUMA. (2021). *Chiffres clés*.

Franken, J., & Cook, M. (2019). Horizon and portfolio investment constraints in agricultural cooperatives. In *Design and Management of Interfirm Networks* (pp. 179–195). Springer. https://link.springer.com/chapter/10.1007/978-3-030-29245-4_10

Franken, J. R. V, & Cook, M. L. (2013). *Impact of Board structure and process on cooperative performance*. https://ageconsearch.umn.edu/record/149420/files/5-21-13_Endogeneity%20of%20Coop%20Gov%20_%20Performance.pdf

Franken, J. R. V, & Cook, M. L. (2015a). Informing measurement of cooperative performance. In *Interfirm networks* (pp. 209–226). Springer. https://scholar.archive.org/work/vkzrzcd56ngvjfd6wlxxpwjplm/access/wayback/http://emnet.univie.ac.at/uploads/media/Franken__Cook__3_.pdf

Franken, J. R. V, & Cook, M. L. (2015b). *Investment constraints in agricultural cooperatives*. https://ageconsearch.umn.edu/record/205427/files/5-16-15_%20Invest%20Constraint.pdf

Friedman, M. (2007). The social responsibility of business is to increase its profits. In *Corporate ethics and corporate governance* (pp. 173–178). Springer. https://www.calrtadivision2.org/s/A-Friedman-doctrine-The-Social-Responsibility-Of-Business-Is-to-Increase-Its-Profits-The-New-York-Ti.pdf

Fuentes, H. J., Grifell-Tatjé, E., & Perelman, S. (2001). A parametric distance function approach for Malmquist productivity index estimation. *Journal of Productivity Analysis*, *15*(2), 79–94. https://link.springer.com/article/10.1023/A:1007852020847

Fulton, M. E., & Harris, A. (2000). *The CUMA Farm Machinery Co-operatives*. https://ageconsearch.umn.edu/record/31774/files/harris03.pdf

Fulton, M., & Giannakas, K. (2012). The value of a norm: open membership and the horizon problem in cooperatives. *Journal of Rural Cooperation*, *40*(886-2016–64682), 145–161. https://ageconsearch.umn.edu/record/249593/files/04%20The%20Value%20of%20a%20Norm-Open%20Membership.pdf

Galdeano-Gomez, E. (2008). Productivity effects of environmental performance: evidence from TFP analysis on marketing cooperatives. *Applied Economics*, *40*(14), 1873–1888. https://www.tandfonline.com/doi/abs/10.1080/00036840600905266

Galdeano-Gómez, E., Céspedes-Lorente, J., & Martinez-del-Rio, J. (2008). Environmental performance and spillover effects on productivity: evidence from horticultural firms. *Journal of Environmental Management*, *88*(4), 1552–1561.

Galdeano-Gómez, E., Céspedes-Lorente, J., & Rodríguez-Rodríguez, M. (2006). Productivity and environmental performance in marketing cooperatives: An analysis of the Spanish horticultural sector. *Journal of Agricultural Economics*, *57*(3), 479–500.

Gardner, J. G., Franken, J. R. V, & Boerngen, M. A. (2022). *A research agenda for cooperatives*. https://accc.k-state.edu/ncera210/jocpdfs/v36/GardnerFrankenBoerngenFinal2022.pdf

Garrido, S. (2019). Cooperatives, opportunism and quality product: Why the early Spanish cooperative wineries produced ordinary wine. *Business History*, 1–16. http://repositori.uji.es/xmlui/bitstream/handle/10234/187866/67776.pdf?sequence=1&isAllowed=y

Gebremedhin, B., & Swinton, S. M. (2003). Investment in soil conservation in northern Ethiopia: the role of land tenure security and public programs. *Agricultural Economics*, *29*(1), 69–84.

Gertler, P. J., Martinez, S., Premand, P., Rawlings, L. B., & Vermeersch, C. M. J. (2011). *L'évaluation d'impact en pratique*. The World Bank. https://documents1.worldbank.org/curated/en/187971468155114516/pdf/599980PUB0FRENCH0l0evaluation0d0impact.pdf

Getnet, K., & Anullo, T. (2012). Agricultural cooperatives and rural livelihoods: Evidence from Ethiopia. *Annals of Public and Cooperative Economics*, *83*(2), 181–198. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-8292.2012.00460.x

Gezahegn, T. W., Van Passel, S., Berhanu, T., D'Haese, M., & Maertens, M. (2019). Big is efficient: Evidence from agricultural cooperatives in Ethiopia. *Agricultural Economics*, *50*(5), 555–566.

Glasbergen, P. (2000). The environmental cooperative: self-governance in sustainable rural development. *The Journal of Environment & Development*, *9*(3), 240–259. https://journals.sagepub.com/doi/pdf/10.1177/107049650000900303?casa_token=FByyJP0c-_cAAAAA:i8mp-ghtHShdyXIquP-CIXqzD65RlPmEYW6Intf8K3NDjgtCINamCnz1DLN7he5DnGhJscFvb4uvhw

Glaser, B. G., & Strauss, A. L. (2017). *Discovery of grounded theory: Strategies for qualitative research*. Routledge. https://books.google.ca/books?hl=en&lr=&id=GTMrDwAAQBAJ&oi=fnd&pg=PP1&dq=The+Discovery+of+Grounded+Theory&ots=JtVfJBqxd0&sig=5kDimupiSbCl02Mz0gq3JpbbVJU#v=onepage&q=The%20Discovery%20of%20Grounded%20Theory&f=false

Gouvernement du Québec. (2023). *Portait général des Coopératives d'utilisation de Matériel Agricole au Québec*.

Grashuis, J. (2020). Agricultural firm survival: The case of farmer cooperatives in the United States. *Agribusiness*, *36*(1), 79–93. https://onlinelibrary.wiley.com/doi/abs/10.1002/agr.21612

Grashuis, J., & Cook, M. (2018). An examination of new generation cooperatives in the upper midwest: successes, failures, and limitations. *Annals of Public and Cooperative Economics*, *89*(4), 623–644.

Greene, W. H. (2003). *Econometric analysis*. Pearson Education India.

Grifell-Tatjé, E., & Lovell, C. A. K. (1997). A DEA-based analysis of productivity change and intertemporal managerial performance. *Annals of Operations Research*, *73*, 177–189. https://idp.springer.com/authorize/casa?redirect_uri=https://link.springer.com/content/pdf/10.1023/A:1018925127385.pdf&casa_token=MQXAYFSIgcMAAAAA:_C74pTqOLK05kXrBbuZ5A-6Wtebg1SwV0DU_nMU81MzfvOsKhpNfvjS1z4JB8q0NNACdnP-_7D-zhILtHQ

Groos, S., Gasselin, P., Hostiou, N., & Petit, S. (2021). Experiencing diversity within French farm machinery cooperatives: member heterogeneity and cooperation. *Cooperatives in Transition Facing Crisis-ICA CCR Europe Research Conference*.

Guariglia, A. (2008). Internal financial constraints, external financial constraints, and investment choice: Evidence from a panel of UK firms. *Journal of Banking & Finance*, *32*(9), 1795–1809.

Gulati, R., Lawrence, P. R., & Puranam, P. (2005). Adaptation in vertical relationships: Beyond incentive conflict. *Strategic Management Journal*, *26*(5), 415–440. https://onlinelibrary.wiley.com/doi/abs/10.1002/smj.458?casa_token=Ksw_IW4sbCQAAAAA:uFdRSViBywmJ74iugcIAHyHim-1ctC_yv3G5_qec8JG50eoCxs31NIVq_G1r2Mg5tX3WztGi4xtxgNsv

Hagos, F., & Holden, S. (2006). Tenure security, resource poverty, public programs, and household plot-level conservation investments in the highlands of northern Ethiopia. *Agricultural Economics*, *34*(2), 183–196. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1574-0864.2006.00117.x?casa_token=ai0vi4kerBsAAAAA%3AkJz5Q7Gj9ZF9uCvu6QsHEOM6MXaUAg9_soYmiaqW1yWbHY70RKBOyHLMbf85W4Nk3zUQrygYt8__h96A

Harris, A., & Fulton, M. E. (1996). *Comparative Financial Performance Analysis of Canadian Co-operatives, Investor-Owned Firms, and Industry Norms*. https://ageconsearch.umn.edu/record/31783/files/opharr01.pdf

Harris, A., & Fulton, M. E. (2000a). *Farm machinery co-operatives: an idea worth sharing*. https://ageconsearch.umn.edu/record/31762/files/harris04.pdf

Harris, A., & Fulton, M. E. (2000b). *Farm machinery co-operatives in Saskatchewan and Quebec*. https://ageconsearch.umn.edu/record/31756/files/harris05.pdf

Hart, O. D. (1988). Incomplete Contracts and the Theory of the Firm. *Journal of Law, Economics, & Organization*, *4*(1), 119–139.

Herbel, D., Rocchigiani, M., & Ferrier, C. (2015). The role of the social and organisational capital in agricultural co-operatives' development Practical lessons from the CUMA movement. *Journal of Co-Operative Organization and Management*, *3*(1), 24–31. http://www.academia.edu/download/35850007/CUMA_paper_final.pdf

Hernández-Espallardo, M., Arcas-Lario, N., Sánchez-Navarro, J. L., & Marcos-Matás, G. (2022). Curbing members' opportunism in first-tier and federated agricultural marketing cooperatives. *Agribusiness*, *38*(1), 195–219. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1002/agr.21718

Hernández-Nicolás, C. M., Martín-Ugedo, J. F., & Mínguez-Vera, A. (2019). The effect of gender diversity on the board of Spanish agricultural cooperatives on returns and debt: An empirical analysis. *Agribusiness*, *35*(4), 639–656.

Hind, A. M. (1999). Cooperative Performance-Is There a Dilemma? *Journal of Cooperatives*, *14*(1142-2016–92752), 31–43. https://ageconsearch.umn.edu/record/46376/files/Vol%2014%201999%20Article%203.pdf

Hoetker, G., & Mellewigt, T. (2009). Choice and performance of governance mechanisms: matching alliance governance to asset type. *Strategic Management Journal*, *30*(10), 1025–1044. http://hoetker.faculty.asu.edu/pdf/Hoetker-2009-Choice-00.pdf

Höhler, J., & Kühl, R. (2018). Dimensions of member heterogeneity in cooperatives and their impact on organization–a literature review. *Annals of Public and Cooperative Economics*, *89*(4), 697–712. https://onlinelibrary.wiley.com/doi/abs/10.1111/apce.12177

Huberman, A. M., Miles, M., & Saldana, J. (2014). Qualitative data analysis: A methods sourcebook. *The United States of America: SAGE Publications*.

Iliopoulos, C. (2003). *Long-term financing in US and European agricultural co-operatives: emerging methods for ameliorating investment constraints*.

Iliopoulos, C., & Valentinov, V. (2012). Opportunism in agricultural cooperatives in Greece. *Outlook on AGRICULTURE*, *41*(1), 15–19. https://www.agreri.gr/sites/default/files/ILIOPOULOS-VALENTINOV%20%282012%29.pdf

International Cooperative Alliance. (2015). *Notes d'orientation pour les principes coopératifs*.

Jakobsen, J. C., Gluud, C., Wetterslev, J., & Winkel, P. (2017). When and how should multiple imputation be used for handling missing data in randomised clinical trials–a practical guide with flowcharts. *BMC Medical Research Methodology*, *17*(1), 1–10. https://bmcmedresmethodol.biomedcentral.com/articles/10.1186/s12874-017-0442-1?report=reader

Jardine, S. L., Lin, C.-Y. C., & Sanchirico, J. N. (2014). Measuring benefits from a marketing cooperative in the Copper River fishery. *American Journal of Agricultural Economics*, *96*(4), 1084–1101. https://www.jstor.org/stable/pdf/24476935.pdf

Jensen-Auvermann, T., Adams, I., & Doluschitz, R. (2018). Trust—Factors that have an impact on the interrelations between members and employees in rural cooperatives. *Journal of Co-Operative Organization and Management*, *6*(2), 100–110. https://www.sciencedirect.com/science/article/pii/S2213297X17300927

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*(2), 112–133.

Kaiser, B. (2014). RHAUSMAN: Stata module to perform a (cluster-) robust Hausman test. *University of Bern*.

Kaplan, S. N., & Zingales, L. (1997). Do investment-cash flow sensitivities provide useful measures of financing constraints? *The Quarterly Journal of Economics*, *112*(1), 169–215. https://academic.oup.com/qje/article-abstract/112/1/169/1870889

Karakaplan, M. U. (2022). Panel stochastic frontier models with endogeneity. *The Stata Journal*, *22*(3), 643–663. https://journals.sagepub.com/doi/abs/10.1177/1536867X221124539

Karakaplan, M. U., & Kutlu, L. (2017). Endogeneity in panel stochastic frontier models: an application to the Japanese cotton spinning industry. *Applied Economics*, *49*(59), 5935–5939. https://scholarworks.utrgv.edu/cgi/viewcontent.cgi?article=1022&context=ef_fac

Karakaplan, M. U., & Kutlu, L. (2019). School district consolidation policies: endogenous cost inefficiency and saving reversals. *Empirical Economics*, *56*(5), 1729–1768. https://link.springer.com/article/10.1007/s00181-017-1398-z

Karaphillis, G., Duguid, F., & Lake, A. (2017). Economic impact of the Canadian co-operative sector (2009 and 2010). *International Journal of Social Economics*. https://www.emerald.com/insight/content/doi/10.1108/IJSE-09-2015-0225/full/html

Kebede, E., & Schreiner, D. F. (1996). Economies of scale in dairy marketing cooperatives in Kenya. *Agribusiness: An International Journal*, *12*(4), 395–402. https://onlinelibrary.wiley.com/doi/abs/10.1002/(SICI)1520-6297(199607/08)12:4%3C395::AID-AGR9%3E3.0.CO

Kenkel, P., & Long, G. (2007). Organizing a machinery cooperative. *Agr. Econ. Bull*, *07042*. http://69.63.68.22/Co-Operatives/Organizing%20a%20Machinery%20Cooperative.pdf

Ketilson, L. H. (1998). *The social and economic importance of the co-operative sector in Saskatchewan*. Study of Co-Operatives University of Saskatchewan.

Keuning, S. J., & de Ruuter, W. A. (1988). Guidelines to the construction of a social accounting matrix. *Review of Income and Wealth*, *34*(1), 71–100. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1475-4991.1988.tb00561.x

Khalil, M. A., & Nimmanunta, K. (2022). Conventional versus green investments: advancing innovation for better financial and environmental prospects. *Journal of Sustainable Finance & Investment*, 1–28. https://www.researchgate.net/profile/Muhammad-Khalil-8/publication/353481388_Conventional_versus_green_investments_advancing_innovation_for_better_financial_and_environmental_prospects/links/633e52d32752e45ef697c054/Conventional-versus-green-investments-advancing-innovation-for-better-financial-and-environmental-prospects.pdf

Kiviet, J. F. (2020). Microeconometric dynamic panel data methods: Model specification and selection issues. *Econometrics and Statistics*, *13*, 16–45. https://www.sciencedirect.com/science/article/pii/S2452306219300498?casa_token=vztlGg5ATUoAAAAA:NKeC9BxZ4DeXLS9HR3ULQdxGnTznvlL8caxX292v1OFhYEs7MM6_0pncAt1pItWgcy39x8C8-pk8

Kleibergen, F., & Paap, R. (2006). Generalized reduced rank tests using the singular value decomposition. *Journal of Econometrics*, *133*(1), 97–126. https://www.sciencedirect.com/science/article/abs/pii/S0304407605000850

Knack, S., & Keefer, P. (1997). Does social capital have an economic payoff? A cross-country investigation. *The Quarterly Journal of Economics*, *112*(4), 1251–1288. https://academic.oup.com/qje/article-abstract/112/4/1251/1911732

Kondo, K., Yamamoto, Y., & Sasaki, J. (2008). Measuring total factor productivity change for agricultural cooperatives in Japan: A nonparametric Malmquist indices approach. *Journal of Rural Cooperation*, *36*(886-2016–64653), 101–113.

Kooiman, J. (2003). *Governing as governance*. Sage. https://www.researchgate.net/profile/Henrik_Bang/publication/230469691_GOVERNING_AS_GOVERNANCE_-_Editied_by_Jan_Kooiman/links/5ebe698992851c11a867eb4b/GOVERNING-AS-GOVERNANCE-Editied-by-Jan-Kooiman.pdf

Koopmans, T. C. (1951). Efficient allocation of resources. *Econometrica: Journal of the Econometric Society*, 455–465. https://apps.dtic.mil/sti/pdfs/AD0604062.pdf

Kripfganz, S. (2019). *Generalized method of moments estimation of linear dynamic panel data models*. *17*. https://www.stata.com/meeting/uk19/slides/uk19_kripfganz.pdf

Kumbhakar, S. C., Tsionas, E. G., & Sipiläinen, T. (2009). Joint estimation of technology choice and technical efficiency: an application to organic and conventional dairy farming. *Journal of Productivity Analysis*, *31*, 151–161.

Kumbhakar, S. C., Wang, H., & Horncastle, A. P. (2015). *A practitioner's guide to stochastic frontier analysis using Stata*. Cambridge University Press. https://books.google.fr/books?hl=en&lr=&id=PT7WBQAAQBAJ&oi=fnd&pg=PR13&dq=A+PRACTITIONER%E2%80%99S+GUIDE+TO+STOCHASTIC+FRONTIER+ANALYSIS+USING+S&ots=9W0g3qsM6v&sig=lwePY7Guo9yoYVL9tsM-_RLQb4w&redir_esc=y#v=onepage&q=A%20PRACTITIONER%E2%80%99S%20GUIDE%20TO%20STOCHASTIC%20FRONTIER%20ANALYSIS%20USING%20S&f=false

Kumbhakar, S. C., & Wang, H.-J. (2005). Estimation of growth convergence using a stochastic production frontier approach. *Economics Letters*, *88*(3), 300–305. http://www.academia.edu/download/56041746/Estimation_of_Growth_Convergence_Using_a_Stochastic_Production_Frontier_Approach.pdf

Lankoski, J., Ollikainen, M., & Uusitalo, P. (2004). *No-till technology: benefits to farmers and the environment?* Helsingin yliopisto, taloustieteen laitos. https://helda.helsinki.fi/bitstream/handle/1975/635/Discuss1.pdf

Lanoie, P., Patry, M., & Lajeunesse, R. (2008). Environmental regulation and productivity: testing the porter hypothesis. *Journal of Productivity Analysis*, *30*(2), 121–128. https://link.springer.com/article/10.1007/s11123-008-0108-4

Lazzarini, S. G., Miller, G. J., & Zenger, T. R. (2004). Order with some law: Complementarity versus substitution of formal and informal arrangements. *Journal of Law, Economics, and Organization*, *20*(2), 261–298. https://academic.oup.com/jleo/article-pdf/20/2/261/2481607/ewh034.pdf?casa_token=khUSS1vonPIAAAAA:Ovtx2VWGKqqCUWZ_gk495F4U6DbaoHFPnCwUxfay1IN1DaLFJ5FF-AnKcYnM06T18uZjdcpJz5tzLg

Le Guernic, M. (2021). *Gouvernance et performance des coopératives en agriculture*. https://tel.archives-ouvertes.fr/tel-03634183/document

Lee, S., & McCann, L. (2019). Adoption of cover crops by US soybean producers. *Journal of Agricultural and Applied Economics*, *51*(4), 527–544. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/C21F7AD1428DA9BDE15410267DECEB7E/S1074070819000208a.pdf/div-class-title-adoption-of-cover-crops-by-u-s-soybean-producers-div.pdf

Lerman, Z., & Parliament, C. (1991). Size and industry effects in the performance of agricultural cooperatives. *Agricultural Economics*, *6*(1), 15–29. https://ageconsearch.umn.edu/record/172794/files/agec1991-1992v006i001a002.pdf

Leviten-Reid, C., & Campbell, R. (2016). Volunteer roles and the benefits of volunteering: An examination of nonprofit housing cooperatives. *Community Development*, *47*(4), 464–480. https://www.tandfonline.com/doi/abs/10.1080/15575330.2015.1134609

Li, Z., Jacobs, K. L., & Artz, G. M. (2015). The cooperative capital constraint revisited. *Agricultural Finance Review*. https://core.ac.uk/download/pdf/38941505.pdf

Liang, Q., & Hendrikse, G. (2013). Cooperative CEO identity and efficient governance: member or outside CEO? *Agribusiness*, *29*(1), 23–38. https://repub.eur.nl/pub/37879/ERS-2012-019-ORG.pdf

Liang, Q., & Hendrikse, G. (2016). Pooling and the yardstick effect of cooperatives. *Agricultural Systems*, *143*, 97–105. https://www.sciencedirect.com/science/article/pii/S0308521X15300627?casa_token=xtaG1gy5KEkAAAAA:1-y19OMxF1SqUp9sbjmNGYooSt_QZ2keJlOLmDFV7Fb_zCbhANb0qRXz9i-Dyr33RpjAJVv4rKO4

Liang, Q., Lu, H., & Deng, W. (2018). Between social capital and formal governance in farmer cooperatives: Evidence from China. *Outlook on Agriculture*, *47*(3), 196–203.

Liebrand, C. (2008). Using the'extra-value index'to measure agricultural cooperative performance. *Rural Cooperatives*, 23. https://naldc.nal.usda.gov/download/16160/PDF

Lind, J. T., & Mehlum, H. (2010). With or without U? The appropriate test for a U-shaped relationship. *Oxford Bulletin of Economics and Statistics*, *72*(1), 109–118. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1468-0084.2009.00569.x

Lucas, V. (2018). *L'agriculture en commun: Gagner en autonomie grâce à la coopération de proximité: Expériences d'agriculteurs français en CUMA à l'ère de l'agroécologie*. https://www.theses.fr/2018ANGE0020

Lucas, V., Gasselin, P., & Van Der Ploeg, J. D. (2019). Local inter-farm cooperation: A hidden potential for the agroecological transition in northern agricultures. *Agroecology and Sustainable Food Systems*, *43*(2), 145–179.

Ma, W., Abdulai, A., & Goetz, R. (2018). Agricultural cooperatives and investment in organic soil amendments and chemical fertilizer in China. *American Journal of Agricultural Economics*, *100*(2), 502–520. https://www.researchgate.net/profile/Renan-Goetz/publication/324018112_Agricultural_Cooperatives_and_Investment_in_Organic_Soil_Amendments_and_Chemical_Fertilizer_in_China/links/5fccef5c299bf188d4f9e697/Agricultural-Cooperatives-and-Investment-in-Organic-Soil-Amendments-and-Chemical-Fertilizer-in-China.pdf

Macneil, I. R. (1977). Contracts: Adjustment of long-term economic relations under classical, neoclassical, and relational contract law. *Nw. UL Rev.*, *72*, 854. https://heinonline.org/HOL/LandingPage?handle=hein.journals/illlr72&div=46&id=&page=

Maietta, O. W., & Sena, V. (2008). Is competition really bad news for cooperatives? Some empirical evidence for Italian producers' cooperatives. *Journal of Productivity Analysis*, *29*(3), 221–233. https://link.springer.com/article/10.1007/s11123-008-0100-z

Maietta, O. W., & Sena, V. (2010). FINANCIAL CONSTRAINTS AND TECHNICAL EFFICIENCY: SOME EMPIRICAL EVIDENCE FOR ITALIAN PRODUCERS'COOPERATIVES. *Annals of Public and Cooperative Economics*, *81*(1), 21–38. https://onlinelibrary.wiley.com/doi/full/10.1111/j.1467-8292.2009.00404.x?casa_token=ZxkrZj1gDykAAAAA%3AqAjojSH82nxaXYdRw1j9bSotsG7fPsMTS7qIym-QGY0ZpXctUZKsIS0D0lYHv1nTcU8Q0iTFNoB24STV

MAPAQ. (2018). *PORTRAIT DES CUMA AU QUÉBEC*.
MAPAQ. (2019). *Profil régional de l'industrie bioalimentaire au Québec*.
Mazé, A., & Ménard, C. (2010). Private ordering, collective action, and the self-enforcing range of contracts. *European Journal of Law and Economics*, *29*(1), 131–153. https://link.springer.com/article/10.1007/s10657-009-9114-x
McFadyen, M. A., & Cannella Jr, A. A. (2004). Social capital and knowledge creation: Diminishing returns of the number and strength of exchange relationships. *Academy of Management Journal*, *47*(5), 735–746. https://www.jstor.org/stable/pdf/20159615.pdf?casa_token=-RJzjsPpgTUAAAAA:z_BjwK3Dza4E3MquiF_EMqHYokWfxfx7cPglrxIlTlTMEDxLdCQRBItmDnUW8-Rjxr62Th-Ano3jao0gOVdOgGXLYXCZXo0iwOTiAU3M_Ss5E5UZksu4
Melia-Marti, E., & Martinez-Garcia, A. M. (2015). Characterization and analysis of cooperative mergers and their results. *Annals of Public and Cooperative Economics*, *86*(3), 479–504. https://onlinelibrary.wiley.com/doi/full/10.1111/apce.12083?casa_token=n7qto10c_9oAAAAA%3At3GAe4fyT38GRMoWifzw_aMMBODpTgij86qdPn-AdFFxWv6cxmTJyFMcksgXNIaUV3XY45xb-6H1oA3qUg
Mertens, S., & Marée, M. (2012). La «performance» de l'entreprise sociale: définition et limites d'une évaluation monétaire. *Revue Internationale PME Économie et Gestion de La Petite et Moyenne Entreprise*, *25*(3–4), 91–122. https://www.erudit.org/en/journals/ipme/1900-v1-n1-ipme0817/1018418ar.pdf
Meunier, V., & Marsden, É. (2009). *Analyse coût-bénéfices: guide méthodologique*. FonCSI. https://books.google.fr/books?hl=en&lr=&id=_dYSCAAAQBAJ&oi=fnd&pg=PA1&dq=analyse+cout+benefice+&ots=WglumR1dsv&sig=U6o3VhFAt8g4B3ry6me9CVDxXl4#v=onepage&q&f=false
Michelson, G., Wailes, N., Van Der Laan, S., & Frost, G. (2004). Ethical investment processes and outcomes. *Journal of Business Ethics*, *52*(1), 1–10. https://www.researchgate.net/profile/Grant-Michelson/publication/226510567_Ethical_Investment_Processes_and_Outcomes/links/543ce7720cf24ef33b764df1/Ethical-Investment-Processes-and-Outcomes.pdf
Ministère de l'Agriculture, des P. et de l'Alimentation du Q. (2018). *Portrait des CUMA au Québec*.
Mintzberg, H. (1993). *Structure in fives: Designing effective organizations.* Prentice-Hall, Inc. https://psycnet.apa.org/record/1992-98280-000
Minviel, J. J., & Sipiläinen, T. (2018). Dynamic stochastic analysis of the farm subsidy-efficiency link: Evidence from France. *Journal of Productivity Analysis*, *50*(1–2), 41–54.
Minviel, J. J., & Sipiläinen, T. (2021). A dynamic stochastic frontier approach with persistent and transient inefficiency and unobserved heterogeneity. *Agricultural Economics*, *52*(4), 575–589. https://helda.helsinki.fi/bitstream/handle/10138/344043/Heterogeneity.pdf?sequence=1
Mojo, D., Fischer, C., & Degefa, T. (2015). Social and environmental impacts of agricultural cooperatives: evidence from Ethiopia. *International Journal of Sustainable Development & World Ecology*, *22*(5), 388–400.

Mojo, D., Fischer, C., & Degefa, T. (2017). The determinants and economic impacts of membership in coffee farmer cooperatives: recent evidence from rural Ethiopia. *Journal of Rural Studies*, *50*, 84–94.

Moller, L. G., Featherstone, A. M., & Barton, D. G. (1996). Sources of financial stress in agricultural cooperatives. *Journal of Cooperatives*, *11*(1142-2016–92722), 38–50. https://ageconsearch.umn.edu/record/46190/files/Vol%2011%201996%20Article%204.pdf

Monitor World Cooperative. (2021). *Exploring the cooperative economy*.

Murillo-Zamorano, L. R., & Vega-Cervera, J. A. (2001). The use of parametric and non-parametric frontier methods to measure the productive efficiency in the industrial sector: a comparative study. *International Journal of Production Economics*, *69*(3), 265–275.

Musson, A., & Rousselière, D. (2020a). Identifying the impact of crisis on cooperative capital constraint. A short note on French craftsmen cooperatives. *Finance Research Letters*, *35*, 101290. https://hal.science/hal-02290727/document

Musson, A., & Rousselière, D. (2020b). Le rôle des coopératives dans la diffusion d'une éco-innovation: le cas de l'adoption de films recyclés par les maraîchers du bassin nantais. *Développement Durable et Territoires. Économie, Géographie, Politique, Droit, Sociologie*, *11*(3).

Mutter, R. L., Greene, W. H., Spector, W., Rosko, M. D., & Mukamel, D. B. (2013). Investigating the impact of endogeneity on inefficiency estimates in the application of stochastic frontier analysis to nursing homes. *Journal of Productivity Analysis*, *39*(2), 101–110. https://mdsoar.org/bitstream/handle/11603/21934/Mutter2013_Article_InvestigatingTheImpactOfEndoge.pdf?sequence=1

Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, *23*(2), 242–266. http://eli.johogo.com/Class/p18.pdf

Nemoto, J., & Goto, M. (1999). Dynamic data envelopment analysis: modeling intertemporal behavior of a firm in the presence of productive inefficiencies. *Economics Letters*, *64*(1), 51–56. https://www.sciencedirect.com/science/article/pii/S0165176599000701

Nicholls, A. (2009). 'We do good things, don't we?':'Blended Value Accounting'in social entrepreneurship. *Accounting, Organizations and Society*, *34*(6–7), 755–769. https://www.sciencedirect.com/science/article/pii/S0361368209000440

Nilsson, J. (1997). New generation farmer co-operatives. *ICA Review*, *90*(1), 32–38. https://www.researchgate.net/profile/Jerker-Nilsson/publication/312993816_New_generation_farmer_co-ops/links/5890722492851c9794c67685/New-generation-farmer-co-ops.pdf

Nilsson, J. (2001). Organisational principles for co-operative firms. *Scandinavian Journal of Management*, *17*(3), 329–356. https://www.researchgate.net/profile/Jerker_Nilsson/publication/222134118_Organisational_principles_for_co-operative_firms/links/59e9d3810f7e9bc89bcae6ab/Organisational-principles-for-co-operative-firms.pdf

Nilsson, J., Svendsen, G. L. H., & Svendsen, G. T. (2012). Are large and complex agricultural cooperatives losing their social capital? *Agribusiness*, *28*(2), 187–204. https://onlinelibrary.wiley.com/doi/abs/10.1002/agr.21285?casa_token=ewD5Z0BSj2QAAAAA:sMpydYT0o_CzrHvE4AW6gj6_9ZyQxouF-mpdyAfKHAZSiSNZ22F_fOA2w2Xy1pXhhI1aPgAbB4id4gmf

Njuki, E., Bravo-Ureta, B. E., & O'Donnell, C. J. (2019). Decomposing agricultural productivity growth using a random-parameters stochastic production frontier. *Empirical Economics*, *57*(3), 839–860. https://link.springer.com/article/10.1007/s00181-018-1469-9

O'Donnell, C. J. (2014). Econometric estimation of distance functions and associated measures of productivity and efficiency change. *Journal of Productivity Analysis*, *41*, 187–200.

O'Donnell, C. J. (2018). *Productivity and efficiency analysis*. Springer. https://link.springer.com/book/10.1007%2F978-981-13-2984-5

Olesen, H. B. (2007). The horizon problem reconsidered. In *Vertical markets and cooperative hierarchies* (pp. 245–253). Springer. https://ageconsearch.umn.edu/record/24489/files/cp05ol01.pdf

Olson, M. (2009). *The logic of collective action* (Vol. 124). Harvard University Press. http://homes.ieu.edu.tr/~ibagdadi/INT230/Mancur%20Olson%20-%20Logic%20of%20Collective%20Action.pdf

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge university press.

Ouchi, W. G. (1979). A conceptual framework for the design of organizational control mechanisms. *Management Science*, *25*(9), 833–848. https://www.researchgate.net/profile/William_Ouchi/publication/227444951_A_Conceptual_Framework_for_Design_of_Organisational_Control_Mechanism/links/56000d2e08ae07629e525d17.pdf

Ouellette, P., & Vierstraete, V. (2010). Malmquist indexes with quasi-fixed inputs: An application to school districts in Québec. *Annals of Operations Research*, *173*(1), 57–76. https://link.springer.com/article/10.1007/s10479-008-0477-0

Ouellette, P., & Yan, L. (2008). Investment and dynamic DEA. *Journal of Productivity Analysis*, *29*(3), 235–247. https://link.springer.com/article/10.1007/s11123-007-0079-x

Pantzios, C. J., Karagiannis, G., & Tzouvelekas, V. (2011). Parametric decomposition of the input-oriented Malmquist productivity index: with an application to Greek aquaculture. *Journal of Productivity Analysis*, *36*, 21–31.

Papke, L. E., & Wooldridge, J. M. (1996). Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. *Journal of Applied Econometrics*, *11*(6), 619–632. https://onlinelibrary.wiley.com/doi/pdfdirect/10.1002/%28SICI%291099-1255%28199611%2911%3A6%3C619%3A%3AAID-JAE418%3E3.0.CO%3B2-1

Parliament, C., Lerman, Z., & Fulton, J. R. (1990). Performance of cooperatives and investor-owned firms in the dairy industry. *Journal of Agricultural Cooperation*, *5*(1141-2016–92505), 1–16. https://ageconsearch.umn.edu/record/46229/files/Vol%205%201990%20Article%201.pdf

Pastor, J. T., Asmild, M., & Lovell, C. A. K. (2011). The biennial Malmquist productivity change index. *Socio-Economic Planning Sciences*, *45*(1), 10–15. https://www.researchgate.net/profile/Ca-Lovell/publication/227422427_The_biennial_Malmquist_productivity_change_index/links/604a97a9299bf1f5d840d925/The-biennial-Malmquist-productivity-change-index.pdf

Pennerstorfer, D., & Weiss, C. R. (2013). Product quality in the agri-food chain: Do cooperatives offer high-quality wine? *European Review of Agricultural Economics*, *40*(1), 143–162. https://academic.oup.com/erae/article-abstract/40/1/143/423693

Pindyck, R. S. (1990). *Irreversibility, uncertainty, and investment*. National Bureau of Economic Research Cambridge, Mass., USA.

Plunkett, B. (2005). *The portfolio problem in agricultural cooperatives: an integrated framework*. https://mospace.umsystem.edu/xmlui/bitstream/handle/10355/4112/research.pdf?sequence=3

Pokharel, K. P., Archer, D. W., & Featherstone, A. M. (2020). The impact of size and specialization on the financial performance of agricultural cooperatives. *Journal of Co-Operative Organization and Management*, *8*(2), 100108. https://www.sciencedirect.com/science/article/pii/S2213297X19300187?casa_token=rb0SPn4BprYAAAAA:bH7zQFi8WwfW_bBpJkimpbhnDtM6o-gFWBd1LmQF6Gs9NLJOysTsS_vg-hJA6kBSIXzagN_Q0OBu

Pokharel, K. P., & Featherstone, A. M. (2021). Examining the productivity growth of agricultural cooperatives: The biennial malmquist index approach. *Journal of Co-Operative Organization and Management*, *9*(2), 100148.

Poppo, L., & Zenger, T. (2002). Do formal contracts and relational governance function as substitutes or complements? *Strategic Management Journal*, *23*(8), 707–725.

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of Economic Perspectives*, *9*(4), 97–118. https://pubs.aeaweb.org/doi/pdf/10.1257/jep.9.4.97

Porter, P. K., & Scully, G. W. (1987). Economic efficiency in cooperatives. *The Journal of Law and Economics*, *30*(2), 489–512. https://www.journals.uchicago.edu/doi/pdfplus/10.1086/467146

Prokopy, L. S., Floress, K., Klotthor-Weinkauf, D., & Baumgart-Getz, A. (2008). Determinants of agricultural best management practice adoption: Evidence from the literature. *Journal of Soil and Water Conservation*, *63*(5), 300–311.

Putnam, R. (1993). The prosperous community: Social capital and public life. *The American Prospect*, *13*(Spring), Vol. 4. Available online: http://www. prospect. org/print/vol/13 (accessed 7 April 2003). http://www.philia.ca/files/pdf/ProsperousCommunity.pdf

Rajan, R., & Zingales, L. (1996). *Financial dependence and growth*. National bureau of economic research Cambridge, Mass., USA. https://www.nber.org/system/files/working_papers/w5758/w5758.pdf

Ramalho, E. A., Ramalho, J. J. S., & Murteira, J. M. R. (2011). Alternative estimating and testing empirical strategies for fractional regression models. *Journal of Economic Surveys*, *25*(1), 19–68.

Ramalho, J., & da Silva, J. V. (2009). A two-part fractional regression model for the financial leverage decisions of micro, small, medium and large firms. *Quantitative Finance*, *9*(5), 621–636. https://www.ssoar.info/ssoar/bitstream/handle/document/22129/ssoar-2009-05-ramalho_et_al-a_two-part_fractional_regression_model.pdf?sequence=1&isAllowed=y&lnkname=ssoar-2009-05-ramalho_et_al-a_two-part_fractional_regression_model.pdf

Ramanathan, R. (2003). *An introduction to data envelopment analysis: a tool for performance measurement*. Sage. https://books.google.fr/books?hl=en&lr=&id=CitbHSWaBxsC&oi=fnd&pg=PA11&dq=Ramanathan+2003+&ots=BAn7iw8vaC&sig=hyikomRS_2w45ha9vOeRthjYP8g#v=onepage&q=Ramanathan%202003&f=false

Revelli, C., & Sentis, P. (2012). L'investissement socialement responsable diffère-t-il vraiment de l'investissement conventionnel? *Revue Des Sciences de Gestion*. https://scholar.archive.org/work/e2rva55iprhhznpv6n2ocdpcja/access/wayback/https://www.cairn.info/load_pdf.php?ID_ARTICLE=RSG_255_0085&download=1

Rey, P., & Tirole, J. (2007). Financing and access in cooperatives. *International Journal of Industrial Organization*, *25*(5), 1061–1088. http://publications.ut-capitole.fr/1168/1/financing.pdf

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, *9*(1), 86–136. https://journals.sagepub.com/doi/pdf/10.1177/1536867X0900900106

Roodman, D. (2011). Fitting fully observed recursive mixed-process models with cmp. *The Stata Journal*, *11*(2), 159–206. https://journals.sagepub.com/doi/pdf/10.1177/1536867X1101100202

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55. https://academic.oup.com/biomet/article-pdf/70/1/41/662954/70-1-41.pdf

Rousselière, D., Bouchard, M. J., & Le Guernic, M. (2020). *On the economic contribution of cooperatives*.

Royer, J. S. (1991). A comparative financial ratio analysis of US farmer cooperatives using nonparametric statistics. *Journal of Agricultural Cooperation*, *6*(1141-2016–92549), 22–44. https://ageconsearch.umn.edu/record/46257/files/Vol%206%201991%20Article%203.pdf

Royer, J. S. (1999). Cooperative organizational strategies: A neo-institutional digest. *Journal of Cooperatives*, *14*(1142-2016–92748), 44–67. https://ageconsearch.umn.edu/record/46367/files/Pages%20from%20Journal%20of%20Cooperative%201999-44.pdf

Royston, P. (2004). Multiple imputation of missing values. *The Stata Journal*, *4*(3), 227–241. https://journals.sagepub.com/doi/abs/10.1177/1536867X0400400301

Rungsuriyawiboon, S., & Hockmann, H. (2015). Adjustment costs and efficiency in Polish agriculture: a dynamic efficiency approach. *Journal of Productivity Analysis*, *44*, 51–68.

Russo, C., Weatherspoon, D., Peterson, C., & Sabbatini, M. (2000). Effects of managers' power on capital structure: a study of Italian agricultural cooperatives. *The International Food and*

Agribusiness Management Review, *3*(1), 27–39. https://www.sciencedirect.com/science/article/pii/S1096750800000252

Schaller, H. (1993). Asymmetric information, liquidity constraints, and Canadian investment. *Canadian Journal of Economics*, 552–574. https://www.jstor.org/stable/135887

Schaltegger, S., & Synnestvedt, T. (2002). The link between 'green'and economic success: environmental management as the crucial trigger between environmental and economic performance. *Journal of Environmental Management*, *65*(4), 339–346. https://www.academia.edu/download/43534557/The_link_between_green_and_economic_su20160309-24667-3mtn0y.pdf

Schmidt, P., & Lin, T.-F. (1984). Simple tests of alternative specifications in stochastic frontier models. *Journal of Econometrics*, *24*(3), 349–361. https://www.sciencedirect.com/science/article/pii/0304407684900587

Schwiebert, J., & Wagner, J. (2015). *A generalized two-part model for fractional response variables with excess zeros*. https://www.econstor.eu/bitstream/10419/113059/1/VfS_2015_pid_63.pdf

Serra, T., Lansink, A. O., & Stefanou, S. E. (2011). Measurement of dynamic efficiency: A directional distance function parametric approach. *American Journal of Agricultural Economics*, *93*(3), 756–767. https://www.jstor.org/stable/pdf/41240356.pdf?casa_token=7x6G0SQ2KS4AAAAA:f7Jwv6nu4NBeYaOdP_XJzhjiMUxiIzoYEkZTMTASaWpAvp2_ZUMuipjcx6TTIXjMWRLbz1Cc7BWzzrC9pznpoN6MUGZdPnN1Z32cyd6xrzL1vCG0yFDC

Sexton, R. J., Iskow, J., & others. (1993). What do we know about the economic efficiency of cooperatives: an evaluative survey. *Journal of Agricultural Cooperation*, *8*.

Sexton, R. J., Wilson, B. M., & Wann, J. J. (1989). Some tests of the economic theory of cooperatives: Methodology and application to cotton ginning. *Western Journal of Agricultural Economics*, 56–66. https://ageconsearch.umn.edu/record/32455/files/14010056.pdf

Shephard, R. W. (2012). *Cost and production functions* (Vol. 194). Springer Science & Business Media. https://books.google.fr/books?hl=en&lr=&id=V6f7CAAAQBAJ&oi=fnd&pg=PA3&dq=Shephard,+R.+W.+(1953).+%E2%80%9CCost+and+Production+Functions.%E2%80%9D+Princeton:+Princeton+University+Press&ots=XpSwWibAbk&sig=v_C1Z4MoIcZoB4Rwop4g2t9HC9w&redir_esc=y#v=onepage&q=Shephard%2C%20R.%20W.%20(1953).%20%E2%80%9CCost%20and%20Production%20Functions.%E2%80%9D%20Princeton%3A%20Princeton%20University%20Press&f=false

Silva, E., & Stefanou, S. E. (2007). Dynamic efficiency measurement: theory and application. *American Journal of Agricultural Economics*, *89*(2), 398–419. https://www.jstor.org/stable/pdf/4492819.pdf?casa_token=EDPw4_Tg4KEAAAAA:YWAbQt7EgM0ahixBS6pyOt2CYku4oe43ft0g8vxlZDroHJRJJB2s6PckDvWybH7Ke4dlXe5uKSDJ8e5k0a-EQAmw33ZK1YMB9CqecBjJGU_4jcugMwfs

Silva, L. F., & Morello, T. (2021). Is there a trade-off between efficiency and cooperativism? Evidence from Brazilian worker cooperatives. *Journal of Co-Operative Organization and Management*, *9*(2), 100136.

Singh, S., Coelli, T., & Fleming, E. (2001). Performance of dairy plants in the cooperative and private sectors in India. *Annals of Public and Cooperative Economics*, *72*(4), 453–479. https://onlinelibrary.wiley.com/doi/abs/10.1111/1467-8292.00178?casa_token=_sKZ2laexSMAAAAA:aVAwoNDhoTHFQFRSzsqx0zSw7B2_gbqY_5aaf1XGuEuRO5xeZkUvM-WGURyHjIZ6f4JWbzav9Q3IleU2

Sipilainen, T., & Oude Lansink, A. G. J. M. (2005). *Learning in organic farming-an application on Finnish dairy farms*. https://ageconsearch.umn.edu/record/24493/files/cp05si01.pdf

Sitkin, S. B., & Roth, N. L. (1993). Explaining the limited effectiveness of legalistic "remedies" for trust/distrust. *Organization Science*, *4*(3), 367–392. https://pubsonline.informs.org/doi/abs/10.1287/orsc.4.3.367

Slade Shantz, A. F., Kistruck, G. M., Pacheco, D. F., & Webb, J. W. (2020). How formal and informal hierarchies shape conflict within cooperatives: A field experiment in Ghana. *Academy of Management Journal*, *63*(2), 503–529.

Soboh, R. A., Lansink, A. O., Giesen, G., & Van Dijk, G. (2009). Performance measurement of the agricultural marketing cooperatives: the gap between theory and practice. *Applied Economic Perspectives and Policy*, *31*(3), 446–469.

Soboh, R., Oude Lansink, A., & Van Dijk, G. (2012). Efficiency of cooperatives and investor owned firms revisited. *Journal of Agricultural Economics*, *63*(1), 142–157. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1477-9552.2011.00324.x?casa_token=mbmdDJOQjnUAAAAA:9-qDEgdn6ww7Olv03Pk_OCw1nWERSCXjz3Wc2ulfz6uIK7Cj3aMqIhzrShyrowCYo_UpiK5bIO_w208

Staiger, D., & Stock, J. (1997). Instrumental Variables Regression with Weak Instruments. *Econometrica*, *65*(3), 557–586. http://drphilipshaw.com/Staiger-Stock-1997.pdf

Starr, M. A. (2014). Qualitative and mixed-methods research in economics: surprising growth, promising future. *Journal of Economic Surveys*, *28*(2), 238–264.

Stefanou, S. E. (2009). A dynamic characterization of efficiency. *Agricultural Economics Review*, *10*(389-2016–23313), 18–33. https://ageconsearch.umn.edu/record/58278/files/10_1_2.pdf

Stiglitz, J. E. (2000). Formal and informal institutions. *Social Capital: A Multifaceted Perspective*, *2000*, 59–68.

Stiglitz, J. E. (2017). Markets, States, and Institutions. *Markets, Governance, and Institutions in the Process of Economic Development*, 13–30. https://academiccommons.columbia.edu/doi/10.7916/d8-sa4a-7m66/download

Sutherland, L.-A., & Burton, R. J. F. (2011). Good farmers, good neighbours? The role of cultural capital in social capital development in a Scottish farming community. *Sociologia Ruralis*, *51*(3), 238–255. https://ruralis.brage.unit.no/ruralis-xmlui/bitstream/handle/11250/2381360/A24_11+Good+Farmers%2C+Good+Neighbours+The+Role+of+Cultural+Capital+in+Social+Capital+Development+in+a+Scottish+Farming+CommunityL.-A.+Sutherland%2C+R.+Burton.pdf?sequence=3

Szymańska, A., & Jegers, M. (2016). Modelling social enterprises. *Annals of Public and Cooperative Economics*, *87*(4), 501–527. https://onlinelibrary.wiley.com/doi/full/10.1111/apce.12127

Tran, K. C., & Tsionas, E. G. (2015). Endogeneity in stochastic frontier models: Copula approach without external instruments. *Economics Letters*, *133*, 85–88. https://eprints.lancs.ac.uk/id/eprint/74587/2/CopulaSF_April_13_2015.pdf

Uzea, N., & Duguid, F. (2015). Challenges in conducting a study on the economic impact of cooperatives. *The Weight of the Social Economy: An International Perspective*, *6*, 251–276. https://www.researchgate.net/profile/F-Uzea/publication/283213723_Challenges_in_conducting_a_study_on_the_economic_impact_of_co-operatives/links/562e41d408ae518e348362de/Challenges-in-conducting-a-study-on-the-economic-impact-of-co-operatives.pdf

Valentinov, V. L. (2004). Toward a social capital theory of cooperative organisation. *Journal of Cooperative Studies*, *37*(3), 5–20. https://www.researchgate.net/profile/Vladislav_Valentinov/publication/256069632_Toward_a_Social_Capital_Theory_of_Cooperative_Organisation/links/551af7f70cf251c35b503d06.pdf

Valiorgue, B. (2021). La restructuration: question prioritaire en matière de gouvernance des coopératives agricoles. *Revue de Droit Rural*. https://hal.archives-ouvertes.fr/hal-03126742/file/Restructuration%20et%20gouvernance%20des%20coop%C3%A9ratives_final.pdf

Valiorgue, B., & Hollandts, X. (2016). *Référentiel pour une gouvernance stratégique des coopératives agricoles*. https://hal.archives-ouvertes.fr/hal-03421964/

Van der Krogt, D., Nilsson, J., & Høst, V. (2007). The impact of cooperatives' risk aversion and equity capital constraints on their inter-firm consolidation and collaboration strategies—with an empirical study of the European dairy industry. *Agribusiness: An International Journal*, *23*(4), 453–472.

Verhofstadt, E., & Maertens, M. (2014). Smallholder cooperatives and agricultural performance in Rwanda: do organizational differences matter? *Agricultural Economics*, *45*(S1), 39–52.

Verhofstadt, E., & Maertens, M. (2015). Can agricultural cooperatives reduce poverty? Heterogeneous impact of cooperative membership on farmers' welfare in Rwanda. *Applied Economic Perspectives and Policy*, *37*(1), 86–106. https://onlinelibrary.wiley.com/journal/20405804

Villena, V. H., Revilla, E., & Choi, T. Y. (2011). The dark side of buyer–supplier relationships: A social capital perspective. *Journal of Operations Management*, *29*(6), 561–576. https://www.sciencedirect.com/science/article/pii/S0272696310000793?casa_token=NdMiiP-wOAwAAAAA:OH1KYkqbG4iOMaTmGcTkDy_hCzB-i11dJ-4VUDXhfGYTXtYpMh4HBrfSTrBWQkBOeGpDDRLE8NS1

Vitaliano, P. (1983). Cooperative enterprise: an alternative conceptual basis for analyzing a complex institution. *American Journal of Agricultural Economics*, *65*(5), 1078–1083. https://www.jstor.org/stable/1240424

Wang, H.-J., & Schmidt, P. (2002). One-step and two-step estimation of the effects of exogenous variables on technical efficiency levels. *Journal of Productivity Analysis*, *18*(2), 129–144. https://idp.springer.com/authorize/casa?redirect_uri=https://link.springer.com/content/pdf/10.1023/A:1016565719882.pdf&casa_token=hjpel2XrX8cAAAAA:WtOc6L2W4jaok2nxeR0_SmUBUOp9VelHtLKusEdJt1odKleRLhX_0Iz7gZvtepVrR7EXV2OhvoouleISOko

Wathne, K. H., & Heide, J. B. (2000). Opportunism in interfirm relationships: Forms, outcomes, and solutions. *Journal of Marketing*, *64*(4), 36–51. https://osmangok.yasar.edu.tr/MNGT%20640%20INDUSTRIAL%20MARKETING%20MANAGEMENT/Interfirm%20relationships%20articles/Opportunism%20in%20Interfirm%20Relationships.pdf

Williams, R. (2017). Using Stata's margins command to estimate and interpret adjusted predictions and marginal effects. *The Stata Journal*, 308–331. http://www3.nd.edu/~rwilliam/stats3/Margins01.pdf

Williamson, O. E. (1985). *The economic intstitutions of capitalism*. Simon and Schuster.

Wooldridge, J. M. (2002). Econometric analysis of cross section and panel data MIT press. *Cambridge, Ma*, *108*(2), 245–254.

Wulff, J. N. (2019). Generalized two-part fractional regression with cmp. *The Stata Journal*, *19*(2), 375–389. https://pure.au.dk/portal/files/198786925/Generalized_two_part_fractional_regression_with_cmp_2019_AM.pdf

Wulff, J. N., & Villadsen, A. R. (2020). Keeping it within bounds: Regression analysis of proportions in international business. *Journal of International Business Studies*, *51*(2), 244–262. https://link.springer.com/article/10.1057/s41267-019-00278-w

Xu, M., Tan, R., & He, X. (2022). How does economic agglomeration affect energy efficiency in China?: Evidence from endogenous stochastic frontier approach. *Energy Economics*, *108*, 105901.

Yen, S. T. (2005). A multivariate sample-selection model: Estimating cigarette and alcohol demands with zero observations. *American Journal of Agricultural Economics*, *87*(2), 453–466. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-8276.2005.00734.x

Yin, R. K. (2018). *Case study research and applications: design and methods* (Sixth edition). SAGE.

Zenger, T. R., Lazzarini, S. G., & Poppo, L. (2000). Informal and formal organization in new institutional economics. In *The new institutionalism in strategic management*. Emerald Group Publishing Limited. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.117.5355&rep=rep1&type=pdf

Zeuli, K. A., & Deller, S. C. (2007). Measuring the local economic impact of cooperatives. *Journal of Rural Cooperation*, *35*(886-2016–64572), 1–17. https://ageconsearch.umn.edu/record/58682/files/Zeuli_%20Deller%20jrc351.pdf

Appendix

Appendix.A

Appendix A.1. Guide d'entretien

1-Portrait général de la CUMA

A. Nom de la CUMA / date de formation de la CUMA / Nombre de membres / types de
membres / Critères généraux (spécifiques) pour adhérer à la CUMA / Nombre de branches / Critères d'appartenance à une branche d'activité
B. Nombre de branches / Nombre maximal de producteur par branche/ Nombre de branches biologiques dans la CUMA /
C. Quelles étaient vos motivations en formant la CUMA ?

2- Organe de gouvernance de la CUMA

A -Composition

1. Quel est l'organigramme de votre CUMA ?
2. Nombre de membres du conseil d'administration ? Les membres sont-ils tous des membres internes à la CUMA? Uniquement des anciens de la CUMA ? Pourquoi.

B- Compétences

Les membres du CA ont des qualifications particulières ou non ? Si oui, quelles sont ces qualifications ? des bénévoles ? Pourquoi.

C- Rôle

Le rôle du CA se limite-t-il principalement à la supervision des activités de la CUMA ? Si oui, qui assure la gestion pratique de la CUMA? Si non, quel est le rôle principal du CA dans votre CUMA ? a-t-il d'autres rôles secondaires ? Lesquels ?

3-Mécanisme de gouvernance

A-Type de mécanisme de gouvernance (coordination et motivation)

1. Les activités de la CUMA se résument-elles uniquement au partage du matériel ? si non. Quelles sont les autres activités de votre CUMA ? Comment sont organisées ces activités de façon générale ?
2. Le partage du matériel est-il fait selon un ordre de priorité ou suit d'autres règles ? (premier arrivé, premier servi) Lesquelles et pourquoi ?
3. Toutes les branches d'activité ont-elles la même organisation ou y a-t-il des différences ? Lesquelles ? Qui définit la façon dont les branches s'organisent ? Arrive-t-il que cette organisation change? Pourquoi ?
4. Arrive-t-il parfois des situations où la branche d'activité ne fonctionne pas bien ? Dans quelles situations par exemple ? (cas de rétention du matériel ? sous-location du matériel non autorisé ? Travail forfaitaire non autorisé ? Désengagement du membre avant terme du contrat d'engagement) ?
5. Comment la CUMA fait pour diminuer ces situations? Ou obliger les membres à respecter

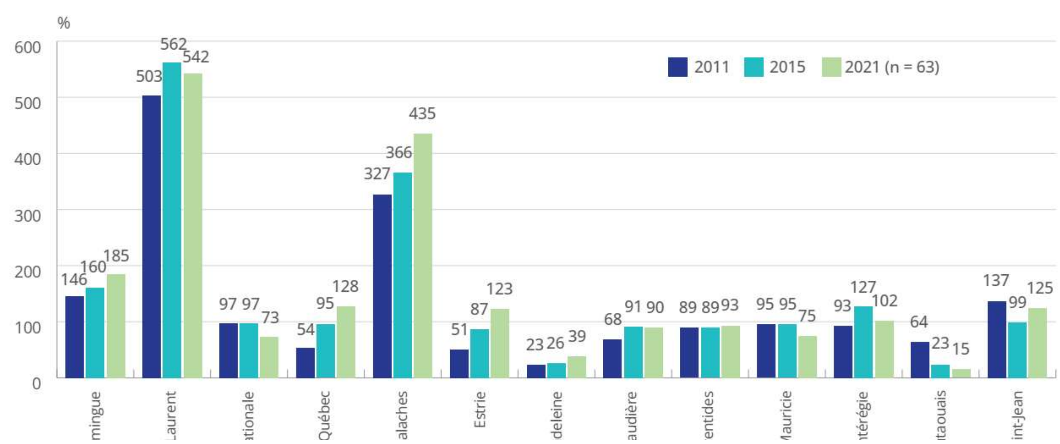
les règles de la branche ? (par exemple, comment la CUMA fait pour diminuer les cas de désengagement des membres avant le terme du contrat ? Réduire le travail forfaitaire non
autorisé ?)

6. En cas de non-respect des règles, la CUMA prévoit-elle des pénalités ? si oui lesquelles par exemple ?

B-Combinaison des règles

1. Est-ce que certaines règles de la CUMA ne sont pas forcément écrites ? Si oui, quelles règles par exemple ? Si non Pourquoi. (les règles de fonctionnement dans la branche par exemple)
2. Les membres de votre CUMA entretiennent-ils des relations basées sur la confiance? Si oui, quel est le rôle de cette confiance et comment se manifeste-t-elle entre les membres ?

Appendix A.2. Évolution du nombre de membre en CUMA au Québec (2011-2015-2022)



Appendix.B

Appendix B.1. Financial ratios

Table B-1 : Financial ratios

Ratio	Calculation	Source
Leverage	Total debt / Equity	(Harris & Fulton, 1996)
Turnover	Turnover / total assets	(Parliament et al., 1990)
Cash flow ratio	CAF / Turnover	(Declerck, 2013)
Cost of debt	Interest Expense/(Total Assets-Reserves)	(Russo et al., 2000)

Appendix B.2. Fractional models results

Table B-2 : Fractional model results

Variables	Probability	Environmental proportion
log (Size)	0.848***	0.484***
	(0.202)	(0.181)
log (Size) × log (Size)	-0.086***	-0.062***
	(0.027)	(0.024)
Leverage	0.203***	-0.036
	(0.042)	(0.032)
Leverage × Leverage	-0.006***	0.001
	(0.002)	(0.001)
Dependence	0.037	0.110**
	(0.062)	(0.050)
Worker	-0.240	-0.498**
	(0.348)	(0.250)
Client	1.593***	0.377*
	(0.302)	(0.225)
Contact	-0.082	-0.081
	(0.602)	(0.518)
Employee	-0.080	-0.044
	(0.068)	(0.053)
CUMA	0.133**	-0.030
	(0.059)	(0.047)
EARL	0.042	-0.049
	(0.152)	(0.140)
GAEC	0.231*	0.162
	(0.125)	(0.119)
log (Age)	-0.040	-0.308**
	(0.159)	(0.139)
log (Age) × log (Age)	0.018	0.053**
	(0.026)	(0.022)
2.REG	-0.069	-0.050
	(0.112)	(0.097)
3.REG	-0.031	-0.044
	(0.127)	(0.103)
4.REG	-0.270*	-0.076
	(0.138)	(0.124)
5.REG	0.102	0.089
	(0.152)	(0.118)
6.REG	0.044	0.067
	(0.106)	(0.088)

7.REG	-0.000	-0.049
	(0.111)	(0.091)
8.REG	-0.068	-0.109
	(0.128)	(0.112)
9.REG	-0.047	0.009
	(0.110)	(0.089)
10.REG	-0.039	0.043
	(0.138)	(0.120)
Farms density	-11.403***	-8.415**
	(3.863)	(3.743)
Usable agricultural area	-0.168	-0.052
	(0.175)	(0.143)
Population density	-0.003	
	(0.005)	
Subsidies	-0.000	-0.000*
	(0.000)	(0.000)
2.TEOF	-0.133	-0.113
	(0.088)	(0.073)
3.TEOF	0.208	-0.036
	(0.186)	(0.130)
4.TEOF	-0.202	0.107
	(0.307)	(0.268)
5.TEOF	0.089	-0.019
	(0.097)	(0.074)
6.TEOF	-0.003	-0.007
	(0.065)	(0.053)
7.TEOF	-0.276*	-0.201
	(0.162)	(0.147)
Cash flow ratio	0.021	-0.037
	(0.035)	(0.042)
Turnover	-0.594	-0.594
	(0.414)	(0.384)
Cost of debt	-0.554	-1.688***
	(0.414)	(0.494)
log (Income)	-0.031	-0.009
	(0.088)	(0.068)

Constant	-1.494	-0.382
	(0.988)	(0.775)
atanhrho_12		4.312**
		(1.870)
Rho		0.99
		0.0013
Observations	2,680	2,680

*.***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1.*

Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base

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. TEOF 1 is the base.

Table B-3 : Marginal effects of control variables

Variables	Probability	Conditional effect	Unconditional effect
log (Size)	0.091***	-0.084***	-0.020
	(0.016)	(0.024)	(0.018)
Leverage	0.065***	-0.132***	-0.063***
	(0.013)	(0.021)	(0.015)
Dependence	0.013	0.090***	0.063***
	(0.021)	(0.034)	(0.024)
Worker	-0.082	-0.372**	-0.275**
	(0.119)	(0.166)	(0.119)
Client	0.545***	-0.460***	-0.102
	(0.102)	(0.162)	(0.113)
Contact	-0.028	-0.038	-0.035
	(0.206)	(0.327)	(0.249)
Employee	-0.027	-0.002	-0.011
	(0.023)	(0.042)	(0.028)
CUMA	0.046**	-0.100***	-0.049**
	(0.021)	(0.030)	(0.022)
EARL	0.014	-0.071	-0.041
	(0.053)	(0.078)	(0.066)
GAEC	0.082*	0.034	0.049
	(0.046)	(0.069)	(0.048)
log (Age)	0.029*	0.023	0.028
	(0.017)	(0.027)	(0.021)
2.REG	-0.024	-0.014	-0.017
	(0.039)	(0.064)	(0.047)
3.REG	-0.011	-0.028	-0.022
	(0.043)	(0.065)	(0.049)
4.REG	-0.096*	0.073	0.008
	(0.049)	(0.072)	(0.055)
5.REG	0.034	0.037	0.038
	(0.050)	(0.080)	(0.061)
6.REG	0.015	0.045	0.036
	(0.036)	(0.055)	(0.043)
7.REG	-0.000	-0.049	-0.033
	(0.038)	(0.062)	(0.045)
8.REG	-0.023	-0.073	-0.055
	(0.044)	(0.075)	(0.054)

9.REG	-0.016	0.033	0.016
	(0.037)	(0.061)	(0.045)
10.REG	-0.013	0.064	0.037
	(0.047)	(0.078)	(0.059)
Farms density	-3.897***	-2.426	-3.034
	(1.316)	(2.603)	(1.915)
Usable agricultural area	-0.058	0.037	0.003
	(0.060)	(0.092)	(0.069)
Subsidies	-0.000	-0.000**	-0.000**
	(0.000)	(0.000)	(0.000)
2.TEOF	-0.047	-0.041	-0.043
	(0.031)	(0.047)	(0.033)
3.TEOF	0.068	-0.139	-0.075
	(0.058)	(0.094)	(0.071)
4.TEOF	-0.072	0.218	0.102
	(0.112)	(0.133)	(0.126)
5.TEOF	0.030	-0.065	-0.033
	(0.032)	(0.050)	(0.037)
6.TEOF	-0.001	-0.005	-0.004
	(0.022)	(0.033)	(0.025)
7.TEOF	-0.099*	-0.047	
	(0.060)	(0.090)	
Cash flow ratio	0.007	-0.048	-0.029
	(0.012)	(0.034)	(0.024)
Turnover	-0.203	-0.282	-0.261
	(0.141)	(0.216)	(0.177)
Cost of debt	-0.190	-1.397***	-0.990***
	(0.141)	(0.420)	(0.287)
log (Income)	-0.011	0.007	0.001
	(0.030)	(0.048)	(0.034)
Population density	-0.001	0.002	
	(0.002)	(0.003)	
Observations	2,680	2,679	2,679

*Note : Standard errors in parentheses.***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1. Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base*
1 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. TEOF 1 is the base.

Appendix B.3. Testing the significance of an inverted-U relationship (Lind and Mehlum (2010)

Table B-4 : Lind and Mehlum test results (2010)

	Proportion		**Probability**	
	Lower bound	Upper bound	Lower bound	Upper bound
Interval	1.09	7.167	1.0986	7.16
Slope	0.34	-0.402	0.66	-0.37
t-value	2.67	-2.36	4.56	-1.89
p>|t|	0.003	0.008	2.57.e-06	0.028
Overall test of inverse U shape				
t-value	2.37		1.90	
p>|t|	0.008		0.028	
95 % Fieller interval	[3.23 ; 5.15]		[4.29 ; 7.35]	

Appendix B.4. Models with logarithmic transformations on the explanatory variables (Benoit, 2011)

Considérons un modèle de régression du type :

$$y_i = \alpha + \log x_i + \varepsilon_i$$

L'interprétation littérale d'un coefficient estimé $\widehat{\beta}$ est que l'augmentation d'une unité de $\log x_i$ implique une augmentation du y_i de $\widehat{\beta}$ unités. Pour obtenir une interprétation en x, cette expression suivante peut être utilisée :

$$\log X + 1 = \log X + \log e = \log\left(Xe\right)$$

En d'autres termes, ajouter 1 au log X revient à multiplier X lui-même par e ≈ 2,72. De cette façon, multiplier X*e équivaut aussi à une augmentation de X de 172 % puisque 100* (2.72-1) =172.

Ainsi en termes d'un changement de X sans transformation logarithmique :

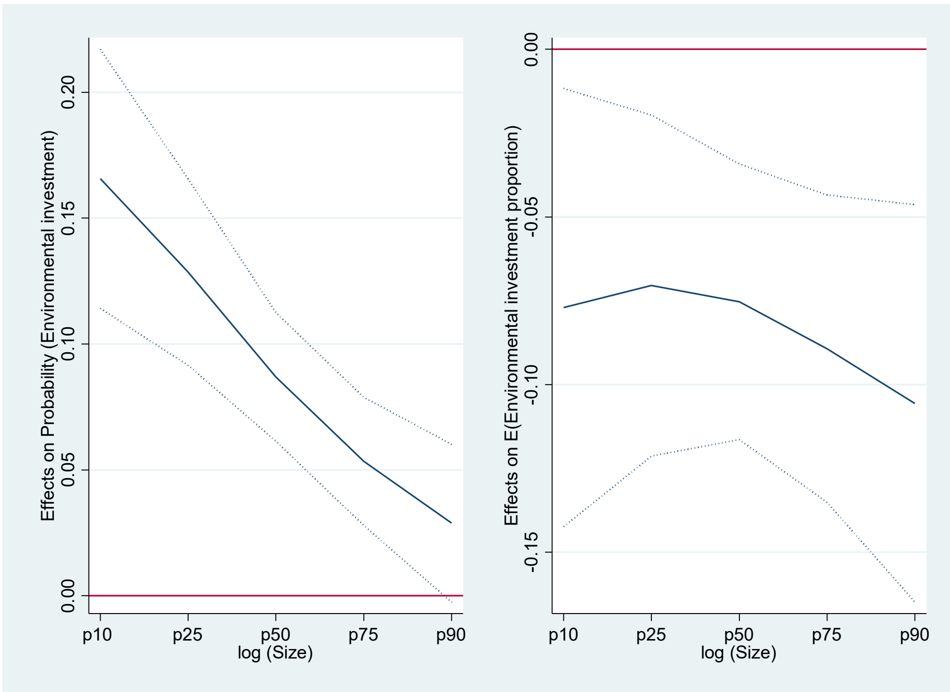
- $\widehat{\beta}$ est le changement espéré en Y lorsque X est multiplié par e
- $\widehat{\beta}$ est le changement espéré en Y lorsque X augmente de 172 %
- De même, pour une augmentation de p % en X, le changement espéré en Y est donnée par

$$\hat{\beta} * \log(100 + p / 100)$$

- Pour de faibles proportion, $\log(100 + p / 100) \approx p / 100$. Par exemple, pour p=1, $\widehat{\beta}$ /100 peut être interprété comme l'augmentation espérée en Y pour 1 % d'augmentation en X.

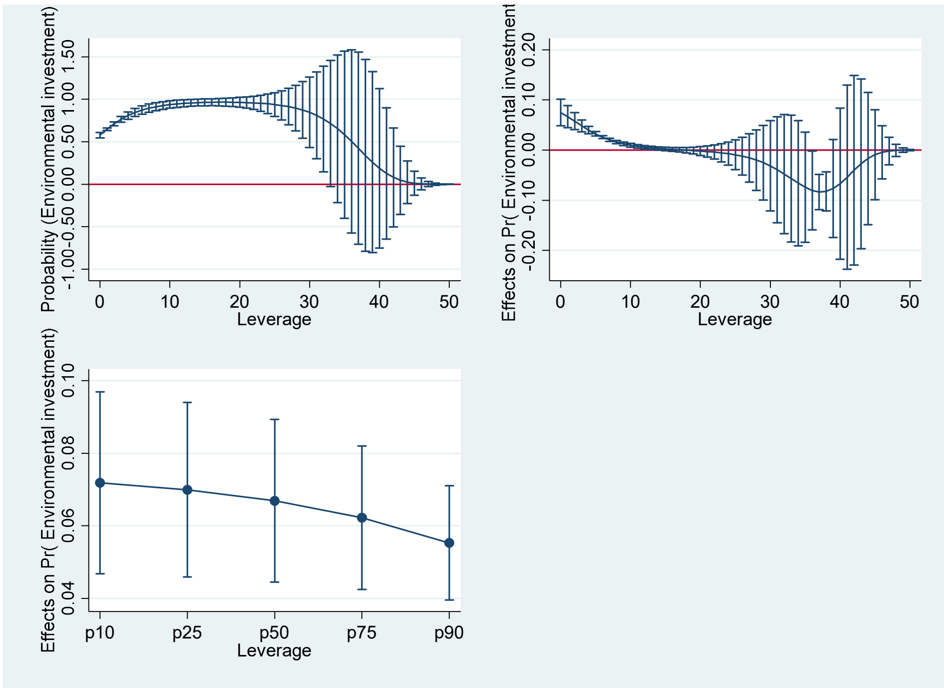
Appendix B.5. Marginal effets on percentiles

Figure B-1 Marginal effect of size on the probability of investment in environmental assets, unconditional effect (90% confidence interval)



Appendix B.6. Marginal effect of financial leverage on the probability of investment in environmental assets (90% confidence interval)

Figure B-2 : Relation entre le levier financier la probabilité d'investissement (Effet marginal, 90 % intervalle de confiance)



Appendix B.7. Tobit and selection model

Table B-5 : Tobit and selection model results

	Tobit	Heckman	
Variables	Environmental proportion	Environmental proportion	Probability
log (Size)	0.322**	0.038	0.874***
	(0.133)	(0.171)	(0.212)
log (Size) × log (Size)	-0.039**	-0.010	-0.087***
	(0.018)	(0.019)	(0.029)
Leverage	0.019	-0.049	0.204***
	(0.021)	(0.033)	(0.042)
Leverage × Leverage	-0.001	0.002	-0.006**
	(0.001)	(0.001)	(0.003)
Dependence	0.080**	0.052**	0.044
	(0.039)	(0.022)	(0.064)
Worker	-0.297	-0.198	-0.329
	(0.212)	(0.132)	(0.338)
Client	0.390**	-0.103	1.685***
	(0.177)	(0.273)	(0.312)
Contact	-0.013	-0.104	0.030
	(0.386)	(0.213)	(0.633)
Employee	-0.037	-0.010	-0.074
	(0.041)	(0.025)	(0.070)
CUMA	0.014	-0.053*	0.149**
	(0.036)	(0.031)	(0.060)
EARL	-0.015	-0.053	0.049
	(0.099)	(0.058)	(0.155)
GAEC	0.190**	0.075	0.183
	(0.086)	(0.064)	(0.133)
log (Age)	-0.150	-0.161***	-0.030
	(0.112)	(0.061)	(0.188)
log (Age) × log (Age)	0.030*	0.026***	0.016
	(0.018)	(0.010)	(0.030)
2.REG	-0.027	-0.025	-0.051
	(0.071)	(0.039)	(0.114)
3.REG	-0.034	0.004	-0.093
	(0.079)	(0.044)	(0.131)
4.REG	-0.083	0.044	-0.281**
	(0.090)	(0.069)	(0.142)
5.REG	0.054	0.041	0.102
	(0.090)	(0.050)	(0.155)

6.REG	0.049	0.021	0.047
	(0.066)	(0.037)	(0.109)
7.REG	-0.034	-0.035	0.013
	(0.069)	(0.037)	(0.113)
8.REG	-0.066	-0.051	-0.053
	(0.085)	(0.047)	(0.136)
9.REG	-0.015	0.013	-0.038
	(0.067)	(0.036)	(0.112)
10.REG	0.048	0.033	-0.037
	(0.086)	(0.046)	(0.139)
Farms density	-7.226***	-1.803	-11.729***
	(2.570)	(2.561)	(4.074)
Usable agricultural area	-0.081	-0.008	-0.170
	(0.110)	(0.064)	(0.184)
Subsidies	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
2.TEOF	-0.088	-0.041	-0.125
	(0.056)	(0.036)	(0.092)
3.TEOF	0.024	-0.051	0.216
	(0.106)	(0.062)	(0.190)
4.TEOF	-0.021	0.129	-0.238
	(0.205)	(0.121)	(0.324)
5.TEOF	0.005	-0.032	0.111
	(0.059)	(0.035)	(0.101)
6.TEOF	-0.004	-0.002	-0.009
	(0.041)	(0.022)	(0.068)
7.TEOF	-0.199*	-0.026	-0.316**
	(0.103)	(0.085)	(0.161)
Cash flow ratio	0.003	-0.034*	0.024
	(0.021)	(0.020)	(0.029)
Turnover	-0.401*	-0.222	-0.580
	(0.233)	(0.168)	(0.359)
Cost of debt	-0.967***	-0.988***	-0.467
	(0.367)	(0.219)	(0.468)
log (Income)	-0.012	-0.005	-0.029
	(0.052)	(0.026)	(0.110)
var(e.penv)	0.547***		
	(0.025)		
Population density			-0.004
			(0.008)
lambda		0.258	
		(0.313)	
Constant	-0.032	0.970	-1.582

	(0.593)	(0.635)	(1.220)
Observations	2,680	2,680	2,680

*Note : Standard errors in parentheses.***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1. Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base*

1 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. TEOF 1 is the base.

Appendix B.8. investment in environmental assets propensity

Table B-6 : Result of the investment in environmental assets probability

	Unrestricted model	Restricted model
Variables	Probability	Probability
log (Size)	0.881***	0.874***
	(0.213)	(0.212)
log (Size)ǀ × log (Size)	-0.087***	-0.087***
	(0.029)	(0.029)
Leverage	0.208***	0.204***
	(0.042)	(0.042)
Leverage × Leverage	-0.006**	-0.006**
	(0.003)	(0.003)
Dependence	0.037	0.044
	(0.064)	(0.064)
worker	-0.338	-0.329
	(0.338)	(0.338)
Client	1.702***	1.685***
	(0.313)	(0.312)
Contact	0.078	0.030
	(0.635)	(0.633)
Employee	-0.076	-0.074
	(0.071)	(0.070)
CUMA	0.144**	0.149**
	(0.060)	(0.060)
EARL	0.044	0.049
	(0.155)	(0.155)
GAEC	0.177	0.183
	(0.133)	(0.133)
log (Age)	-0.024	-0.030
	(0.187)	(0.188)
log (Age) × log (Age)	0.015	0.016
	(0.030)	(0.030)
2.REG	-0.046	-0.051
	(0.115)	(0.114)
3.REG	-0.100	-0.093
	(0.131)	(0.131)
4.REG	-0.259*	-0.281**
	(0.143)	(0.142)
5.REG	0.104	0.102
	(0.156)	(0.155)
6.REG	0.022	0.047
	(0.110)	(0.109)
7.REG	0.020	0.013

	(0.113)	(0.113)
8.REG	-0.050	-0.053
	(0.137)	(0.136)
9.REG	-0.043	-0.038
	(0.112)	(0.112)
10.REG	-0.015	-0.037
	(0.140)	(0.139)
Farms density	78.430	-11.729***
	(110.984)	(4.074)
Usable agricultural area	-0.161	-0.170
	(0.185)	(0.184)
Population density	0.040*	-0.004
	(0.023)	(0.008)
Population density × Population density	-0.000	
	(0.000)	
Population density × Farms density	-2.234**	
	(1.010)	
log (Income)	0.124	-0.029
	(0.270)	(0.110)
Income × Farms density	-8.480	
	(11.074)	
Subsidies	-0.000	-0.000
	(0.000)	(0.000)
2.TEOF	-0.132	-0.125
	(0.093)	(0.092)
3.TEOF	0.223	0.216
	(0.190)	(0.190)
4.TEOF	-0.213	-0.238
	(0.325)	(0.324)
5.TEOF	0.107	0.111
	(0.101)	(0.101)
6.TEOF	-0.008	-0.009
	(0.068)	(0.068)
7.TEOF	-0.318**	-0.316**
	(0.162)	(0.161)
Cash flow ratio	0.022	0.024
	(0.029)	(0.029)
Turnover	-0.583	-0.580
	(0.359)	(0.359)
Cost of debt	-0.468	-0.467
	(0.469)	(0.468)
Constant	-3.234	-1.582
	(2.748)	(1.220)

Observations	2,680	2,680

*Note : Standard errors in parentheses.***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1 Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base*

1 *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. TEOF 1 is the base.*

Appendix B.9. Fractional model by environmental issues

Table B-7 : Results of the generalized fractional model by environmental issues

Variables	SHF	ISHF	NA	INA	FPA	IFPA
log (Size)	-0.077	0.613***	0.598	0.906***	-0.568**	0.363
	(2.295)	(0.231)	(0.382)	(0.243)	(0.272)	(0.227)
log (Size) × log (Size)	0.003	-0.052*	-0.055	-0.072**	0.022	-0.028
	(0.217)	(0.030)	(0.046)	(0.032)	(0.034)	(0.030)
Leverage	-0.081	0.149***	-0.026	0.162***	-0.159***	0.148***
	(0.504)	(0.043)	(0.053)	(0.041)	(0.060)	(0.040)
Leverage × Leverage	0.008	-0.006**	0.001	-0.004**	0.004*	-0.004*
	(0.029)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Dependence	0.054	0.059	0.141**	0.062	0.099	0.107*
	(0.108)	(0.068)	(0.069)	(0.068)	(0.074)	(0.064)
Worker	-0.844*	-0.613	-0.132	0.067	0.219	-0.572
	(0.451)	(0.436)	(0.282)	(0.363)	(0.387)	(0.397)
Client	-0.089	1.107***	0.640*	1.258***	-1.352***	0.908***
	(2.722)	(0.306)	(0.353)	(0.313)	(0.377)	(0.297)
Contact	-0.235	1.091	0.861	0.296	-0.635	-1.001
	(3.092)	(0.679)	(0.705)	(0.704)	(0.807)	(0.659)
Employee	-0.124*	-0.095	0.058	0.052	0.000	-0.065
	(0.074)	(0.071)	(0.065)	(0.068)	(0.075)	(0.067)
CUMA	-0.134	0.056	-0.124**	-0.069	-0.099	0.197***
	(0.436)	(0.062)	(0.062)	(0.063)	(0.084)	(0.060)
EARL	0.077	0.349*	0.025	0.038	-0.491**	-0.126
	(0.757)	(0.201)	(0.202)	(0.197)	(0.216)	(0.170)
GAEC	-0.147	-0.221	0.547**	0.523***	-0.077	0.375**
	(0.518)	(0.167)	(0.232)	(0.200)	(0.253)	(0.157)
log (Age)	-0.279	-0.027	-0.350**	-0.160	-0.265	0.238
	(0.480)	(0.210)	(0.174)	(0.192)	(0.262)	(0.210)
log (Age) × log (Age)	0.043	0.013	0.056**	0.032	0.042	-0.032
	(0.052)	(0.032)	(0.028)	(0.031)	(0.039)	(0.033)
2.REG	0.083	0.001	0.228*	0.103	-0.282*	-0.211*
	(0.216)	(0.127)	(0.119)	(0.120)	(0.158)	(0.118)
3.REG	0.233	0.314**	0.146	-0.074	-0.100	-0.161
	(0.312)	(0.145)	(0.137)	(0.134)	(0.132)	(0.131)
4.REG	0.104	-0.066	0.055	-0.092	0.182	-0.131
	(0.362)	(0.157)	(0.166)	(0.159)	(0.182)	(0.148)
5.REG	-0.050	0.159	0.196	0.115	-0.189	0.264*
	(0.343)	(0.157)	(0.165)	(0.159)	(0.162)	(0.149)
6.REG	0.363	0.365***	-0.085	-0.138	-0.169	0.113
	(0.232)	(0.117)	(0.120)	(0.114)	(0.118)	(0.110)

7.REG	0.270	0.267**	-0.395***	-0.413***	-0.050	-0.094
	(0.193)	(0.123)	(0.121)	(0.124)	(0.129)	(0.114)
8.REG	0.411	0.495***	-0.277*	-0.344**	-0.078	-0.550***
	(0.433)	(0.144)	(0.156)	(0.157)	(0.271)	(0.154)
9.REG	0.263	0.234**	-0.118	-0.192*	0.006	0.071
	(0.195)	(0.117)	(0.120)	(0.116)	(0.119)	(0.110)
10.REG	0.360	0.366**	0.014	-0.242	0.078	-0.220
	(0.221)	(0.152)	(0.160)	(0.154)	(0.190)	(0.146)
Farms density	-11.185	-6.445	2.622	-2.127	-1.100	-10.223**
	(10.772)	(4.741)	(4.686)	(4.606)	(6.983)	(4.609)
Usable agricultural area	0.229	0.373*	-0.215	-0.304	0.387*	-0.290
	(0.846)	(0.195)	(0.217)	(0.199)	(0.215)	(0.181)
Population density		0.005		-0.002		0.003
		(0.025)		(0.006)		(0.009)
Subsidies	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2.TEOF	0.216	0.082	-0.378***	-0.325***	0.032	-0.158*
	(0.276)	(0.106)	(0.100)	(0.102)	(0.107)	(0.095)
3.TEOF	0.060	0.290	-0.039	-0.085	-0.144	-0.047
	(0.374)	(0.181)	(0.176)	(0.194)	(0.174)	(0.183)
4.TEOF	0.569	-0.276	0.055	-0.052	0.540	-0.505
	(2.644)	(0.400)	(0.341)	(0.354)	(0.356)	(0.369)
5.TEOF	0.083	0.101	-0.225**	-0.044	-0.027	0.155
	(0.183)	(0.113)	(0.094)	(0.101)	(0.098)	(0.097)
6.TEOF	0.145	0.156*	-0.129*	-0.082	0.039	-0.070
	(0.149)	(0.080)	(0.067)	(0.071)	(0.072)	(0.069)
7.TEOF	0.222	-0.002	-0.686***	-0.541**	0.382	-0.326*
	(0.714)	(0.188)	(0.240)	(0.224)	(0.271)	(0.188)
Cash flow ratio	-0.222	-0.032	0.079	0.065	-0.159*	0.027
	(0.456)	(0.042)	(0.051)	(0.041)	(0.082)	(0.026)
Turnover	-0.823	-0.560	-2.361***	-2.283***	0.508*	0.231
	(0.882)	(0.377)	(0.685)	(0.564)	(0.266)	(0.360)
Cost of debt	-3.284	-0.552	-0.077	0.450***	-5.076***	-0.582
	(3.728)	(0.594)	(0.714)	(0.110)	(0.934)	(0.522)
log (Income)	-0.049	0.017	0.140	0.190*	-0.148*	0.076
	(0.121)	(0.248)	(0.102)	(0.107)	(0.076)	(0.123)
Constant	0.429	-3.084	-3.585***	-4.906***	4.576***	-2.735**
	(10.984)	(2.431)	(1.354)	(1.232)	(1.397)	(1.353)
atanhrho_12	1.220		2.605		-0.064	
	(5.805)		(1.620)		(0.424)	
Observations	2,680	2,680	2,680	2,680	2,680	2,680

*Note : Robust standard errors in parentheses..***,**,* means the estimated coefficient is statistically significant at* $p<0.01$, $p<0.05$, $p<0.1$. *Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base*

Table B-8 : Control variables marginal effects

	Probability			Conditional effect			Unconditional effect		
Variables	SHF	NA	FPA	SHF	NA	FPA	SHF	NA	FPA
log (Size)	0.080***	0.111***	0.056***	-0.216	-0.095	-0.408***	-0.071	-0.002	-0.138***
	(0.016)	(0.014)	(0.016)	(0.803)	(0.079)	(0.067)	(0.103)	(0.012)	(0.021)
Leverage	0.044***	0.043***	0.047***	-0.146	-0.137***	-0.143***	-0.049	-0.025***	-0.053***
	(0.012)	(0.010)	(0.012)	(0.442)	(0.039)	(0.055)	(0.072)	(0.009)	(0.017)
Dependence	0.019	0.017	0.036*	0.017	0.094**	0.104	0.001	0.024**	0.030
	(0.022)	(0.019)	(0.021)	(0.112)	(0.046)	(0.074)	(0.018)	(0.010)	(0.022)
Worker	-0.199	0.019	-0.194	-0.463	-0.183	0.192	-0.094	-0.040	0.085
	(0.141)	(0.103)	(0.135)	(0.372)	(0.176)	(0.386)	(0.237)	(0.040)	(0.117)
Client	0.359***	0.359***	0.309***	-0.778	-0.316	-1.310***	-0.294	-0.016	-0.475***
	(0.099)	(0.089)	(0.100)	(2.684)	(0.315)	(0.376)	(0.331)	(0.066)	(0.117)
Contact	0.354	0.084	-0.340	-0.913	0.636	-0.681	-0.332	0.162	-0.197
	(0.220)	(0.201)	(0.224)	(2.947)	(0.415)	(0.810)	(0.422)	(0.104)	(0.253)
Employee	-0.031	0.015	-0.022	-0.064	0.018	-0.003	-0.012	0.007	0.001
	(0.023)	(0.019)	(0.023)	(0.065)	(0.042)	(0.075)	(0.049)	(0.010)	(0.025)
CUMA	0.018	-0.020	0.068***	-0.170	-0.072**	-0.090	-0.052	-0.020**	-0.037
	(0.020)	(0.018)	(0.021)	(0.442)	(0.035)	(0.084)	(0.105)	(0.009)	(0.024)
EARL	0.102**	0.011	-0.043	-0.147	-0.005	-0.497**	-0.049	0.001	-0.185**
	(0.052)	(0.055)	(0.060)	(0.746)	(0.086)	(0.215)	(0.040)	(0.024)	(0.082)
GAEC	-0.075	0.123***	0.118***	-0.013	0.134	-0.059	0.010	0.034**	-0.026
	(0.059)	(0.037)	(0.045)	(0.563)	(0.120)	(0.253)	(0.117)	(0.015)	(0.057)
log (Age)	0.022	0.019	0.004	-0.015	-0.001	0.034	-0.008	0.004	0.013
	(0.019)	(0.017)	(0.019)	(0.155)	(0.030)	(0.056)	(0.022)	(0.008)	(0.019)
2.REG	0.000	0.033	-0.071*	0.082	0.152**	-0.292*	0.018	0.050**	-0.081*
	(0.036)	(0.038)	(0.040)	(0.200)	(0.065)	(0.158)	(0.046)	(0.021)	(0.048)

3.REG	0.100**	-0.023	-0.055		0.036	0.202**	-0.108		-0.016	0.048*	-0.031
	(0.046)	(0.041)	(0.045)		(0.274)	(0.089)	(0.132)		(0.066)	(0.025)	(0.043)
4.REG	-0.018	-0.028	-0.045		0.147	0.123	0.176		0.035	0.027	0.056
	(0.044)	(0.048)	(0.051)		(0.349)	(0.105)	(0.182)		(0.051)	(0.029)	(0.059)
Table A-8 (Continued)											
5.REG	0.048	0.037	0.097*		-0.152	0.112	-0.178		-0.054	0.038	-0.082
	(0.048)	(0.051)	(0.055)		(0.316)	(0.117)	(0.162)		(0.041)	(0.036)	(0.061)
6.REG	0.117***	-0.041	0.041		0.135	0.018	-0.164		0.013	0.000	-0.066
	(0.037)	(0.034)	(0.040)		(0.215)	(0.090)	(0.118)		(0.101)	(0.022)	(0.043)
7.REG	0.083**	-0.112***	-0.033		0.101	-0.077	-0.054		0.008	-0.022	-0.017
	(0.038)	(0.033)	(0.040)		(0.162)	(0.070)	(0.128)		(0.082)	(0.016)	(0.044)
8.REG	0.164***	-0.095**	-0.170***		0.105	-0.014	-0.104		-0.004	-0.011	-0.012
	(0.049)	(0.041)	(0.044)		(0.411)	(0.084)	(0.271)		(0.085)	(0.018)	(0.061)
9.REG	0.072**	-0.056	0.025		0.114	0.027	0.010		0.013	0.001	0.003
	(0.036)	(0.034)	(0.039)		(0.185)	(0.080)	(0.119)		(0.058)	(0.020)	(0.042)
10.REG	0.118**	-0.070	-0.075		0.131	0.198**	0.068		0.012	0.033	0.022
	(0.050)	(0.043)	(0.049)		(0.181)	(0.089)	(0.190)		(0.127)	(0.024)	(0.058)
Farms density	-2.092	-0.606	-3.474**		-7.176	4.237**	-1.566		-1.655	0.892	-0.182
	(1.539)	(1.313)	(1.565)		(11.548)	(2.153)	(6.959)		(5.911)	(0.609)	(2.179)
Usable agricultural area	0.121*	-0.087	-0.098		-0.003	0.016	0.373*		-0.025	-0.010	0.136*
	(0.063)	(0.057)	(0.061)		(0.872)	(0.167)	(0.216)		(0.112)	(0.041)	(0.070)
Subsidies	-0.000	-0.000	0.000		-0.000	0.000	-0.000		-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)		(0.000)	(0.000)	(0.000)
2.TEOF	0.026	-0.089***	-0.053*		0.165	-0.128**	0.024		0.040	-0.042***	0.014
	(0.034)	(0.027)	(0.032)		(0.242)	(0.059)	(0.106)		(0.098)	(0.014)	(0.033)
3.TEOF	0.097	-0.025	-0.016		-0.118	0.025	-0.147		-0.066	-0.000	-0.047
	(0.064)	(0.056)	(0.062)		(0.347)	(0.077)	(0.174)		(0.057)	(0.025)	(0.060)
4.TEOF	-0.077	-0.016	-0.155		0.748	0.094	0.516		0.155	0.019	0.122

	(0.101)	(0.104)	(0.097)		(2.637)	(0.208)	(0.355)		(0.376)	(0.062)	(0.082)
5.TEOF	0.032	-0.013	0.055		0.020	-0.192***	-0.020		-0.002	-0.051***	-0.014
	(0.036)	(0.030)	(0.035)		(0.202)	(0.058)	(0.098)		(0.029)	(0.015)	(0.035)
6.TEOF	0.050**	-0.024	-0.024		0.048	-0.068*	0.036		0.002	-0.022**	0.015
	(0.025)	(0.021)	(0.024)		(0.164)	(0.036)	(0.072)		(0.023)	(0.011)	(0.025)
7.TEOF	-0.001	-0.136***	-0.105*		0.223	-0.263**	0.366		0.057		0.104
	(0.058)	(0.046)	(0.057)		(0.744)	(0.134)	(0.270)		(0.189)		(0.071)
Cash flow ratio	-0.011	0.018	0.009		-0.202	0.030	-0.157*		-0.056	0.010	-0.054*
	(0.014)	(0.012)	(0.009)		(0.457)	(0.038)	(0.083)		(0.145)	(0.009)	(0.028)
Turnover	-0.182	-0.651***	0.078		-0.475	-0.628	0.518**		-0.101	-0.251**	0.168*
	(0.122)	(0.160)	(0.122)		(0.837)	(0.411)	(0.264)		(0.209)	(0.109)	(0.090)
Cost of Debt	-0.179	0.128***	-0.198		-2.940	-0.418	-5.103***		-0.811	-0.077	-1.710***
	(0.193)	(0.031)	(0.177)		(3.499)	(0.710)	(0.941)		(1.203)	(0.164)	(0.298)
log (Income)	0.006	0.054*	0.026		-0.060	-0.005	-0.145*		-0.018	0.008	-0.052**
	(0.080)	(0.030)	(0.042)		(0.127)	(0.070)	(0.077)		(0.054)	(0.017)	(0.025)
Population density	0.002	-0.000	0.001		-0.003	0.001	0.000		-0.001	0.000	-0.000
	(0.008)	(0.002)	(0.003)		(0.016)	(0.005)	(0.000)		(0.008)	(0.001)	(0.000)
Observations	2,680	2,680	2,680		2,678	2,680	2,679		2,678	2,680	2,679

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at $p<0.01$, $p<0.05$, $p<0.1$ Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.*
1 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. TEOF 1 is the base.

Appendix B.10. Additional exclusion variables

Table B-9 : Additional exclusion variables

Variables	SHF	ISHF	NA	INA	FPA	IFPA
log (Size)	0.075	0.621***	0.612	0.908***	-0.629**	0.363
	(0.310)	(0.231)	(0.421)	(0.243)	(0.250)	(0.227)
log (Size) × log (Size)	-0.012	-0.053*	-0.056	-0.072**	0.029	-0.028
	(0.041)	(0.031)	(0.051)	(0.032)	(0.033)	(0.030)
Leverage	-0.049	0.148***	-0.023	0.162***	-0.191***	0.148***
	(0.052)	(0.040)	(0.058)	(0.041)	(0.053)	(0.040)
Leverage × Leverage	0.006*	-0.006***	0.001	-0.004**	0.005**	-0.004*
	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Dependence	0.058	0.050	0.141**	0.063	0.056	0.106*
	(0.069)	(0.065)	(0.069)	(0.068)	(0.095)	(0.064)
Worker	-0.831*	-0.609	-0.139	0.060	0.392	-0.577
	(0.430)	(0.426)	(0.284)	(0.364)	(0.411)	(0.397)
Client	0.073	1.116***	0.653*	1.259***	-1.509***	0.916***
	(0.343)	(0.302)	(0.357)	(0.312)	(0.298)	(0.297)
Contact	-0.137	1.194*	0.878	0.292	-0.236	-0.999
	(0.731)	(0.650)	(0.720)	(0.704)	(0.917)	(0.659)
Employee	-0.126*	-0.104	0.057	0.055	0.020	-0.064
	(0.072)	(0.069)	(0.065)	(0.068)	(0.074)	(0.068)
CUMA	-0.104*	0.051	-0.122*	-0.070	-0.153*	0.196***
	(0.063)	(0.061)	(0.063)	(0.063)	(0.086)	(0.060)
EARL	0.119	0.349*	0.020	0.036	-0.402	-0.128
	(0.234)	(0.202)	(0.201)	(0.197)	(0.275)	(0.170)
GAEC	-0.186	-0.214	0.550**	0.524***	-0.196	0.368**
	(0.155)	(0.141)	(0.230)	(0.201)	(0.269)	(0.157)
log (Age)	-0.241	-0.031	-0.348**	-0.160	-0.318	0.236
	(0.162)	(0.188)	(0.174)	(0.192)	(0.232)	(0.210)
log (Age) × log (Age)	0.039	0.014	0.056**	0.032	0.049	-0.031
	(0.027)	(0.030)	(0.028)	(0.031)	(0.035)	(0.033)
2.REG	0.071	0.000	0.226*	0.106	-0.186	-0.206*
	(0.146)	(0.127)	(0.119)	(0.120)	(0.217)	(0.119)
3.REG	0.242*	0.310**	0.142	-0.073	-0.039	-0.163
	(0.135)	(0.138)	(0.141)	(0.134)	(0.153)	(0.131)
4.REG	0.090	-0.035	0.049	-0.090	0.211	-0.127
	(0.168)	(0.157)	(0.168)	(0.160)	(0.172)	(0.149)
5.REG	-0.038	0.153	0.193	0.126	-0.250	0.267*
	(0.164)	(0.155)	(0.176)	(0.160)	(0.158)	(0.150)
6.REG	0.369***	0.333***	-0.086	-0.133	-0.189*	0.109
	(0.118)	(0.117)	(0.128)	(0.114)	(0.111)	(0.111)
7.REG	0.278**	0.275**	-0.398***	-0.410***	-0.014	-0.092
	(0.123)	(0.119)	(0.123)	(0.124)	(0.134)	(0.114)

8.REG	0.434***	0.499***	-0.275*	-0.341**	0.117	-0.551***
	(0.136)	(0.141)	(0.155)	(0.157)	(0.332)	(0.155)
9.REG	0.272**	0.225*	-0.122	-0.191	-0.015	0.070
	(0.126)	(0.116)	(0.123)	(0.116)	(0.119)	(0.111)
10.REG	0.375**	0.379***	0.010	-0.232	0.143	-0.210
	(0.155)	(0.146)	(0.169)	(0.155)	(0.189)	(0.146)
Farms density	-9.871*	153.993*	2.393	55.087	2.316	-11.130
	(5.574)	(85.144)	(4.755)	(62.854)	(8.247)	(153.274)
Usable agricultural area	0.276	0.394**	-0.208	-0.314	0.445**	-0.290
	(0.221)	(0.189)	(0.238)	(0.202)	(0.196)	(0.181)
Population density		0.062***		-0.002		0.014
		(0.019)		(0.015)		(0.023)
Population density × Population density		-0.000**		0.000		0.000
		(0.000)		(0.000)		(0.000)
Population density × Farms density		-2.430***		-0.167		-0.722
		(0.894)		(0.610)		(1.086)
Subsidies	-0.000	-0.000	-0.000	-0.000	-0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2.TEOF	0.201**	0.070	-0.375***	-0.326***	0.076	-0.158*
	(0.097)	(0.096)	(0.105)	(0.102)	(0.113)	(0.095)
3.TEOF	0.074	0.293	-0.038	-0.082	-0.117	-0.040
	(0.165)	(0.179)	(0.178)	(0.194)	(0.178)	(0.183)
4.TEOF	0.412	-0.275	0.069	-0.072	0.647*	-0.502
	(0.413)	(0.399)	(0.330)	(0.338)	(0.332)	(0.369)
5.TEOF	0.100	0.095	-0.224**	-0.045	-0.073	0.153
	(0.100)	(0.100)	(0.094)	(0.101)	(0.108)	(0.097)
6.TEOF	0.157**	0.149**	-0.129*	-0.082	0.056	-0.069
	(0.074)	(0.070)	(0.068)	(0.071)	(0.070)	(0.069)
7.TEOF	0.187	-0.008	-0.677***	-0.535**	0.448*	-0.323*
	(0.188)	(0.178)	(0.250)	(0.224)	(0.250)	(0.188)
Cash flow ratio	-0.188**	-0.035	0.078	0.064	-0.152*	0.026
	(0.081)	(0.042)	(0.052)	(0.041)	(0.081)	(0.026)
Turnover	-0.845	-0.568	-2.371***	-2.292***	0.399	0.239
	(0.736)	(0.378)	(0.682)	(0.564)	(0.317)	(0.362)
Cost of Debt	-3.058***	-0.525	-0.040	0.451***	-4.369**	-0.558
	(1.009)	(0.491)	(0.728)	(0.110)	(1.888)	(0.518)
log (Income)	-0.082	0.265	0.149	0.360*	-0.154**	0.075
	(0.106)	(0.193)	(0.102)	(0.197)	(0.064)	(0.347)
Income × Farms density		-15.567*		-5.756		0.314
		(8.456)		(6.265)		(15.397)
Constant	0.092	-5.674***	-3.719***	-6.592***	5.310***	-2.755
	(1.248)	(2.017)	(1.366)	(2.002)	(1.146)	(3.492)
atanhrho_12	1.720***		2.734		-0.555	
	(0.537)		(2.296)		(0.795)	

Observations	2,680	2,680	2,680	2,680	2,680	2,680

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1 Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.*

1 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. TEOF 1 is the base.

Table B-10 : Control variables marginal effet

	Unrestricted	restricted	Unrestricted	restricted	Unrestricted	restricted
	Probability				Conditional effect	
Variables	ISHF	ISHF	INA	INA	FPA	FPA
log (Size)	0.081***	0.080***	0.111***	0.111***	-0.368***	-0.408***
	(0.015)	(0.016)	(0.014)	(0.014)	(0.055)	(0.067)
Leverage	0.043***	0.044***	0.043***	0.043***	-0.129***	-0.143***
	(0.011)	(0.012)	(0.010)	(0.010)	(0.048)	(0.055)
Dependence	0.016	0.019	0.018	0.017	0.095	0.104
	(0.021)	(0.022)	(0.019)	(0.019)	(0.092)	(0.074)
Worker	-0.197	-0.199	0.017	0.019	0.184	0.192
	(0.138)	(0.141)	(0.104)	(0.103)	(0.376)	(0.386)
Client	0.362***	0.359***	0.359***	0.359***	-1.179***	-1.310***
	(0.097)	(0.099)	(0.088)	(0.089)	(0.277)	(0.376)
Contact	0.387*	0.354	0.083	0.084	-0.596	-0.681
	(0.210)	(0.220)	(0.201)	(0.201)	(0.903)	(0.810)
Employee	-0.034	-0.031	0.016	0.015	-0.003	-0.003
	(0.022)	(0.023)	(0.019)	(0.019)	(0.071)	(0.075)
CUMA	0.017	0.018	-0.020	-0.020	-0.082	-0.090
	(0.020)	(0.020)	(0.018)	(0.018)	(0.084)	(0.084)
EARL	0.102*	0.102**	0.010	0.011	-0.448*	-0.497**
	(0.052)	(0.052)	(0.055)	(0.055)	(0.268)	(0.215)
GAEC	-0.073	-0.075	0.123***	0.123***	-0.059	-0.059
	(0.049)	(0.059)	(0.037)	(0.037)	(0.266)	(0.253)
log (Age)	0.021	0.022	0.019	0.019	0.033	0.034
	(0.018)	(0.019)	(0.017)	(0.017)	(0.052)	(0.056)
2.REG	0.000	0.000	0.034	0.033	-0.261	-0.292*
	(0.036)	(0.036)	(0.038)	(0.038)	(0.213)	(0.158)
3.REG	0.098**	0.100**	-0.022	-0.023	-0.099	-0.108
	(0.044)	(0.046)	(0.041)	(0.041)	(0.144)	(0.132)
4.REG	-0.010	-0.018	-0.027	-0.028	0.165	0.176
	(0.044)	(0.044)	(0.048)	(0.048)	(0.163)	(0.182)
5.REG	0.046	0.048	0.040	0.037	-0.158	-0.178
	(0.048)	(0.048)	(0.052)	(0.051)	(0.149)	(0.162)
6.REG	0.106***	0.117***	-0.040	-0.041	-0.151	-0.164
	(0.037)	(0.037)	(0.034)	(0.034)	(0.104)	(0.118)
7.REG	0.086**	0.083**	-0.111***	-0.112***	-0.047	-0.054
	(0.037)	(0.038)	(0.033)	(0.033)	(0.126)	(0.128)
8.REG	0.166***	0.164***	-0.094**	-0.095**	-0.091	-0.104
	(0.048)	(0.049)	(0.041)	(0.041)	(0.325)	(0.271)
9.REG	0.070**	0.072**	-0.056	-0.056	0.009	0.010
	(0.035)	(0.036)	(0.034)	(0.034)	(0.111)	(0.119)

10.REG	0.122**	0.118**	-0.067	-0.070	0.066	0.068
	(0.048)	(0.050)	(0.043)	(0.043)	(0.181)	(0.190)
Farms density	-1.752	-2.092	-0.655	-0.606	-1.164	-1.566
	(1.347)	(1.539)	(1.333)	(1.313)	(8.094)	(6.959)
Usable agricultural area	0.128**	0.121*	-0.090	-0.087	0.340*	0.373*
	(0.061)	(0.063)	(0.057)	(0.057)	(0.186)	(0.216)
Subsidies	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
2.TEOF	0.022	0.026	-0.089***	-0.089***	0.019	0.024
	(0.030)	(0.034)	(0.027)	(0.027)	(0.106)	(0.106)
3.TEOF	0.098	0.097	-0.024	-0.025	-0.131	-0.147
	(0.063)	(0.064)	(0.056)	(0.056)	(0.167)	(0.174)
4.TEOF	-0.077	-0.077	-0.021	-0.016	0.457	0.516
	(0.101)	(0.101)	(0.099)	(0.104)	(0.297)	(0.355)
5.TEOF	0.030	0.032	-0.014	-0.013	-0.020	-0.020
	(0.032)	(0.036)	(0.030)	(0.030)	(0.105)	(0.098)
6.TEOF	0.048**	0.050**	-0.024	-0.024	0.031	0.036
	(0.022)	(0.025)	(0.021)	(0.021)	(0.065)	(0.072)
7.TEOF	-0.002	-0.001	-0.135***	-0.136***	0.328	0.366
	(0.055)	(0.058)	(0.046)	(0.046)	(0.238)	(0.270)
Cash flow ratio	-0.011	-0.011	0.018	0.018	-0.142*	-0.157*
	(0.014)	(0.014)	(0.012)	(0.012)	(0.081)	(0.083)
Turnover	-0.184	-0.182	-0.653***	-0.651***	0.485*	0.518**
	(0.122)	(0.122)	(0.160)	(0.160)	(0.287)	(0.264)
Cost of debt	-0.170	-0.179	0.129***	0.128***	-4.570**	-5.103***
	(0.159)	(0.193)	(0.031)	(0.031)	(1.931)	(0.941)
log (Income)	-0.003	0.006	0.073**	0.054*	-0.125	-0.145*
	(0.037)	(0.080)	(0.036)	(0.030)	(0.078)	(0.077)
Population density	0.006*	0.002	-0.001	-0.000	0.000	0.000
	(0.003)	(0.008)	(0.002)	(0.002)	(0.004)	(0.000)
Observations	2,680	2,680	2,680	2,680	2,679	2,679

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1 Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.*

1 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. TEOF 1 is the base.

Appendix B.11. Estimate on sub sample

Table B-11 : Estimate results (renewal)

Variables	Probability	Environmental investment proportion
log (Size)	0.673***	0.151
	(0.235)	(0.464)
log (Size) × log (Size)	-0.054*	-0.022
	(0.031)	(0.048)
Leverage	0.201**	-0.068
	(0.083)	(0.130)
Leverage × Leverage	-0.034*	-0.003
	(0.018)	(0.021)
Dependence	0.175***	0.188***
	(0.067)	(0.067)
Worker	0.004	0.096
	(0.334)	(0.305)
Client	2.077***	0.823
	(0.325)	(0.723)
Contact	1.147*	-0.103
	(0.665)	(0.817)
Employee	-0.134**	-0.097
	(0.068)	(0.071)
CUMA	0.084	-0.023
	(0.062)	(0.087)
EARL	-0.092	-0.266
	(0.183)	(0.255)
GAEC	0.356**	0.160
	(0.176)	(0.240)
Log (Age)	0.802**	0.513
	(0.395)	(0.427)
log (Age) × log (Age)	-0.120**	-0.079
	(0.058)	(0.063)
2.REG	0.148	0.213
	(0.126)	(0.142)
3.REG	0.221	0.206
	(0.137)	(0.130)
4.REG	0.154	0.346
	(0.155)	(0.233)
5.REG	0.444***	0.330**
	(0.153)	(0.159)
6.REG	0.800***	0.564***
	(0.113)	(0.155)

7.REG	0.305***	0.125
	(0.116)	(0.140)
8.REG	-0.323*	-0.212
	(0.173)	(0.254)
9.REG	0.258**	0.260**
	(0.115)	(0.116)
10.REG	0.073	0.067
	(0.156)	(0.158)
Farms density	1.238	0.152
	(4.725)	(5.442)
Usable agricultural area	0.194	0.271
	(0.185)	(0.182)
Population density	0.001	
	(0.007)	
Subsidies	-0.000**	-0.000
	(0.000)	(0.000)
2.TEOF	-0.060	-0.004
	(0.098)	(0.094)
3.TEOF	0.055	-0.011
	(0.176)	(0.173)
4.TEOF	0.036	0.035
	(0.359)	(0.366)
5.TEOF	0.345***	0.146
	(0.097)	(0.116)
6.TEOF	0.144**	0.108
	(0.070)	(0.069)
7.TEOF	-0.953***	-0.824**
	(0.277)	(0.321)
Cash flow ratio	0.064*	0.085
	(0.035)	(0.080)
Turnover	-0.400	-0.574
	(0.357)	(0.668)
Cost of debt	0.061	-2.136
	(0.087)	(1.369)
log (Income)	-0.006	-0.038
	(0.097)	(0.109)
Constant	-4.719***	-1.942
	(1.253)	(2.374)
atanhrho_12		1.660
		(1.379)
Observations	2,680	2,680

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at $p<0.01$, $p<0.05$, $p<0.1$ Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.*
1 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. TEOF 1 is the base.

Table B-12 : Variables marginal effect

Variables	Probability
log (Size)	0.093***
	(0.015)
Leverage	0.038**
	(0.015)
Dependence	0.055***
	(0.021)
Worker	0.001
	(0.107)
Client	0.664***
	(0.101)
Contact	0.367*
	(0.212)
Employee	-0.043**
	(0.022)
CUMA	0.027
	(0.020)
EARL	-0.030
	(0.060)
GAEC	0.105**
	(0.047)
log (Age)	-0.018
	(0.018)
2.REG	0.045
	(0.038)
3.REG	0.068
	(0.042)
4.REG	0.046
	(0.047)
5.REG	0.144***
	(0.051)
6.REG	0.273***
	(0.037)
7.REG	0.096***
	(0.036)
8.REG	-0.082**
	(0.041)
9.REG	0.080**
	(0.035)

10.REG	0.022
	(0.046)
Farms density	0.396
	(1.511)
Usable agricultural area	0.062
	(0.059)
Subsidies	-0.000**
	(0.000)
2.TEOF	-0.018
	(0.030)
3.TEOF	0.017
	(0.056)
4.TEOF	0.011
	(0.114)
5.TEOF	0.116***
	(0.033)
6.TEOF	0.047**
	(0.022)
7.TEOF	-0.212***
	(0.040)
Cash flow ratio	0.020*
	(0.011)
Turnover	-0.128
	(0.114)
Cost of debt	0.020
	(0.028)
log (Income)	-0.002
	(0.031)
Population density	0.000
	(0.002)
Observations	2,680

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at $p<0.01$, $p<0.05$, $p<0.1$ Region 1 = Auvergne-Rhône-Alpes ; Region 2= Bourgogne-Franche-Comté ; Region 3= Bretagne ; Region 4 = Centre-Val de Loire ; Region 5 =Nord-Pas-de-Calais-Picardie ; Region 6 = Normandie ; Region 7 = Nouvelle Aquitaine ; Region n 8 = Occitanie ; Region 9 = Pays de la Loire ; Region 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.*

1 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. TEOF 1 is the base.

Appendix.C

Appendix C.1. Almost homogeneity condition

Followin Cuesta and Zofio (2009), assuming that $F\left(x, I, y\right)$ is continuously differentiable, to be almost homogenous , it must satisfy :

$$k_1 \sum_{n=1}^{N} \frac{\partial F}{\partial x_n} x_n + k_2 \sum_{h=1}^{H} \frac{\partial F}{\partial I_h} I_h + k_3 \sum_{g=1}^{G} \frac{\partial F}{\partial y_g} y_g = k_4 F$$

Dividing by F and noting that

$$\frac{\partial F}{\partial x_n} \frac{x_n}{F} = \frac{\partial \ln F}{\partial \ln x_n};$$

$$\frac{\partial F}{\partial I_n} \frac{I_h}{F} = \frac{\partial \ln F}{\partial \ln I_n} \text{ and}$$

$$\frac{\partial F}{\partial y_g} \frac{y_g}{F} = \frac{\partial \ln F}{\partial \ln y_g}$$

we obtain the following expression considering that our enhanced hyperbolic distance function is homogenous of degree (-1,1,1,1) :

$$-\sum_{n=1}^{N} \frac{\partial \ln F}{\partial \ln x_n} + \sum_{h=1}^{H} \frac{\partial \ln F}{\partial \ln I_h} + \sum_{g=1}^{G} \frac{\partial \ln F}{\partial \ln y_g} = 1$$

Using our functional form, we obtain the following expression:

$$-\sum_{n} \beta_n + \sum_{g} \alpha_g + \sum_{h} \beta_h = 1$$

Appendix C.2. Instrumental variable approach (Karakaplan & Kutlu, 2017)

To solve the endogeneity problem in stochastic frontier model, Karakaplan and Kutlu (2017) considered the following expressions :

$$y_{it} = \boldsymbol{x1'_{it}\beta} + v_{it} - u_{it}$$
$$u_{it} = \boldsymbol{h}\left(\boldsymbol{r'_{it}\delta}\right)\boldsymbol{u_i^*}$$
$$\boldsymbol{x3_{it}} = \boldsymbol{R_{it}\gamma} + \boldsymbol{\varepsilon_{it}}$$

Where $x1_{it}$ is a vector of explanatory variables ; u_{it} captures inefficiency ; $x2_{it}$ captures both endogenous and exogenous variables ; $x3_{it}$ a column vector of endogenous variables. R_{it} a vector of instruments and other variables. $u_i^* \sim N\left(\mu, \sigma_u^2\right)$. We further assume that:

$$\begin{bmatrix} \tilde{\boldsymbol{\varepsilon}}_{\boldsymbol{it}} \\ v_{it} \end{bmatrix} = \begin{bmatrix} \boldsymbol{\Omega}^{-1/2}\boldsymbol{\varepsilon_{it}} \\ v_{it} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} I_m & \sigma_v \boldsymbol{\rho} \\ \sigma_v \boldsymbol{\rho}' & \sigma_v^2 \end{bmatrix}\right),$$

where Ω is the covariance -variance matrix of ε_{it} ; ρ the correlation between $\tilde{\varepsilon}_{it}$ and v_{it} ; σ_v^2 the variance of v_{it} .

By Cholesky decomposition, of the covariance variance matrix of $\left(\tilde{\varepsilon}_{it}, v_{it}\right)'$, it can be expressed by $\begin{bmatrix} \tilde{\varepsilon}_{it} \\ v_{it} \end{bmatrix} = \begin{pmatrix} I_m & 0 \\ \sigma_v \rho' & \sigma_v \sqrt{1-\rho'\rho} \end{pmatrix} \begin{bmatrix} \tilde{\varepsilon}_{it} \\ \tilde{w}_{it} \end{bmatrix}$. Both $\tilde{\varepsilon}_{it}$ and $\tilde{w}_{it}$ follow a standard normal distribution. Thus, the frontier equation can be expressed as :

$$y_{it} = x1'_{it}\beta + \sigma_v \rho' \tilde{\varepsilon}_{it} + w_{it} - u_{it}$$
$$y_{it} = x1'_{it}\beta + \left(x3_{it} - R_{it}\gamma\right)'\eta + e_{it}$$

Where: $e_{it} = w_{it} - u_{it}; w_{it} = \sigma_v \sqrt{1-\rho'\rho}\,\tilde{w}_{it}$ and $\eta = \sigma_w \Omega^{\frac{-1}{2}} \rho \Big/ \sqrt{1-\rho\rho'}$ The term $\left(x3_{it} - R_{it}\gamma\right)'\eta$ represents the bias correction.

The maximum likelihood function can be used to estimate the parameters, and for each panel i, the log-likelihood function is

$$\ln L_i = \ln L_{i,y|x3} + \ln L_{i,x3}$$

$$\ln L_{i,y|x3} = -\frac{1}{2}\left(T_i \ln\left(2\pi\sigma_w^2\right) + \frac{\boldsymbol{e_i'e_i}}{\sigma_w^2} + \left(\frac{\mu^2}{\sigma_u^2} - \frac{\mu_{i^*}{}^2}{\sigma^2_{i^*}}\right) + \ln\left(\frac{\sigma_{i^*}\Phi\left(\frac{\mu_{i^*}}{\sigma_{i^*}}\right)}{\sigma_u\Phi\left(\frac{\mu}{\sigma_\mu}\right)}\right)\right)$$

$$\ln L_{i,x3} = -\frac{1}{2}\sum_t^{T_i}\left(\ln\left(\left|2\pi\Omega\right|\right) + \varepsilon_{it}{}'\Omega^{-1}\varepsilon_{it}\right)$$

Where :

$$\mu_{i^*} = \frac{\sigma_w^2\mu - \sigma_u^2\boldsymbol{e_i'h_i}}{\sigma_u^2\boldsymbol{h_i'h}_i + \sigma_w^2}; \sigma_{i^*}^2 = \frac{\sigma_w^2}{\sigma_u^2\boldsymbol{h_i'h_i} + \sigma_w^2}$$

$$\boldsymbol{e_{it}} = y_{it} - \boldsymbol{x1_{it}'}\beta - \varepsilon_{it}{}'\eta; \varepsilon_{it} = x3_{it} - R_{it}\gamma$$

T_i the number of periods for panel I and Φ a standard normal cumulative distribution.

Appendix C.3. Prediction equation for endogenous variables Investment

Table C-1 : Prediction equation for endogenous variables Investment

Enhanced Endogenous model

	Coeff.	Std.Error	z	P>z	95 % Conf. Interval	
Leverage (log)	0.124	0.017	7.470	0.000	0.091	0.156
Subsidy	0.003	0.004	0.770	0.439	-0.004	0.010
Size (log)	0.057	0.082	0.700	0.485	-0.103	0.218
Size × Size (log)	0.000	0.011	0.040	0.971	-0.021	0.022
Age (log)	0.205	0.105	1.960	0.050	0.000	0.410
Age × Age (log)	-0.034	0.016	-2.170	0.030	-0.065	-0.003
Debt cost (log)	0.519	0.058	8.920	0.000	0.405	0.634
Debt cost × Debt cost (log)	-0.012	0.007	-1.680	0.094	-0.026	0.002
TEOF						
2	-0.032	0.032	-1.030	0.305	-0.094	0.029
3	-0.035	0.057	-0.610	0.541	-0.147	0.077
4	-0.098	0.125	-0.780	0.436	-0.343	0.148
5	-0.126	0.028	-4.470	0.000	-0.182	-0.071
6	-0.044	0.023	-1.930	0.053	-0.089	0.001
7	-0.148	0.069	-2.140	0.032	-0.283	-0.013
Employee	-0.226	0.013	-16.900	0.000	-0.252	-0.199
Constant	1.767	0.242	7.290	0.000	1.292	2.242

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. TEOF 1 is the base.

Table C-2 : Estimates results

	Dynamic endogeneity - corrected model (1)	Augmented dynamic endogeneity-corrected model (2)	Augmented Static model (3)
Investment	0.043***	0.047***	
	(0.004)	(0.006)	
Stock	-0.247***	-0.250***	-0.171***
	(0.01)	(0.011)	(0.009)
Subsidy	0.001	-0.007	-0.008
	(0.007)	(0.01)	(0.01)
Subsidy $\times$ Subsidy	0.000	0.001	0.001
	(0.001)	(0.001)	(0.001)
Energy	-0.014***	-0.021***	-0.020***
	(0.001)	(0.002)	(0.002)
2.REG	0.196***	0.211***	0.243***
	(0.047)	(0.042)	(0.048)
3.REG	-0.044	-0.038	-0.015
	(0.05)	(0.044)	(0.051)
4.REG	-0.028	-0.012	0.009
	(0.062)	(0.057)	(0.062)
5.REG	-0.074	-0.107*	-0.054
	(0.059)	(0.054)	(0.06)
6.REG	-0.079+	-0.04	-0.049
	(0.047)	(0.042)	(0.048)
7.REG	-0.149***	-0.132***	-0.127**
	(0.043)	(0.039)	(0.043)
8.REG	(0.019)	0.041	0.124
	0.083	(0.075)	(0.078)
9.REG	-0.222***	-0.191***	-0.221***
	(0.042)	(0.037)	(0.043)
10.REG	0.00	0.007	0.044
	(0.059)	(0.054)	(0.061)
Dum	-0.017*	-0.039**	0.007
	(0.007)	(0.012)	(0.012)
Salary (dummy)	-0.108**	-0.126**	-0.105*
	(0.04)	(0.039)	(0.041)
Time	-0.054***	-0.046***	-0.056***
	(0.004)	(0.004)	(0.004)
Dum $\times$ Investment		0.033***	

		(0.005)	
Dum $\times$ Stock		-0.123***	-0.107***
		(0.009)	(0.008)
Dum $\times$ Subsidy		0.004	0.006
		(0.009)	(0.009)
Dum $\times$ Energy		0.010***	0.008***
		(0.001)	(0.001)
Dum $\times$ Subsidy2		0.000	-0.001
		(0.001)	(0.001)
Constant	1.412***	1.243***	1.428***
	(0.045)	(0.044)	0.046
η Endogeneity test $X^2 = 5.48$	$p > Chi2 = 0.01$		
η Endogeneity test $X^2 = 9.48$		$p > Chi2 = 0.002$	

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1 + p<0.10, * p<0.05, ** p<0.01, *** p<0.001*

Region includes 11 categories ; Region 1 = Auvergne-Rhône-Alpes ; Région 2= Bourgogne-Franche-Comté ; Région 3= Bretagne ; Région 4 = Centre-Val de Loire ; Région 5 =Nord-Pas-de-Calais-Picardie ; région 6 = Normandie ; Région 7 = Nouvelle Aquitaine ; Région 8 = Occitanie ; Région 9 = Pays de la Loire ; Région 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.

Appendix C.4. Efficiency and technical change by year

Table C-3 Efficiency change and technical change

	Eficiency change				*Technical change*		
Period	Mean	Sd.	Median		Mean	Sd.	Median
2010-2011	0.88	0.305	0.843		1.172	0.132	1.168
2011-2012	1.138	0.362	1.051		0.922	0.145	0.921
2012-2013	1.537	0.471	1.497		0.657	0.12	0.61
2013-2014	1.028	0.332	0.989		1.093	0.115	1.102
2014-2015	0.919	0.288	0.886		1.18	0.116	1.192
2015-2016	1.237	0.379	1.195		0.843	0.074	0.832

Appendix C.5. Fixed effect and instrumental variable (IV) model

Table C-4 : Fixed effect and Instrumental Variable (IV) model

	Fixed effect (a)			Panel IV-Fixed effect (b)		
	Productivity	Technical change	Efficiency change	Productivity	Technical change	Efficiency change
Environment	-0.152*	-0.059	-0.038	1.139+	0.549	0.402
	(0.073)	(0.059)	(0.107)	(0.623)	(0.369)	(0.54)
Environment × Environment	0.181*	0.021	0.135			
	(0.072)	(0.059)	(0.106)			
Environment (lag1)	-0.028	-0.014	-0.001			
	(0.019)	(0.016)	(0.028)			
Environment (lag2)	0.005	0.017	-0.011			
	(0.019)	(0.014)	(0.028)			
Subsidy	0.026	0.113***	-0.120***	0.086	0.145***	-0.103*
	(0.036)	(0.013)	(0.036)	(0.055)	(0.0)3	(0.045)
Subsidy (lag1)	0.018+	0.010*	0.001	0.025	0.013	0.003
	(0.01)	(0.005)	(0.011)	(0.018)	(0.01)	(0.012)
Subsidy (lags2)	-0.007	0.005	-0.011	-0.01	0.003	-0.012
	(0.007)	(0.005)	(0.009)	(0.013)	(0.008)	(0.01)
Branche	-0.053***	-0.008**	-0.048***	-0.045***	-0.002	-0.048***
	(0.004)	(0.003)	(0.006)	(0.008)	(0.005)	(0.008)
Diversity						
	.	.	.	.	.	.
Time	0.001	0.040***	-0.060***	-0.006	0.036***	-0.062***
	(0.006)	(0.003)	(0.008)	(0.01)	(0.006)	(0.008)
Time × Subsidy	-0.006	-0.017***	0.016**	-0.016+	-0.022***	0.013+
	(0.006)	(0.002)	(0.006)	(0.009)	(0.005)	(0.007)
Salary (Dummy)	-0.029	-0.091*	0.078			
	(0.051)	(0.043)	(0.071)			
Constant	1.244***	0.821***	1.580***			
	(0.042)	(0.024)	(0.053)			
Robust Hausman test	102.25***	41.37***	41.10***			
Kleibergen-Paap rk LM Statisitic				5.470*	5.470*	5.470*
IV redundancy test				5.470*	5.470*	5.470*
Kleibergen-Paap rk Wald F-Statistic				5.545	5.545	5.545
Endogeneity test				7.307**	5.098*	0.333

*Note : + p<0.10, * p<0.05, ** p<0.01, *** p<0.001*

Appendix C.6. First difference result

The difference between the within estimator and the first difference estimator lies in the way in which the fixed effects are eliminated. For a within estimator mean model is written as follows :

$$\left(y_{it} - \overline{y}_i\right) = \left(x_{it} - \overline{x}_i\right)' \beta + \left(\varepsilon_{it} - \overline{\varepsilon}_i\right)$$

Where : $\overline{x}_i = T_i^{-1} \sum_{t=1}^{T_i} x_{it}$

The first difference is obtained by OLS of first differenced variables as follows:

$$\left(y_{it} - y_{i,t-1}\right) = \left(x_{it} - x_{i,t-1}\right)' \beta + \left(\varepsilon_{it} - \varepsilon_{i,t-1}\right)$$

The result may be different between these two estimator for T>2 (Cameron & Trivedi, 2009)

Table C-5 : First difference result

	Productivity	Technical change	Efficiency change
D.Environment	2.777+	0.65	1.971+
	(1.477)	(0.475)	(1.164)
D.Subsidy	0.107	0.084*	-0.011
	(0.121)	(0.034)	(0.091)
D. Subsidy (lag1)	0.036	0.002	0.029
	(0.056)	(0.014)	(0.04)
D.Subsidy (lag2)	-0.038	-0.005	-0.029
	(0.037)	(0.012)	(0.027)
D.Branche	-0.041*	-0.003	-0.042**
	(0.018)	(0.006)	(0.014)
Diversity			
Time			
D.Time $\times$ Subsidy	-0.023	-0.012+	-0.005
	(0.021)	(0.006)	0.015
Constant	-0.018	0.014+	-0.038+
	(0.027)	(0.008)	(0.021)
Kleibergen-Paap rk LM Statisitic	3.909*	3.909*	3.909*
IV redundancy test	3.909*	3.909*	3.909*
Kleibergen-Paap rk Wald F-Statistic	3.938	3.938	3.938
Endogeneity test	27.013***	4.537*	7.093**

*Note : D is the Difference operator. Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1. D is the Difference operator.*

Appendix C.7. Model specification test (Andrews & Lu, 2001)

Table C-6 : Endogenous and Exogenous model comparison

Model	N	J	nmom	npar	MMSC-AIC	MMSC-BIC	MMSC-HQIC
.	1030	26.4109	40	12	-29.589	-167.833	-83.141
Productivity_endo	1030	24.7356	41	12	-33.264	-176.446	-88.728
Productivity_exo	1030	29.6832	40	12	-26.316	-164.561	-79.8687
Technical change_endo	1030	76.4394	41	12	18.439	-124.742	-37.0251
Technical change_exo	1030	72.8245	40	12	16.824	-121.420	-36.727
Efficiency change_endo	1030	20.4303	41	12	-37.569	-180.751	-93.034
Efficiency change_exo	1030	26.4109	40	12	-29.589	-167.833	-83.141

Note : ENDO =Endogenous ; EXO=Exogenous. Models with lower value of the criteria are preferred

Appendix C.8. First difference model in dynamic panel

Table C-7 : First difference model (Arellano & Bond, 1991)

	AB-Endogenous model (c)			AB-Endogenous model / Subsidy exogenous (d)		
	Productivity	Technical change	Efficiency change	Productivity	Technical change	Efficiency change
Productivity (lag 1)	-0.260***			-0.270***		
	(0.047)			(0.045)		
Technical change (lag 1)		0.175+			0.163+	
		(0.104)			(0.096)	
Efficiency change (lag 1)			-0.188***			-0.207***
			(0.046)			(0.041)
Environment	0.378**	-0.068	0.464*	0.379*	-0.049	0.510*
	(0.142)	(0.09)2	(0.213)	(0.178)	(0.084)	(0.234)
Environment (lag 1)	0.01	-0.001	0.053	-0.01	-0.003	0.031
	(0.065)	(0.03)	(0.092)	(0.067)	(0.024)	(0.083)
Environment (lag 2)	0.047	-0.002	0.053	0.039	-0.002	0.032
	(0.05)	(0.026)	(0.067)	(0.05)	(0.02)	(0.06)
Subsidy	0.053	-0.055	-3.224	-0.454	-0.207	-3.333
	(1.128)	(1.784)	(3.607)	(0.898)	(0.477)	(2.983)
Subsidy (lag 1)	-0.028	-0.012	-0.865	-0.072	-0.044	-0.816
	(0.21)	(0.314)	(0.719)	(0.242)	(0.126)	(0.715)
Branch	-0.024	-0.025+	-0.017	-0.027	-0.017	-0.026
	(0.015)	(0.013)	(0.04)	(0.02)	(0.011)	(0.036)
2013	0.064		-0.946	-0.21	-0.252	-1.059
	(0.545)		(1.666)	(0.473)	(0.228)	(1.423)
2014	0.132	0.546+	-1.012	-0.041	0.314*	-1.059
	(0.357)	(0.28)	(1.107)	(0.315)	(0.146)	90.951)
2015	0.111	0.543	-0.743	0.016	0.335***	-0.78
	(90.184)	(0.549)	(90.554)	(0.171)	(0.078)	(0.489)
2016		0.186				
	.	(0.82)	.	.	.	.
Time × Subsidy	-0.033	0.021	0.518	0.081	0.038	0.591
	(0.2)	(0.298)	(0.607)	(0.17)	(0.086)	(0.514)
Salary (Dummy)	-0.346	0.389*	-0.228	-0.402	0.494+	-0.228
	(0.663)	(0.192)	(0.668)	(0.824)	(0.269)	(0.748)

AR1 (p-value)	0.000	0.046	0.435	0.000	0.002	0.000
AR2 (p-value)	0.565	0.001	0.104	0.680	0.000	0.307
Sargan-Hansen Test	0.691	0.000	0.866	0.37	0.000	0.555
Observations	1756	1756	1756	1756	1756	1756

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at $p<0.01$, $p<0.05$, $p<0.1$*

Appendix C.9. Other estimation

Table C-8 : Estimation result (Enhanced endogenous model)

Investment	0.047***
	(0.006)
Stock	-0.249***
	(0.011)
Subsidy	-0.007
	(0.01)
Subsidy × Subsidy	0.001
	(0.001)
Energy	-0.021***
	(0.002)
2.REG	0.211***
	(0.042)
3.REG	-0.042
	(0.044)
4.REG	-0.013
	(0.057)
5.REG	-0.106+
	(0.054)
6.REG	-0.038
	(0.042)
7.REG	-0.132***
	(0.039)
8.REG	0.042
	(0.075)
9.REG	-0.191***
	(0.037)
10.REG	0.006
	(0.054)
Dum	-0.038**
	(0.012)
Employee	-0.032
	(0.024)
Time	-0.047***
	(0.004)
Dum × Investment	0.033***
	(0.005)
Dum × Stock	-0.121***
	(0.009)
Dum × Subsidy	0.004
	(0.009)

Dum $\times$ Energie	0.010***
	(0.001)
Dum $\times$ Subsidy	0.000
	(0.001)
Dum $\times$ Employee	-0.033
	(0.021)
Constant	1.251***
	(0.044)
η Endogeneity test $X^2 = 9.05$	$p > Chi2 = 0.002$
Mean efficiency	0.426
Standard dev.	0.190

*Note : Standard errors in parentheses. ..***,**,* means the estimated coefficient is statistically significant at p<0.01, p<0.05, p<0.1*
Region includes 11 categories ; Region 1 = Auvergne-Rhône-Alpes ; Région 2= Bourgogne-Franche-Comté ; Région 3= Bretagne ; Région 4 = Centre-Val de Loire ; Région 5 =Nord-Pas-de-Calais-Picardie ; région 6 = Normandie ; Région 7 = Nouvelle Aquitaine ; Région 8 = Occitanie ; Région 9 = Pays de la Loire ; Région 10 = Alsace-Champagne-Ardenne-Lorraine, Ile-de-France, Provence-Alpes-Côte d'Azur. Region 1 is the base.
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. TEOF 1 is the base.

Table C-9 : Endogenous model with quadratic term

	Productivity	Technical change	Efficiency change
Productivity (lag 1)	-0.441***		
	(0.068)		
Technical change (lag 1)		-0.248**	
		(0.086)	
Efficiency change (lag 1)			-0.417***
			(0.068)
Environment	1.051	0.566+	1.199
	(0.766)	(0.323)	(0.878)
Environment (lag 1)	0.236	0.019	0.297
	(0.31)	(0.115)	(0.404)
Environment (lag 2)	0.444+	-0.003	0.698*
	(0.232)	(0.084)	(0.307)
Environment $\times$ Environment	-0.684	-0.567	-0.769
	(0.745)	(0.366)	(0.874)
Environment $\times$ Environment (lag 1)	-0.286	-0.04	-0.292
	(0.306)	(0.118)	(0.396)
Environment $\times$ Environment (lag 2)	-0.527*	-0.003	-0.792**

	(0.233)	(0.085)	(0.303)
Subsidy	-2.86	0.446	-7.234
	(2.577)	(1.83)	(5.742)
Subsidy (lag 1)	-0.095	0.187	-0.963
	(0.486)	(0.291)	(0.923)
Subsidy (lag 2)			
Subsidy × Subsidy	0.107	0.022	0.168
	(0.125)	(0.039)	(0.174)
Subsidy × Subsidy (lag 1)	-0.059	-0.018	-0.035
	(0.057)	(0.03)	(0.104)
Branche	-0.410***	-0.092*	-0.412***
	(0.089)	(0.042)	(0.121)
Branch × Branch	0.024**	0.008+	0.021
	(0.009)	(0.004)	(0.013)
Diversity			
Diversity × Diversity			
2013		0.012	
		(0.821)	
2014	0.35	0.306	0.454
	(0.399)	(0.548)	(0.863)
2015	0.66	0.419	0.957
	(0.782)	(0.274)	(1.716)
2016	0.889	-	2.16
	(1.18)	.	(2.585)
Temp × Subsidy	0.369	-0.1	1.067
	(0.429)	(0.299)	(0.939)
Salary (Dummy)	-0.374	0.375*	0.176
	(0.714)	(0.164)	(0.998)
AR1 (p-value)	0.000	0.014	0.068
AR2 (p-value)	0.895	0.000	0.218
Sargan-Hansen Test	0.000	0.000	0.000
Observation	1756	1756	1756

Note : +,*,**,*** means the estimated coefficient is statistically significant at p< 0.10, p<0.05, p<0.01, p<0.001

Table C-10 : First difference and GMM system (Arellano & Bover, 1995)

Model	N	J	nmom	npar	MMSC-AIC	MMSC-BIC	MMSC-HQIC
.	1030	31.005	47	15	-32.995	-190.989	-94.197
Productivity_endo	1030	24.735	41	12	-33.264	-176.446	-88.728
Technical change_endo	1030	76.439	41	12	18.439	-124.742	-37.025
Efficiency change_endo	1030	20.430	41	12	-37.569	-180.751	-93.034
Productivity_sys	1030	53.958	47	15	-10.042	-168.036	-71.244
Technical change_sys	1030	47.801	47	15	-16.199	-174.193	-77.401
Efficiency change_sys	1030	31.005	47	15	-32.995	-190.989	-94.197

Note SYS : System GMM

Appendix C.10. First difference model with additional covariates new investment

Table C-11 : First difference model , additional covariates and new equipment investment (Arellano & Bond, 1991)

	Productivity Additional covariates	Productivity
Productivity (lag)	-0.278***	-0.261***
	(0.049)	(0.048)
Environment	0.244+	
	(0.128)	
Environment (lag 1)	-0.009	
	(0.065)	
Environment (lag 2)	0.045	
	(0.047)	
Environment (new equipment)		0.404*
		(0.16)
Environment (new equipment lag 1)		0.017
		(0.067)
Environment (mew equipment lag 2)		0.04
		(0.05)
Subsidy	0.142	0.252
	(1.154)	(1.09)
Subsidy (lag 1)	0.015	-0.014
	(0.212)	(0.221)
Subsidy (lag 2)		
Branche	-0.021	-0.029+
	(0.016)	(0.015)
Diversity		
2011	0.000	
2012		
2013		
2014	0.054	0.04

	(0.199)	(0.183)
2015	0.014	-0.017
	(0.388)	(0.351)
2016	-0.108	-0.148
	(0.585)	(0.529)
Time × Subsidy	-0.042	-0.068
	(0.204)	(0.193)
Salary (Dummy)	-0.84	-0.462
	(0.648)	(0.69)
Age (log)	0.199	
	(0.156)	
Age × Age (log)	-0.029	
	(0.173)	
Size (log)	216.956	
	(246.432)	
Size × Size (log)	-27.791	
	(32.957)	
AR1 (p-value)	0.000	0.000
AR2 (p-value)	0.476	0.450
Sargan-Hansen Test	0.642	0.642
Observations	1756	1756

Note : +,,**,*** means the estimated coefficient is statistically significant at p< 0.10, p<0.05, p<0.01, p<0.001*

Table C-12 : First difference and GMM system (Arellano & Bover, 1995)

Model	N	J	nmom	npar	MMSC-AIC	MMSC-BIC	MMSC-HQIC
.	1409	150.204	87	10	-3.796	-408.095	-157.934
TFPCH ENDO	1409	51.3023	51	8	-34.697	-260.475	-120.775
TECCH ENDO	1409	144.454	51	8	58.454	-167.322	-27.622
TECH ENDO	1409	64.727	51	8	-21.272	-247.049	-107.349
TFPCH SYS	1409	120.472	87	10	-33.527	-437.826	-187.665
TECCH SYS	1409	210.448	87	10	56.448	-347.850	-97.690
TECH SYS	1409	150.204	87	10	-3.796	-408.095	-157.934

Note SYS : System GMM

Appendix C.11. Other estimation

Table C-13 : Estimation results (Enhanced endogenous model)

Investment	0.047***
	0.006
Stock	-0.249***
	0.011
Subsidy	-0.007
	0.01
Subsidy2	0.001
	0.001
Energy	-0.021***
	0.002
2.REG	0.211***
	0.042
3.REG	-0.042
	0.044
4.REG	-0.013
	0.057
5.REG	-0.106+
	0.054
6.REG	-0.038
	0.042
7.REG	-0.132***
	0.039
8.REG	0.042
	0.075
9.REG	-0.191***
	0.037
10.REG	0.006
	0.054
D	-0.038**
	0.012
Employee	-0.032
	0.024
Time	-0.047***
	0.004
Dum*Investment	0.033***

	0.005
Dum*Stock	-0.121***
	0.009
Dum*Subsidy	0.004
	0.009
Dum*Energie	0.010***
	0.001
Dum*Subsidy2	0.000
	0.001
Dum*empl	-0.033
	0.021
Constant	1.251***
	0.044
η Endogeneity test $X^2 = 9.05$	$p > Chi2 = 0.002$
Mean efficiency	0.42
Standard dev.	0.190

Note : +,,**,*** means the estimated coefficient is statistically significant at p< 0.10, p<0.05, p<0.01, p<0.001*

COLLEGE ECONOMIE
DOCTORAL ET GESTION
PAYS DE LA LOIRE

L'INSTITUT agro Rennes Angers

Titre : Arrangements coopératifs, investissement environnemental et performance des coopératives agricoles

Mots clés : CUMA, gouvernance, investissement environnemental, frontière

Résumé : L'évolution des formes coopératives et les questions environnementales relance le débat sur la gouvernance des coopératives, leur implication environnementale ainsi que les effets de cette implication environnementale sur leur performance. Cette thèse s'intéresse d'une part à la gouvernance des Coopératives d'Utilisation de Matériel Agricole (CUMA), d'autre part à l'effet de la gouvernance sur les investissements environnementaux et l'implication de ces investissements sur la performance des CUMA. A travers une approche qualitative, un modèle économétrique en deux parties avec sélection et une analyse de frontière en dynamique, nos résultats font ressortir la capacité des adhérents en CUMA à se coordonner efficacement en ayant recours principalement aux mécanismes de gouvernance relationnels. La volonté des CUMA de maintenir ce type de mécanisme influence la taille du groupe qui devient critique au-delà d'un seuil en limitant leur propension et leur proportion à s'impliquer dans les questions environnementales. Cependant, l'implication environnementale des CUMA est nécessaire et avantageuse lorsque les investissements environnementaux concernent les équipements agricoles de premier choix.

Title : Cooperative arrangements, environmental investment and performance of agricultural cooperatives............... ....

Keywords : CUMA, governance, environmental assets

Abstract: The evolution of cooperative forms and environmental issues has reopened the debate on the governance of cooperatives, their environmental involvement and the effects of this environmental involvement on their performance. This thesis focuses on the governance of Cooperatives for the Use of Agricultural Equipment (CUMA) and on the effect of governance on investments in environmental assts and the implication of these investments on CUMA performance. Through a qualitative approach, a two-part econometric model with selection and a dynamic frontier analysis, our results highlight the ability of CUMA members to coordinate effectively by using mainly relational governance mechanism.The willingness of CUMAs to maintain this type of mechanism influences the size of the group, which becomes critical beyond a threshold by limiting their propensity and proportion to become involved in environmental issues. However, the environmental involvement of CUMAs is necessary and beneficial for their economic performance when environmental investments are made in equipment of first choice.