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Farm sustainability and the involvement of economic actors in the agri-food value chain

Ahmet Candemir

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agri-food value chain**

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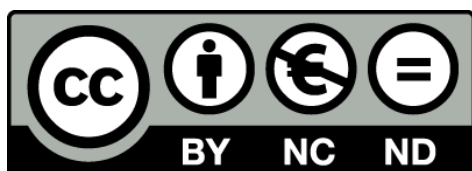
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List of Abbreviations

AEI	Agri-Environmental Indicators
AES	Agri-Environmental Schemes
AT	Austria
AWU	Annual Working Unit
CAP	Common Agricultural Policy
CMEF	Common Monitoring and Evaluation Framework
Coop	Cooperative
DE	Germany
EC	European Commission
EFA	Ecological Focus Area
EL	Greece
EN	England
EU	European Union
FADN	Farm Accountancy Data Network
FR	France
ha	Hectare
HU	Hungary
IE	Ireland
IT	Italy
LFA	Less Favoured Areas
LIFT	Low-Input Farming and Territories
LU	Livestock Unit
N	Nitrogen
PL	Poland
PO	Producer Organisation
RO	Romania
SC	Scotland
sd	Standard Deviation
SE	Sweden
UAA	Utilised Agricultural Area

Chapter 1 General introduction

1.1 Context/background

The European agricultural sector faces sustainability related challenges. Especially detrimental environmental effects of agricultural production are more and more present and discussed in academic and professional spheres. In 2019, it is estimated that the European agricultural sector is contributor of 11 % of total European greenhouse gases emissions (European Environment Agency 2021). The use of chemical fertilisers and pesticides is often associated with biodiversity losses in European agricultural areas (Montanarella and Panagos 2021). Moreover, livestock production is often pointed out for inefficient transformation of vegetable proteins and for animal welfare issues (Guyomard et al. 2021).

These challenges influence public discourse on agricultural production (Leduc et al. 2021). Public authorities react to these facts by setting radical objectives and requirements. In the European Union (EU), the European Commission (EC) presented the Green Deal policy targets with the objective of being the first carbon neutral continent in the globe by 2050. In the agricultural sector, this initiative is reflected in the “Farm to Fork” and the “Biodiversity Strategies 2030” (European Commission 2020a). Overall reduction in pesticide and antimicrobial use by 50 %, reduction in chemical fertilisers by 20 % and having at least 25 % of the EU agricultural area in organic production, can be cited as the main objectives of these strategies by 2030 (European Commission 2020b).

These ambitious targets of the EC are not limited to improving the environmental sustainability of EU farms. It is also clearly stated that all these environmental objectives should be accompanied with farms’ economic viability (European Commission, 2020a). This issue, which is vital for farmers to adopt sustainable practices, is not straightforward. The structural changes needed in order to reach these targets can disturb the EU agricultural sector in terms of reduction of overall production, decrease in competitiveness in international markets and increase in final prices which may deteriorate consumer welfare (Beckman et al. 2021).

Assessment of farm sustainability

Being widely used and defined in a multitude way, the notion of environmental sustainability may be interpreted differently (Rega et al. 2018). The original concept defines sustainability as “economically viable, environmentally sound and socially acceptable development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED 1987). In practice, it is still debated how to operationalise sustainability, in particular environmental sustainability, and how to measure it (Diazabakana et al. 2014; Repar et al. 2017). Nevertheless, public policies such as the EU Common Agricultural Policy (CAP) provide incentives to farmers to adopt sustainable practices, e.g. through the agri-environmental schemes (AES) or green direct payments. The EC measures the effectiveness of the CAP in reaching its environmental targets with the common monitoring and evaluation framework (CMEF) and agri-environmental indicators (AEIs).

Farm sustainability is not limited to the environmental dimensions. Economic sustainability related issues should not be undermined. More importantly, the perceptions and motivations of farmers towards new practices are often constructed by economic motives. It is clear that the development of a more environmentally-friendly agri-food production necessitates an adaptation strategy that can be economically viable on farm and industry level. This economic viability condition should be reflected as monetary returns to farmers. The expected rise in adoption of environmentally-friendly ways of production should be economically interesting to farmers in order to increase their incentives to change their way of production (Pannell and Claassen 2020; Waş et al. 2021). In other words, the financial attractiveness may have a crucial role for boosting farmers willingness to change their practices and improve their environmental performance.

Supply chain organisation

The supply of agricultural goods that are produced in a more environmentally-friendly way is expected to increase to respond to rising consumers’ sensibilities and governments’ initiatives. However, improvements of environmental quality in agri-food industry face supply side-related economic obstacles. These supply-side issues contribute to the explanation of the persistence of conventional practices even if there is growing demand for environmentally-friendly practices (Cecere et al. 2014; Barbieri et al. 2016; Magrini et al. 2016). In order to overcome these obstacles, actors in agri-food supply chains have crucial roles. Actors in supply chains

may enhance the adoption of these practices by developing access to food labels that can create a product differentiation, by providing technical assistance and information campaigns or by clearly defining minimum quality standards through contracting.

There are various ways that farmers may sell their farm level product. Farmers can use cooperatives or producer organisations (PO) or they can choose to engage with processors, wholesaler and retailers in agri-food supply chains. Farmers' selling strategy is not limited to these options. They can also deliver part or the totality of their product directly to consumers (Pascucci et al. 2012; Agbo et al. 2015). The choices of marketing channel for farm production may have direct relations with quality related objectives and requirements (Goodhue 2011; Bouamra-Mechemache et al. 2015). In this respect, these channel choices may impact also farmers' behaviour toward sustainable practices.

1.2 Scope of the PhD and research questions

As sustainable practices are becoming more and more important in the agricultural sector, researchers in agricultural economics are increasingly interested in analysing the patterns, providing scientific evidence and offering public policy tools (Fresco et al. 2021). One of the most important objectives of researchers is to capture behavioural tendencies of farmers towards these practices (Hansson et al. 2019). Researchers use empirical and theoretical tools for identifying drivers/obstacles, which influence farmers' decision-making. Empirical works may consist of experimental frameworks or of ex-post analysis of observational data. In this respect, farm specific characteristics (age, education, experience, specialisation, farm labour, economic performance) and public policy interventions (taxes, subsidies, input bans) are often subjected to analysis to investigate farmers' perceptions and decisions towards sustainable practices (Dessart et al. 2019). The empirical literature on farms' adoption of environmentally-friendly practices is rich, in particular as regards organic farming practices (Padel 2001; Latruffe and Nauges 2014; Casagrande et al. 2016; Jouzi et al. 2017). This literature examines the drivers and obstacles behind the adoption decisions from an empirical point of view, by using econometric analyses where several explanatory variables (generally chosen in an ad hoc way) explain the decision to adopt or the extent of adoption (e.g. number of hectares under specific practices). In light of the various studies, it can be summarised that farmers adopt environmentally-friendly practices for several reasons. Firstly, socio-demographic

characteristics have significant impacts on farmers' decisions. These characteristics include age, education level, political or ideological opinions and beliefs of farmers, and household composition (Dessart et al. 2019). For instance, older farmers may have lower incentives to switch their production methods. Secondly, farms' economic characteristics – such as organisational structure, size, indebtedness, or main production – play a crucial role. Thirdly, external factors such as market prices and government interventions, via policies and regulations, have direct effects on the adoption decision. Perceived economic opportunities are also one of the main drivers that influence farmers decision-making toward more environmentally-friendly practices (Hansson et al. 2019). However, there is a scarcity of academic studies that analyse the role of supply chain organisation on the adoption of farmers' sustainable practices. It is also not clear-cut from the literature whether sustainability pillars, in particular environmental and economic pillars, can be reconciled at the farm level. Trade-offs between the short-term components of farm-level sustainability, namely farm environmental performance and economic performance, are receiving increasing attention from researchers but the scope of their studies is generally limited to a small case study or/and a short period.

In this context, the PhD aims at contributing to the issue of farm sustainability and the involvement of economic actors in the agri-food value chain, through two main research questions and three original works, one comprehensive literature review and two empirical studies.

First, the PhD aims at investigating the crucial relation between environmental performance and economic performance. This question has a fundamental importance in the development of more environmentally-friendly and economically viable way of production, and sustainability of farming in general (Sulewski et al. 2018). In the literature, although there are various attempts to identify performance, research on the subject is generally limited to one pillar of the farm sustainability and investigates synergy/trade-off relations among sustainability components (Latruffe et al. 2016; Lynch et al. 2019). A shortcoming of the existing literature is that the evolution of performance over time is not taken into account. By contrast, one of the objectives of the PhD is to focus on the possible interaction between environmental performance and economic performance considering the time dimension. In other words, this crucial relation between economic and environmental performances is analysed by taking into account the evolution of farm performance indicators over a 9-year period.

Research Question 1: Are there trade-offs between farm environmental performance and economic performance over time?

The second research question of the PhD is related to the supply chain organisation on the farm sustainability. Supply chain organisation may have crucial importance on the development of sustainable practices (Gonzalez 2018; Meemken et al. 2021). The relation between the evolution of environmentally-friendly production and market channel choices may be investigated differently. We can analyse marketing channel choices in a specific environmentally-friendly production system (Corsi et al. 2009). On the other hand, we can analyse the impact of a supply chain organisation choice on the adoption of environmentally-friendly ways of production (Duvaleix et al. 2020; Westerholz and Höhler 2021). This is the approach followed in this PhD.

The literature on the impacts of supply chain organisation is mainly focused on the impacts of cooperatives on farmers' economic performance (Grashuis and Su 2019). The underdevelopment of studies on environmental sustainability and supply chain organisation may be related to unavailability of data concerning sustainability related information, as well as concerning supply chain organisation. The originality of this PhD is that it uses farm-level data that include farm accountancy information and supply chain information for several EU countries, collected in the frame of the LIFT project funded under the EU H2020 programme.

Research Question 2: Does supply chain organisation has a role on the adoption of sustainable practices at farm level?

1.3 Outline and summary of the manuscript

The PhD manuscript consists in five chapters, including a general introduction and a general conclusion. Chapter 2 provides an empirical analysis on the relation between environmental performance and economic performance for livestock farms in a region of France over a 9-year period. Chapter 3 is a literature review, investigating the economic literature on the agricultural cooperatives to assess the possible influence of cooperative membership on farm sustainability. This literature review critically examines major contributions on both theoretical and empirical literature in the subject. Chapter 4 offers an empirical analysis on the role played by farmers' decision on their marketing channel for a sample of EU farmers in 2018, specifically on their decision to adopt organic practices. In this chapter, a special attention is given to the impact of marketing through an agricultural cooperative. Finally, Chapter 5 provides a general conclusion to the PhD manuscript.

In **Chapter 2**, we assess the relationship between economic performance and environmental performance for the specific case of livestock farms, with an application in North-Eastern France region of Meuse for the period 2008-2016. We use clustering analysis to create a typology based on farm-level accountancy data. The contribution of our study is that we consider the evolution of performance over several years to create the clusters. This is important for sustainability since the latter is related to long-term performance. Our results suggest that farms who are less environmentally-friendly are better performing in economic terms when the average picture over the full period is considered. However, when the evolution of environmental performance over time is accounted for, no significant difference exist in terms of economic performance between less and more environmentally-friendly farms. This suggests that the time dimension should be more included in farm performance analyses.

Chapter 3's objective is to examine the role of agricultural cooperatives in agri-food supply chains in the adoption of farm level sustainable practices. This study provides a literature review on agricultural cooperatives by examining both theoretical and empirical literature from different contextual angles and backgrounds. The study shows that the theoretical literature offers analytical analysis concentrated on market power, heterogeneity among farmers, decision making process in the cooperative, adoption cost and dynamics related to information asymmetries in the cooperative. The empirical literature, on the other side, employs econometric tools in order to investigate the effects of cooperative membership.

This literature review shows that there are diverging historical and contextual understandings of cooperatives in the world. These differences can be originated from countries trajectories or by sectorial differences. The empirical literature is mainly based on developing countries. As a result, the results of empirical works show that, for newly founded and rural development oriented cooperatives in these countries, there is generally positive evidence about quality in cooperatives. Cooperatives generally offer many advantages to farmers by coping with market uncertainties and information asymmetries. Especially for farmers in developing countries, cooperatives can ease the access to international food labels (mainly organic and fair trade) which represent export-oriented high quality products. In this case, cooperative membership may increase the positive evolution of product quality and farm sustainability. In developed countries, this issue becomes more ambiguous. In these countries, cooperatives are historically strong and in some sectors they dominate the markets. As we observe in cereal, sugar and pig meat markets in the EU, cooperatives may choose cost-reducing strategy by concentrating on conventional production. The theoretical literature is mainly focused on the performance comparison between investor-owned firms and cooperatives. In general, the trade-off is made by comparing the cooperatives' advantages, such as democratic decision making and coping with double marginalisation in supply chains, and disadvantages, mainly originated by farmers' heterogeneity in terms of performance and economic objectives.

Overall, the literature review shows that the conception of cooperatives may have diverging legal and organisational definitions. In the case of adoption of sustainable practices, cooperatives may increase incentives by decreasing adoption costs, providing technical assistance and easing access to markets. On the other hand, cooperatives are also characterised

by problems related to farmer heterogeneity that can create inefficiencies in decision making process and can slow down the adoption process.

Chapter 4 aims at capturing how farmers' choice of marketing channels for their output can influence farmers' decision on their participation in organic certification. Using data from an original farmers' survey for the year 2018 in the EU, we observe a diversity of marketing channels used by farmers. The sample used includes 680 farms from 7 EU countries (Germany, France, Greece, Ireland, Poland, Romania and Sweden). The database provides information about the shares of output sold through 6 marketing channels. Most farms choose a dominant marketing channel (cooperative/PO, processor, wholesaler, retailer, consumer, and other type of dominant marketing channel), where dominant is identified when at least 50 % of the output is sold through this channel.

The organic farms represent 26 % (176 farms) out of 680 farms in the sample. We analyse the impacts of marketing channel choices on the adoption of organic farming certification. In order to assess this relation, we employ a binomial logistic regression model. The results show that only cooperative marketing channel has a significant effect on the probability of being certified organic farming and this effect is negative.

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Chapter 2 Evolution of farm economic and environmental performance over time: A typology of livestock farms in France*

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2.1 Introduction

Farming activities have strong impacts on the environment, whether negative impacts (e.g. on water quality due to intensive pesticide and fertiliser use) or positive impacts (e.g. on biodiversity or landscape through ecological focus areas (EFA) and livestock grazing in marginal areas). As Repar et al. (2017) stress, the “monitoring, assessment and enhancement of farm environmental performance is therefore an issue of the utmost importance for improving the environmental sustainability of the entire food chain”. While public concerns are rising about the environmental impacts of agriculture, public authorities try to mitigate negative and enhance positive environmental effects of agricultural activity in an economically sustainable way. The European Commission underlines the importance of the economic feasibility of environmentally-friendly ambitions in the “Farm to Fork Strategy Plan” of the Green Deal (European Commission 2020). In this respect, interrelations, namely trade-offs or synergies, between economic performance and environmental performance for farms should be analysed carefully.

Several studies have investigated both economic and environmental performances of farms but their scope remains limited. They generally cover a small sample of farms, a short period and/or few environmental dimensions. The main issue is the lack of data. While economic performance can be assessed easily from classic accountancy data, information needed to assess environmental performance is missing from such databases. Measuring environmental impacts of specific farming practices is complex as there are a multitude of themes (e.g. biodiversity, greenhouse gases...), impacts may be global and not only local, and direct measurement is often not possible or too costly (Bockstaller and Girardin 2003; Diazabakana et al. 2014; Repar et al. 2017). In this study, we contribute to the literature with an assessment of farm economic and environmental performances over a long period, using farm-level data in a French region on 9 years.

Studies investigating farm economic performance and environmental performance generally compute several indicators, and map them on spider diagrams (e.g. Galioto et al. 2017), or aggregate them in overall scores on which they rank farms (e.g. Dolman et al. 2012; Jan et al. 2012), or carry out a correlation analysis (Lambotte et al. 2021), or perform a clustering analysis (Latruffe et al. 2016). The latter approach has the advantage of summarising all indicators, similar to aggregating in overall scores, but does not need assumptions on weights to apply to each indicator since, with clustering, farms are grouped based on statistical analysis. This is the approach that we will follow here. However, contrary to Latruffe et al. (2016) who cluster farms

based on the economic indicators and compare clusters in terms of environmental performance, here we cluster farms based on the environmental indicators and compare clusters in terms of economic performance. This is because we assume that environmental performance is the first objective in the society's eye, and it has to be assessed whether high environmental performance is traded against economic performance or go hand-in-hand.

The article is structured as follow. Firstly, we describe the data, and secondly, we explain the methodology. Finally, we explain the results and then we conclude.

2.2 Data

In this study, we use a balanced panel data set that has 1,521 observations from 169 farms for the period of 2008-2016. The farms are located in Meuse region, a NUTS3¹ region in North-Eastern France. The database contains accountancy data, which provide farm-level information. More precisely, we have information on farm-level characteristics such as legal status, labour, utilised agricultural area (UAA); economic characteristics such as output, expenses and subsidy values in Euros²; and environmental characteristics such as fertiliser and pesticide use in Euros and nitrogen (N) value per hectare.

As farming practices and constraints differ depending on the farms production specialisation, we consider here only one type of farm, livestock farms. More precisely, we keep only farms whose revenues from livestock production are higher than or equal to 50 % of the farms' total revenues excluding subsidies. Furthermore, we exclude 4 farms which have missing values for key variables such as N value, livestock units and pasture area. In the end, the final sample contains 864 observations from 96 farms for the 9-year period between 2008-2016.

In Table 2.1, we provide summary statistics for the key variables used in the empirical analysis. The average farm size in terms of UAA is 196 hectares (ha). Labour (paid and family labour) on the farm is on average 2.32 annual working units (AWU) that is to say full time equivalents.

¹ 'The Nomenclature of territorial units for statistics, abbreviated NUTS (from the French version Nomenclature des Unités territoriales statistiques) is a geographical nomenclature subdividing the economic territory of the European Union (EU) into regions at three different levels (NUTS 1, 2 and 3 respectively, moving from larger to smaller territorial units)' ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Nomenclature_of_territorial_units_for_statistics_\(NUTS\)\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Nomenclature_of_territorial_units_for_statistics_(NUTS))))

² All values in Euros are deflated by taking 2016 as the base year (source of price indices: INSEE).

To study potential differences in farm behaviour depending on the legal status of farms, we introduce a dummy variable which takes the value 1 for individual farms and 0 otherwise³. Only 10 % of the farms in the sample have the individual legal status.

In order to capture economic performance of farms, we created a variable which computes the overall farm revenue in Euros excluding public subsidies, with an average of 336.6 thousand Euros per farm. Further, we calculate the value of output per hectare aiming to illustrate farm-level economic performance. The farms in the sample produce (subsidies excluded) 1,754 Euros per hectare on average. Another important indicator of farm size for livestock farming is the number of livestock units (LU)⁴. The farms in the sample have 150.4 LU and the livestock density is 0.81 LU per ha of UAA on average. Taking into account that farms in our sample are not fully specialised in livestock farming, since the sample contains mixed crop and livestock farms, we show in Table 2.1 the percentage of output from livestock production with respect to total output. On average, farms in the sample earn 71.1 % of their revenue from livestock production. Public subsidies constitute an important driver of farms' performance (Minviel and Sipiläinen 2018; Boussemart et al. 2019). We compute the total of operational subsidies received per ha by farms, where subsidies include both coupled and decoupled subsidies from the Common Agricultural Policy (CAP). Over the period farms in the sample receive 371.3 Euros per ha of CAP operational subsidies on average.

In order to measure farm level environmental performance, we create four variables. Two variables reflect the extent of pesticide use and fertiliser use respectively, namely the expenses in pesticides (84.8 Euros/ha on average for the sample) and the expenses in fertilisers (154.8 Euros/ha on average) related to the UAA. The third variable to proxy farm performance is the N value on the farms, which is on average 23.24 thousand units per ha of UAA. The fourth variable shows the magnitude of the pasture area in the total farm area. Farms in the sample have 40.4 % pasture area in overall UAA.

To allow the performance comparison of farms with respect to the main livestock production, we create three main types. A farm is classified within a specific livestock specialisation, when

³ In France, there are several forms of farm governance structure that are not individual farms (i.e. EARL (*Exploitations Agricoles à Responsabilité Limitée*), GAEC (*Groupement Agricole d'Exploitation en Commun*), SCEA (*Sociétés Civiles d'Exploitation Agricole*)).

⁴ "A reference unit which facilitates the aggregation of livestock from various species and age as per convention, via the use of specific coefficients established initially on the basis of the nutritional or feed requirement of each type of animal" ([https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_\(LSU\)](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Livestock_unit_(LSU)))

at least two third of its revenue excluding subsidies comes from this livestock activity. We define 3 types of farms: 33 beef cattle farms, 25 dairy farms, 38 mixed (crop and livestock) farms. In Table 2.2, we provide mean values for key variables by livestock specialisation. Farm size of mixed farms is significantly greater than beef cattle and dairy farms' size. This reflects the co-existence of crop and livestock production on the mixed farms. However, mixed farms earn less per ha compared to beef cattle and dairy farms.

Table 2.1: Summary statistics of livestock farms over 2008-2016 (N=96)

	Mean	sd	Min	Q1	Median	Q3	Max
General							
UAA (ha)	196.4	99.5	73.6	133.1	177.7	229.6	680.2
Labour (AWU)	2.32	0.97	1	1.82	2	2.98	6.56
Livestock units (LU)	150.4	67.7	65.1	96.2	133.5	191.6	380.7
Dummy for legal form (1=individual;0=otherwise)	0.1	0.3	0	0	0	0	1
Economic							
Output (1,000€)	336.6	177.0	83.0	223.1	295.0	421.7	1,098.0
Output/UAA (€/ha)	1,754.0	445.3	757.8	1,430.8	1,745.9	2,056.7	2,878.5
Output/LU (€/LU)	2,361.5	882.6	943.3	1,615	2,287.1	2,986.3	5,082.7
Stocking rate (LU/ha of UAA)	0.81	0.25	0.31	0.63	0.78	0.96	1.59
Share of livestock output in total output (%)	71.1	11.7	51.1	61.7	69.7	81.0	98.8
Operational subsidies (€/ha)	371.3	50.5	269.5	335.1	371.5	395.6	580.7
Environmental							
Pesticide expenses (€/ha)	84.8	33.8	22.7	58.6	83.9	112.8	156.0
Fertiliser expenses (€/ha)	154.8	38.6	67.4	126.8	156.4	180.3	234.9
N value/ha (1,000 units)	23.2	15.0	6.1	13.3	17.6	28.9	92.2
Percentage of pasture area in UAA (%)	40.4	16.3	10.2	27.2	39.7	51.4	82.1

Table 2.2: Mean values over 2008-2016 per livestock specialisation

	Beef cattle farms	Dairy farms	Mixed crop and livestock farms
Number of farms	33	25	38
General			
UAA (ha)	193.5	129.5	242.9
Labour (AWU)	2.33	2.06	2.49
Livestock units (LU)	182.2	111.9	148.3
Dummy for legal form (1=individual; 0=otherwise)	0.09	0.12	0.10
Economic			
Output (1,000€)	342.7	245.4	391.4
Output/UAA (€/ha)	1,821.4	1,909.7	1,593.1
Output/LU (€/LU)	1,981.9	2,275.5	2,747.7
Stocking rate (LU per ha of UAA)	0.97	0.89	0.63
Share of livestock output in total output (%)	76.9	80.9	59.6
Operational subsidies (€/ha)	374.8	369.3	369.6
Environmental			
Pesticide expenses (€/ha)	74.5	63.9	107.4
Fertiliser expenses (€/ha)	151.1	139.3	168.4
N value/ha (1,000 units)	21.5	12.9	31.6
Percentage of pasture area in UAA (%)	47.5	44.7	31.4

2.3 Methodology

2.3.1 Environmental indicators

Several indicators are needed to assess environmental performance since there are numerous environmental dimensions. In general, as mentioned above, accountancy data are limited in terms of environmental information. However, compared to classic accountancy databases, we have the N value in quantitative terms in the database used here. Therefore, environmental performance is assessed here with four indicators, reflecting four different environmental

dimensions: (1) expenses in pesticides per hectare in Euros, (2) expenses in fertilisers per hectare in Euros, (3) N quantity per hectare, and (4) percentage of pasture area in UAA.

The first two indicators reflect the intensity of use in pesticides and fertilisers, controlling for the size of the farm. The latter is proxied here with UAA since pesticides and fertilisers are spread on land. The limit in these two indicators is that high expenses may not reflect high quantities used but high price of the inputs. But here we can reasonably assume that in the region Meuse all grazing livestock farms face the same prices. In addition, the third indicator provides complementary information on fertiliser quantity. Finally, the fourth indicator gives information on the farm's potential for own feed and outdoor grazing. Higher indicators indicate lower environmental performance, except for the percentage of pasture whose increase indicates higher environmental performance. These four indicators may not reflect precisely the environmental impacts of farming practices but are computable from accountancy data and can be related to some indicators used by the European Commission to monitor the CAP effectiveness through the common monitoring and evaluation framework (CMEF) and agri-environmental indicators (AEIs).⁵

2.3.2 Clustering

We apply hierarchical clustering on the basis of the four environmental indicators. Hierarchical clustering is a statistical method that classifies farms into groups based on their distance to each other. We will therefore obtain clusters with farms that are similar to each other in terms of environmental performance.

In order to assess whether the evolution over time has an importance, we carry out three strategies for clustering. In the first strategy, clustering is based on the farms' mean values of these four environmental indicators over the whole period 2008-2016. In the second strategy, clustering is based on the rate of change of each environmental indicator between 2008 and 2016 (value in 2016 minus value in 2008, related to value in 2008). Finally, in third strategy, clustering is based on both means and rates of change.

Ward's model of hierarchical clustering is used to create farm typologies in the three strategies (Ward 1963). This methodology is used in the literature of agricultural economics (Latruffe et al. 2016; Micha et al. 2017). In hierarchical clustering, we start with n clusters for n individuals, and then create clusters with similar individuals until we have one big cluster. We use the R

⁵ https://ec.europa.eu/info/food-farming-fisheries/sustainability/environmental-sustainability/cap-and-environment_en

software package NbClust (Charrad et al. 2014). There are numerous (28) different indices that can be used to determine the optimal number of clusters, but the decision must also be made on practical reasons such as ease of analysis and visibility. As an example, in the case of our second clustering strategy, 13 indices out of 28 suggest to determine the number of clusters to two clusters (see Table 2.6 in Appendix). Indeed, when the number of clusters is increased to 3, the third cluster is made of one single farm only. For the sake of comparison, we keep the number of two clusters for all three clustering strategies.

2.4 Clustering results

2.4.1 First clustering strategy

In the first clustering strategy, the clustering is based on the abovementioned four environmental indicators as averages over the full period 2008-2016. In Table 2.3, we provide mean values of the 2 clusters identified. The four environmental indicators indicate that Cluster A is less environmentally-friendly than Cluster B on average. More precisely, farms in Cluster A spend 117.1 €/ha for pesticides on average, while this value is 61.6 €/ha for Cluster B. Similarly, Cluster A has an average of 181.5 €/ha for fertiliser expenses while the figure for Cluster B is 135.8 €/ha. The same is observed for N value. Namely, farms in Cluster A have an N value of 32.6 (1,000 units/ha) on average, while Cluster B has an N value of 16.6 (1,000 units/ha). Finally, the percentage of pasture area in UAA is higher for Cluster B with an average value 50.5 %, while in Cluster A the percentage is 26.2 %.

The evolution of environmental indicators between 2008 and 2016 by clusters is presented in Figures 2.1, 2.2, 2.3 and 2.4 in Appendix. We see that expenses in pesticides (Figure 2.1) stay more stable over the period compared to expenses in fertilisers (Figure 2.2). More precisely, for the fertilisers we observe a significant decrease in expenses between 2009 and 2010, whereas the expenses in pesticides stay relatively stable for this period. This suggests that farmers demand for pesticides is less elastic than their demand for fertilisers. The evolution of N value is stable for both clusters on the whole period 2008-2016 (Figure 2.3). Similarly, the percentage of pasture area has a stable evolution for both clusters with a slight decrease in Cluster B (Figure 2.4).

Table 2.3: Mean values over 2008-2016 per cluster for the first clustering strategy

	Cluster A	Cluster B	p-value for difference
Number of farms			
All farms	40	56	
Beef cattle farms	8	25	
Dairy farms	5	20	
Mixed farms	27	11	
Variables used in clustering			
Pesticide expenses (€/ha)	117.1	61.6	<0.01
Fertiliser expenses (€/ha)	181.5	135.8	<0.01
N value/ha (1,000 units)	32.6	16.6	<0.01
Percentage of pasture area in UAA (ha)	26.2	50.5	<0.01
Variables not-used in clustering			
UAA (ha)	235.0	168.8	<0.01
Labour (AWU)	2.57	2.14	0.03
Dummy for legal form (1=individual; 0=otherwise)	0.07	0.12	0.43
Output (1,000€)	431.8	268.6	<0.01
Output/UAA (€/ha)	1,890.1	1,656.9	0.01
Output/Livestock units (€/LU)	3077.9	1849.8	<0.01
Livestock units (LU)	146.9	153.0	0.67
Stocking rate (LU per ha of UAA)	0.65	0.93	<0.01
Share of livestock output in total output (%)	63.2	76.7	<0.01
Operational subsidies (€/ha)	376.5	367.6	0.4
Rate of change in pesticide expenses (2008-2016) (%)	0.22	0.17	0.59
Rate of change in fertiliser expenses (2008-2016) (%)	0.14	0.11	0.78
Rate of change in N value (2008-2016) (%)	0.17	0.16	0.88
Rate of change in pasture area (2008-2016) (%)	-0.11	-0.09	0.59
Rate of change in UAA (2008-2016) (%)	0.05	0.04	0.72
Rate of change in total labour (2008-2016) (%)	-0.11	-0.06	0.42
Rate of change in output (2008-2016) (%)	-0.1	-0.06	0.3
Rate of change in output/UAA (2008-2016) (%)	-0.15	-0.08	0.11
Rate of change in output/LU (2008-2016) (%)	-0.13	-0.14	0.81
Rate of change in LU (2008-2016) (%)	0.1	0.16	0.47
Rate of change in stocking rate (2008-2016) (%)	0.05	0.14	0.28

Rate of change in subsidies per ha of UAA (2008-2016) (%)	-0.18	-0.07	0.01
Rate of change in share of livestock in total output (2008-2016) (%)	0.1	0.14	0.38
<i>The p-values are obtained with the t-test for the difference between clusters' means.</i>			

Cluster A has 40 farms, including 8 beef cattle farms, 5 dairy farms and 27 mixed farms, while Cluster B is made of 25 beef cattle farms, 20 dairy farms and 11 mixed farms. The farms in the less environmentally-friendly cluster A have larger UAA (235 ha in average) and higher output per hectare (1890.1 Euros/ha) than farms in the more environmentally-friendly Cluster B. The majority of the sample's mixed farms belong to Cluster A (71 %). It is worth noting that these mixed farms that are in Cluster A have significantly higher output per hectare than the sample mean (Table 2.2). These mixed farms, sharing characteristics of both crop and livestock farms, have fewer livestock units on average than farms in Cluster B. For Cluster A, 63.2 % of the total output (excluding subsidies) come from livestock production, while this percentage is 76.7 % for the farms in the Cluster B. Similarly, in Cluster A the stocking rate (LU per ha of UAA) is 0.65 LU/ha compared to 0.93 LU/ha in Cluster B.

The bottom part of Table 2.3 shows the change in the environmental indicators and other variables over the period for both clusters. The figures show that farms with a lower average environmental performance over the period (Cluster A) also have a worse evolution of this performance over the period, although the difference for the rates of change with Cluster B is not significant. Farms in Cluster A record a stronger increase rate in pesticide and fertiliser expenses, and a stronger decrease in the share of permanent pasture.

In summary, when basing the clustering on the whole period's average indicators, we find that the farms identified as less environmentally-friendly over the period (Cluster A) perform better from an economic point of view (output per ha and subsidies per ha) on average (Figure 2.5). However, in terms of evolution, the farms have become even less environmentally-friendly over the period and decreased more their performance than the more environmentally-friendly farms. This reveals that considering only the average values over the period could lead to misleading conclusion. In Figure 2.6, we observe that the difference between both clusters in terms of economic performance decreases through time. Hence, on a static point of view, while we could be tempted to conclude that low environmental performance goes with high economic performance, from a dynamic point of view the conclusion is reverse: a decrease in environmental performance goes with a decrease in economic performance.

2.4.2 Second clustering strategy

In the second clustering strategy, clustering is based on the rate of change in the four indicators between 2008 and 2016. In Table 2.4, we display mean values of these rates of change as well as additional variables for both clusters. Cluster B shows a significant increase in pesticide and fertiliser use between 2008 and 2016. Namely, the expenses per hectare for pesticides and fertilisers are increased on average by 47 % and 42 %, respectively. Similarly, there is an average increase in the per ha N value by 44 %, while the percentage of the pasture area in UAA is diminished by 33 % on average. The farms in Cluster A have a more stable evolution between 2008 and 2016. Their expenses on pesticides have increased by 6 % only, while there is a decrease in the expenses on fertilisers by 2 % on average. The N value stays more stable in Cluster A than in Cluster B, with an average increase of 3 %. And the percentage of the pasture area for Cluster A is decreased only by 1 % on average between 2008 and 2016. Cluster B has thus a worse environmental performance when the latter is defined as rates of changes over the period.

Cluster A is made of 65 farms namely 25 beef cattle farms, 20 dairy farms and 20 mixed farms. In Cluster B, we have 31 farms including 8 beef cattle farms, 5 dairy farms and 18 mixed farms. The farms in the less environmentally-friendly Cluster B have larger UAA compared to farms in Cluster A (208 vs. 190.9 ha). The labour force (in AWU) has similar values for both clusters (2.33 for Cluster A and 2.31 for Cluster B on average). In terms of legal form, individual farms represent 11 % in Cluster A, while they represent 10 % in Cluster B. Farms in the more environmentally-friendly Cluster A have higher output per hectare with 1,789.4 €/ha compared to Cluster B which has 1,680 €/ha on average. The same pattern is observed for the herd size. The farms in Cluster A have fewer LU compared to Cluster B (149.0 LU vs. 153.5 LU), respectively. When we look at the stocking rate (LU per ha of UAA), Cluster A has higher value compared to Cluster B on average (0.83 LU/ha and 0.79 LU/ha, respectively). The farms in Cluster A are more livestock oriented. In Cluster A 72.3 % of the farm output comes from livestock production, while this share is 68.5 % for Cluster B. The subsidies received per ha by Cluster A farms are slightly lower than Cluster B on average (368.8 € and 376.6 €, respectively). In general however, both clusters show limited differences in the farms' average structural and economic characteristics, as none are significantly different between both clusters. However, the rates of change of economic variables are significantly different, with the more environmentally-friendly Cluster A showing a lower decrease in output per ha but a higher decrease in subsidies per ha, than the less environmentally-friendly Cluster B.

Table 2.4: Mean values over 2008-2016 per cluster for the second clustering strategy

	Cluster A	Cluster B	p-value for difference
Number of farms			
Total	65	31	
Beef cattle farms	25	8	
Dairy farms	20	5	
Mixed farms	20	18	
Variables used in clustering			
Rate of change in pesticide expense (2008-2016) (%)	0.06	0.47	<0.01
Rate of change in fertiliser expense (2008-2016) (%)	-0.02	0.42	<0.01
Rate of change in N value (2008-2016) (%)	0.03	0.44	<0.01
Rate of change in pasture area (2008-2016) (%)	0.01	-0.33	<0.01
Variables not-used in clustering			
UAA (ha)	190.9	208.0	0.43
Labour (Annual Working Units-AWU)	2.33	2.31	0.95
Dummy for legal form (1=individual; 0=otherwise)	0.11	0.10	0.87
Output (1,000€)	333.6	343.0	0.81
Output/UAA (€/ha)	1,789.4	1,680.0	0.26
Output/Livestock units (€/LU)	2356.2	2372.7	0.93
Livestock units (LU)	149.0	153.5	0.76
Stocking rate (LU per ha of UAA)	0.83	0.79	0.43
Share of livestock output in total output (%)	72.3	68.5	0.14
Operational subsidies (€/ha)	368.8	376.6	0.48
Output/LU (€/LU)	2,356.2	2,372.7	0.93
Pesticide expenses (€/ha)	82.9	88.7	0.44
Fertiliser expenses (€/ha)	153.8	157.1	0.69
N value/ha (1,000 units)	22.3	25.1	0.4
Percentage of pasture area in UAA (%)	40.9	39.2	0.64
Rate of change in UAA (2008-2016) (%)	0.02	0.10	0.02
Rate of change in total labour (2008-2016) (%)	-0.08	-0.08	0.94
Rate of change in output (2008-2016) (%)	-0.07	-0.09	0.61
Rate of change in output/ha of UAA (2008-2016) (%)	-0.08	-0.17	0.05
Rate of change in output/LU (2008-2016) (%)	-0.17	-0.07	0.03
Rate of change in LU (2008-2016) (%)	0.18	0.03	0.1

Rate of change in stocking rate (2008-2016) (%)	0.17	-0.05	0.01
Rate of change in subsidies/UAA (2008-2016) (%)	-0.13	-0.1	0.5
Rate of change in share of livestock in total output (2008-2016) (%)	0.19	-0.01	<0.01
The p-values are obtained by the t-test for the difference between sample means of clusters.			

It is also interested to study the average values for the four environmental indicators over the whole period. While Cluster A is clearly identified as the more environmentally-friendly cluster on the basis of rates of change of environmental performance, Cluster A is not significantly different from Cluster B in terms of average values of environmental performance over the period. The average values are close and their difference is not significant. Notably, the expenses on pesticides and fertilisers per ha are 82.9 €/ha (88.7 €/ha) and 153.8 €/ha (157.1 €/ha) for Cluster A (Cluster B respectively). The average value for N (1,000 units/ha) is equal to 22.3 for Cluster A, while it is equal to 25.1 for Cluster B. Finally, the percentage of the pasture area in UAA has similar values too. The farms in Cluster A have 40.9 % pasture area and this share is 39.2 for Cluster B.

In summary, when basing the clustering on the rate of change of environmental performance, the environmentally-friendly cluster, which shows more favourable changes in environmental performance over the period, also shows the better performance in terms of rate of change of output per ha, but the worse performance in terms of rate of change of output per LU and subsidies per ha. And when only averages over the period are considered, both clusters are not significantly different in terms of both environmental performance and economic performance. This again highlights the importance of considering the evolution rather than a period average.

2.4.3 Third clustering strategy

In the third clustering strategy, we combine the two approaches already used for the first and the second clustering strategies. In other words, we base the clustering on 8 decision variables: average values over the period, and rates of change of the four indicators between 2008 and 2016 per farms. In Table 2.5, we provide mean values of these 8 decision variables and other variables. On average terms, the farms in Cluster A have larger average pesticide and fertiliser expenses and N value, but no significantly different rates of change. However, they have a lower average percentage of pasture area and a significant greater decrease in pasture area, than Cluster B. This reveals that Cluster A can be considered as the less environmentally-friendly cluster. More precisely, Cluster A has an average value of 125.6 €/ha and 191.2 €/ha for

expenses in pesticides and fertilisers respectively. For Cluster B these values are 70.4 €/ha and 142.0 €/ha, respectively. The N value is also higher for Cluster A compared to Cluster B with values of 40.5 and 17.2 (1,000 units/ha) respectively. The farms in Cluster A have a lower average share of pasture area in UAA of 24.9 % compared to Cluster B whose figure is 45.8 %. The rates of changes for the four environmental indicators between 2008-2016 show that the pesticides expenses have risen by 19 % for both clusters. Similarly, the expenses in fertilisers increased by 10 % for Cluster A and by 13 % for Cluster B during the period of 2008-2016. The rate of pasture area in UAA has decreased for both clusters. The decrease is higher for Cluster A with 17 %, while this decrease is equal to 7 % on average in Cluster B.

Table 2.5: Mean values over 2008-2016 per cluster for the third clustering strategy

	Cluster A	Cluster B	p-value for difference
Number of farms			
All farms	25	71	
Beef cattle farms	5	28	
Dairy farms	1	24	
Mixed farms	19	19	
Variables used in clustering			
Pesticide expenses (€/ha)	125.6	70.4	<0.01
Fertiliser expenses (€/ha)	191.2	142.0	<0.01
N value/ha (1000 units)	40.5	17.2	<0.01
Percentage of pasture area in UAA (%)	24.9	45.8	<0.01
Rate of change in pesticide expense (2008-2016) (%)	0.19	0.19	0.98
Rate of change in fertiliser expense (2008-2016) (%)	0.10	0.13	0.84
Rate of change in N value (2008-2016) (%)	0.15	0.17	0.83
Rate of change in pasture area (2008-2016) (%)	-0.17	-0.07	0.08
Variables not-used in clustering			
UAA (ha)	282.2	166.2	<0.01
Labour (Annual Working Units-AWU)	3.04	2.07	<0.01
Dummy for legal form (1=individual; 0=otherwise)	0	0.14	0.05
Output (1,000€)	520.0	272.0	<0.01
Output/UAA (€/ha)	1,888.7	1,706.6	0.08
Output/Livestock units (€/LU)	3205.1	2064.5	<0.01
Livestock units (LU)	173.3	142.4	0.05

Stocking rate (LU per ha of UAA)	0.63	0.88	<0.01
Share of livestock output in total output (%)	61.6	74.4	<0.01
Operational subsidies (€/ha)	381.1	367.9	0.26
Rate of change in UAA (2008-2016) (%)	0.08	0.04	0.29
Rate of change in total labour (2008-2016) (%)	-0.1	-0.07	0.71
Rate of change in output (2008-2016) (%)	-0.1	-0.07	0.63
Rate of change in output/UAA (2008-2016) (%)	-0.16	-0.09	0.15
Rate of change in output/LU (2008-2016) (%)	-0.16	-0.13	0.56
Rate of change in LU (2008-2016) (%)	0.12	0.14	0.81
Rate of change in stocking rate (2008-2016) (%)	0.04	0.12	0.43
Rate of change in subsidies/UAA (2008-2016) (%)	-0.18	-0.1	0.06
Rate of change in share of livestock in total output (2008-2016) (%)	0.13	0.13	0.98
The p-values are obtained by the t-test for the difference between sample means of clusters.			

Cluster A is made of 25 farms namely 5 beef cattle farms, 1 dairy farm and 19 mixed farms. Cluster B has 71 farms including 28 beef cattle farms, 24 dairy farms and 19 mixed farms. Contrary to the second clustering strategy, in this third clustering the values describing farm characteristics that are not used in the clustering process, show significantly different tendencies. Firstly, on average the farms in Cluster A have a larger UAA (282.2 vs 166.2 ha in Cluster B) and uses more labour (3.04 AWU vs 2.07 AWU in Cluster B). The legal forms of farms in both clusters are significantly different. None of the farms in Cluster A has an individual status, while the share of individual farms is 14 % in Cluster B. Cluster A shows significantly higher per ha output compared to Cluster B. The average output per ha is 1,888.7 Euros per ha, while the figure is 1,706.6 € for Cluster B. This finding is quite interesting, considering the high presence of mixed farms in Cluster A. In the whole sample mixed farms have a lower output per ha compared to other specialisations with 1,593.1 Euros/ha (see Table 2.2). Therefore, this result implies that there are heterogeneities between mixed farms in terms of output per ha. The mixed farms which use pesticide and fertiliser inputs more intensively, also produce more output compared to other mixed farms. However, this relation between input use and output per ha may be misleading. More precisely, some mixed farms are more oriented to crop (livestock, respectively) farming and therefore, may have higher (lower, respectively) values for pesticides expenses per ha.

The farms in Cluster A have a larger herd size, namely 173.3 LU compared to 142.4 LU in Cluster B. However, when we look at the stocking rate (LU per ha of UAA), Cluster A has a smaller average value compared to Cluster B (0.63 and 0.88 LU/ha, respectively). The magnitude of livestock production in total farm output is lower in Cluster A compared to Cluster B (61.6 % and 74.4 %, respectively). Finally, farms in Cluster A receive higher subsidies per ha than farms in Cluster B with respective figures of 381.1 Euros/ha and 367.9 Euros/ha.

In summary, when basing the clustering on both whole period's average values and rates of changes of indicators, only average values are significantly different between both clusters as well as the rate of change for pasture area. The less environmentally-friendly cluster (Cluster A) displays higher output per ha on average over the period but a stronger decrease in subsidies per ha, compared to the more environmentally-friendly cluster (Cluster B).

2.5 Conclusion

In this study, we investigated the trade-offs between environmental and economic performance between 2008 and 2016 for a sample of livestock farms in the French North-Eastern region Meuse. Contrary to other studies which investigate farms' performance in a specific year, we considered here the evolution of performance in the long term, taking into account not only the period's averages but also the rates of changes between 2008 and 2016.

To assess whether different clustering strategies can give varying results, we carried out three types of clustering. In the first clustering strategy, clustering was based only on farms' average values of indicators over the whole period. This clustering reveals that the farms who are less environmentally-friendly (they use more pesticide and fertiliser inputs and have a lower share of pasture area) are more economically performing in terms of average output per ha of UAA. In the second clustering strategy, clustering was based on the rate of changes between 2008 and 2016 period for the four environmental indicators. The reason was to account for the possible evolution during this time period. Results of this clustering strategy show that the less environmentally-friendly farms are those that have a worse deterioration of environmental performance indicators between 2008 and 2016, than farms in the other cluster. Both clusters however do not distinguish significantly in terms of average environmental indicators over the period. In terms of economic performance, the average output per ha of UAA is not significantly

different between both clusters, but the rate of change between 2008 and 2016 is significantly worse for the less environmentally-friendly farms. Lastly, in a third clustering strategy, we combined the first two clustering strategies to see whether this can capture better environmental performance. However, both clusters distinguish significantly only in terms of period's average environmental indicators, similarly to the first clustering strategy, and not in terms of rates of change. In terms of economic performance, in line also with the first clustering strategy, the less environmentally-friendly farms have a significantly higher average output per ha of UAA.

To sum up, this analysis provides some insightful results to understand the relation between environmental and economic characteristics. Results imply that there is a negative correlation between environmental performance and economic performance when averages over the 9-year period are considered. However, when we take into account the evolution over time, this correlation becomes non-significant. Our findings therefore highlight that the trade-off between environmental and economic sustainability is rather ambiguous, and depends whether we take an average picture or the evolution over time. The negative correlation between environmental performance and economic performance on average would suggest that improving environmental performance may not be profitable for farms. However, this is not true when the evolution over time is considered. This suggests that it is important to consider a long period when comparing farms in terms of environmental and economic performances. This is important for sustainability since the latter is related to long term performance. What matters is the sustainability target, and not only the yearly performance situation.

The contribution of this study is that we show that a trade-off between economic and environmental performances may exist if we do not include the time dimension in the analysis. More precisely, we show that the inclusion of the time dimension weakens the trade-off relationships between these two pillars of farm sustainability. Considering this, we recommend that the complex nature of farm sustainability can be better understood if we analyse farmers' decisions' and farming practices' evolution in time. In this sense, time-oriented targeting policies may have more efficient results on the development of farm sustainability.

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2.7 Appendix

2.7.1 Tables

Table 2.6: Different indices to choose the optimal number of clusters in the second clustering strategy

Number	Method	Optimal number	Index value
1	DB	2	0.1513
2	Silhouette	2	0.8109
3	Duda	2	0.6747
4	PseudoT2	2	44.8459
5	Beale	2	1.1518
6	PtBiserial	2	0.7368
7	Gap	2	0.3228
8	Frey	2	17.8751
9	McClain	2	0.0039
10	Gamma	2	1
11	Gplus	2	0
12	Dunn	2	1.0732
13	SDindex	2	4.1866
14	Scott	3	84.8874
15	TrCovW	3	90.2694
16	TraceW	3	7.1039
17	Cindex	3	0.2322
18	Ratkowsky	3	0.3632
19	Ball	3	12.3898
20	KL	4	10.7459
21	CH	4	57.3349
22	Hartigan	4	18.4001
23	Rubin	4	-0.3697
24	Tau	4	709.1664
25	Marriot	6	1654.7875
26	Friedman	8	4.6742
27	CCC	15	0.4367
28	SDbw	15	0.1275

2.7.2 Figures

Cluster graphs based on first clustering strategy

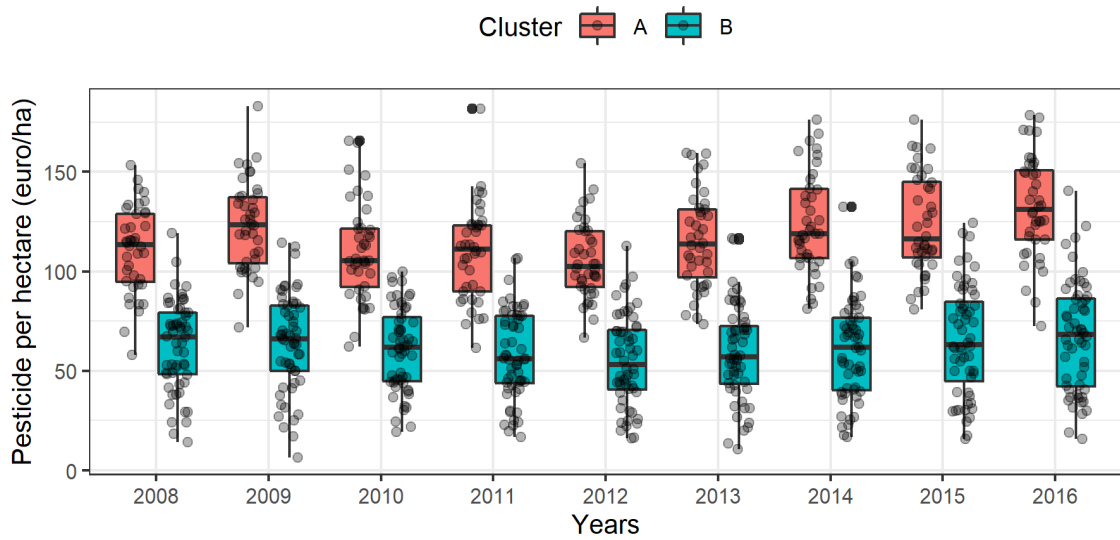


Figure 2.1: Per hectare pesticide expenses per year for each cluster

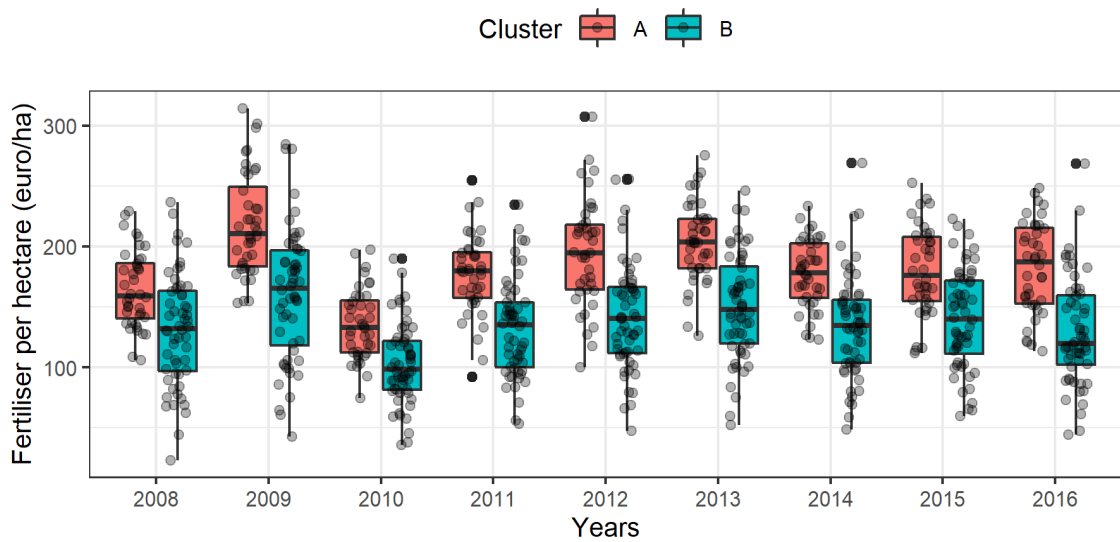


Figure 2.2: Per hectare fertiliser expenses per year for each cluster

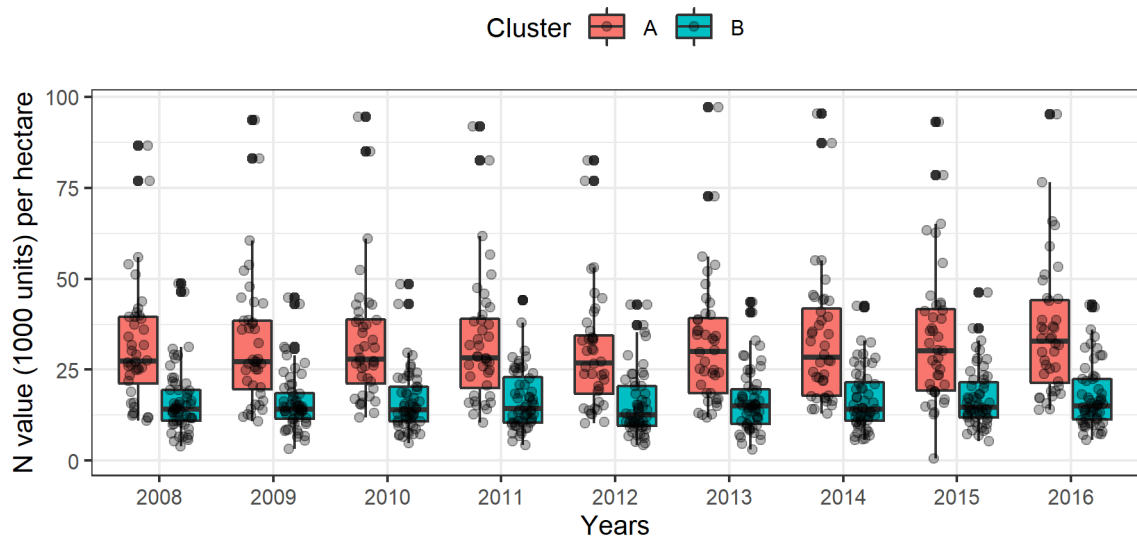


Figure 2.3: Per hectare N value per year for each cluster

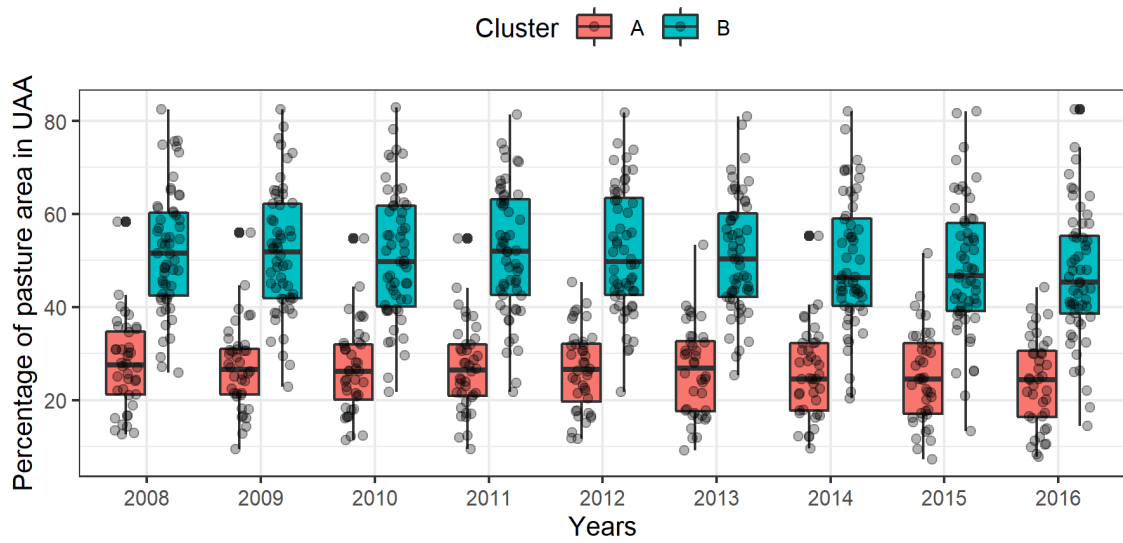


Figure 2.4: Percentage of pasture area per year for each cluster

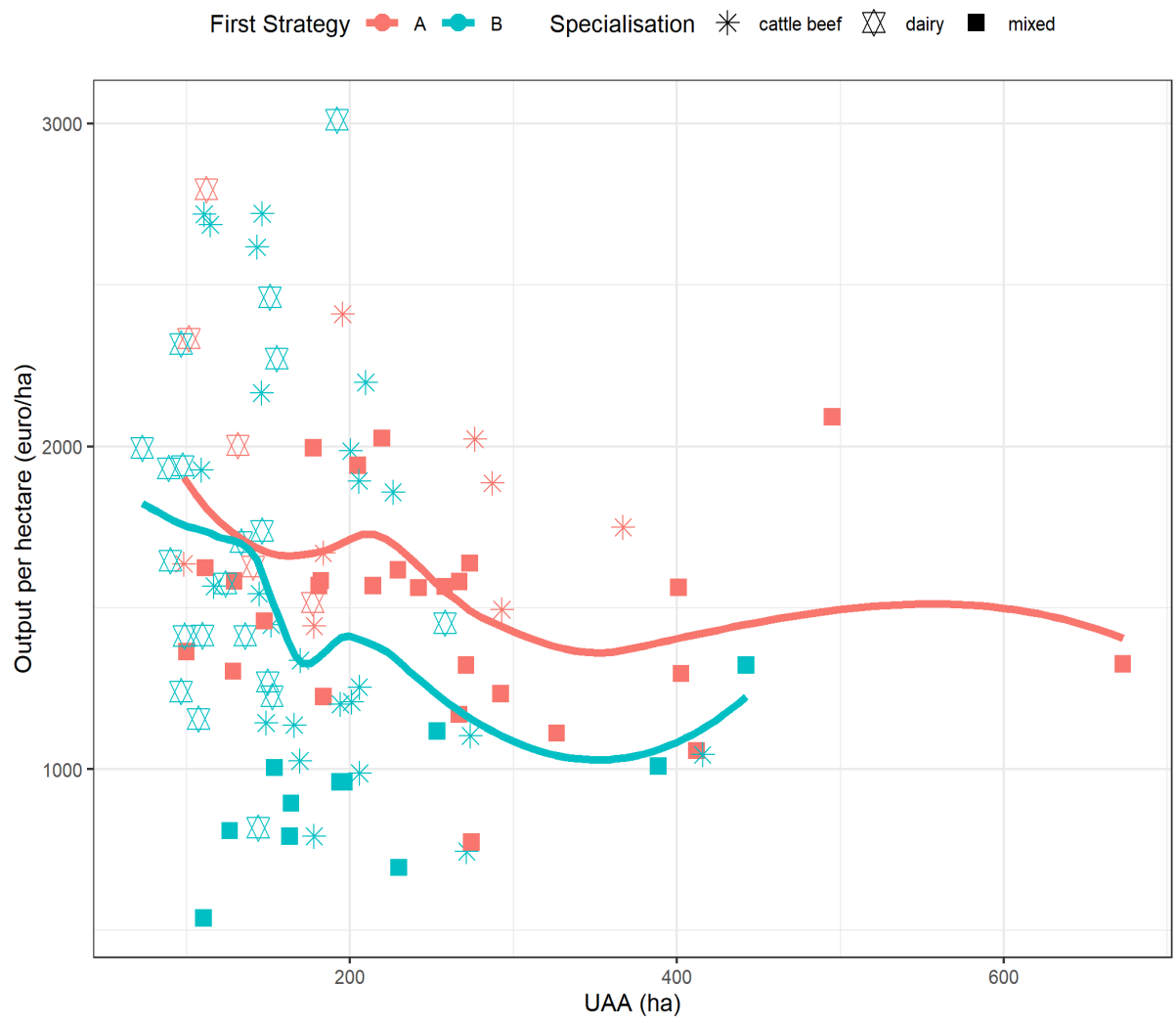


Figure 2.5: Per hectare output and UAA per cluster in 2016 (96 farms)

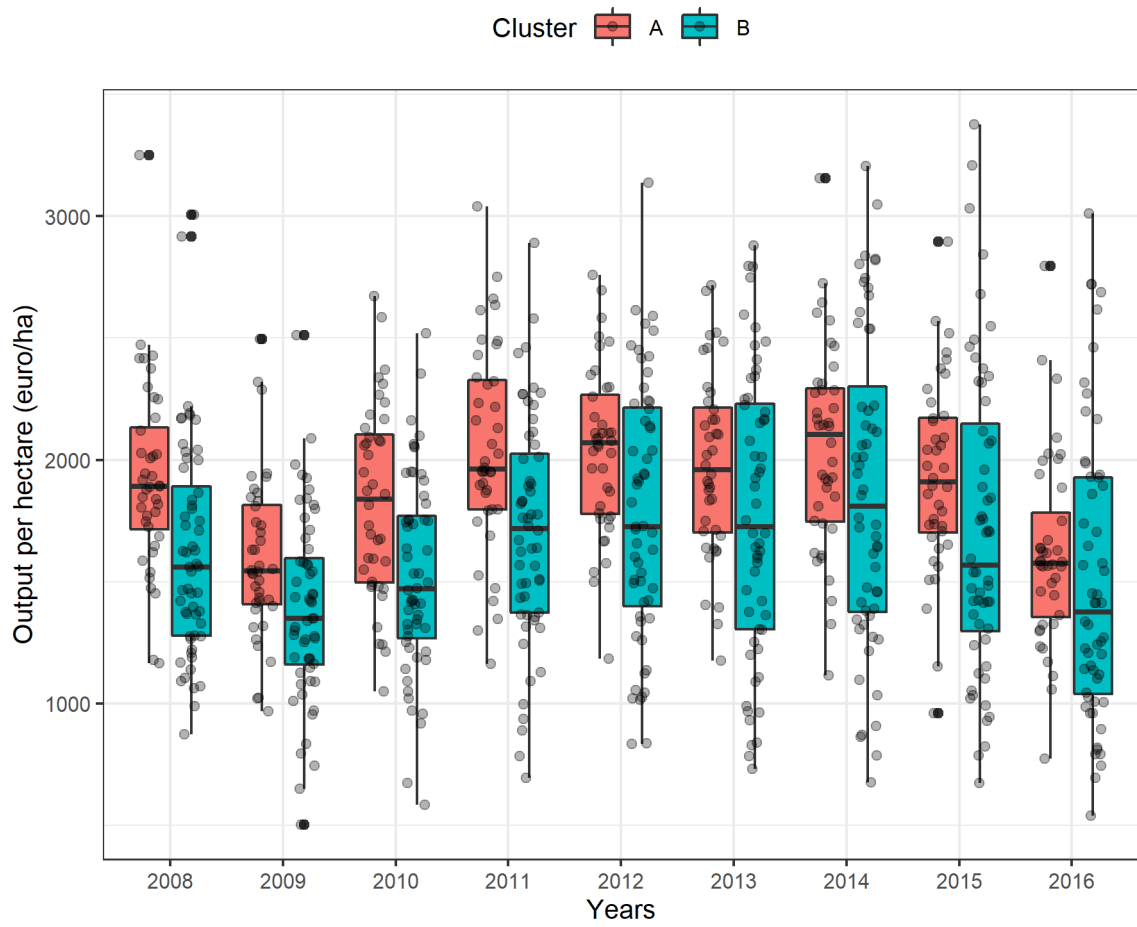


Figure 2.6: Per hectare output per year for each cluster for first strategy

Chapter 3 Agricultural cooperatives and farm sustainability – A literature review*

Chapter 1 * Published in Journal of Economic Surveys <https://doi.org/10.1111/joes.12417> . Co-written with Sabine Duvaleix and Laure Latruffe

3.1 Introduction

The supply of agricultural goods that are more sustainable is expected to increase in response to increasing consumer sensibilities and governments' initiatives in the future (Saitone and Sexton, 2017). In this context, farmers are expected to produce in a sustainable way, reconciling all dimensions of sustainability; namely, economic, environmental and social. Assessments of farm sustainability, as well as of the underlying factors, are numerous in the empirical literature (Dessart *et al.*, 2019). These factors relate to farmers' socio-demographic characteristics (e.g. age, education), farm's characteristics (e.g. organisational structure, size, indebtedness, main production), and external factors such as the type of supply chain, market prices and government interventions (Rasmussen *et al.*, 2017; Hansson *et al.*, 2019; Malak-Rawlikowska *et al.*, 2019). However, the role of supply chain organisation has been under-investigated so far, in particular as regards environmental and social sustainability. We contribute to the literature by considering agricultural cooperatives, key actors in food supply chains.

Agricultural cooperatives have substantial market shares in agri-food supply chains in western countries (40% in agri-food sectors in the European Union (EU) in 2010). Within the EU, the cooperatives' market share for the whole agricultural sector exceeds 50% in Austria, Denmark, Finland, France, Ireland, The Netherlands and Sweden (Bijman and Iliopoulos, 2014). Moreover, in the case of highly perishable products, farmers may be even more likely to engage in vertical integration via cooperatives (57% and 42% in the dairy and fruit and vegetable sectors, respectively, in the EU) (Bijman *et al.*, 2012). In the United States (US), dairy cooperatives marketed more than 75% of the milk produced in the country in 2017 (Wadsworth, 2019). Moreover, the market shares of cooperatives differ considerably with respect to sectors and countries. In 2010, in the olive oil sector, the Spanish cooperatives' market share was 70%, while in Italy it was 5%. In Denmark and France, the market shares of pig meat cooperatives reached 86% and 94%, respectively, while in the other EU countries, the figures were much lower (Bijman *et al.*, 2012).

Thus, cooperatives cover a large part of the agricultural sectors, and could therefore play a role in the improvement of farm sustainability. Through their close relationships with farmers, agricultural cooperatives may be key actors in supply chains to help farmers change their agricultural practices and to favour the adoption of more sustainable practices. Cooperative values such as democratic decision-making, equality and solidarity give cooperatives a unique identity, which differentiates them from other types of enterprise and implies that they have a

distinct organisational characteristic (ICA, 2020). Solidarity within the cooperative enables farmers to cope with market risks and favours investment by sharing fixed costs. As cooperatives' members are the owners, investors and users of the cooperative, agricultural cooperatives have thus a large spectrum of action. They can design incentives to encourage farmers to change their practices through the services provided, a stronger market position and the pooling of investments resulting in cost sharing among members. Cooperatives may also promote the adoption of these practices by decreasing farmers' perceived risks and by making investment more feasible. However, some deficiencies exist in cooperatives' governance, especially in monitoring and management that can impede the changes. The unique governance structure of cooperatives may then have mixed effects since the majority of members might not favour the changes needed. Membership heterogeneity may even diminish farmers' incentives.

Our main objective is to review and discuss the literature on the role played by agricultural cooperatives in farm sustainability. Our contribution to a better understanding of agricultural cooperatives is twofold. First, we gather a diversified set of theoretical models to examine how the economic behaviour of agricultural cooperatives differ from other organisations. As no unified modelling of the economic behaviour of cooperatives exists, we discuss the different features of the cooperatives' behaviour and we explain their main theoretical weaknesses. Second, we provide insights about how agricultural cooperatives may influence farm sustainability. The empirical literature is rich, however unbalanced between developing and developed countries. We specifically investigate the three dimensions of sustainability and we highlight the topics that are scarcely covered.

The article is structured as follows. The next section gives background on the economic behaviour of agricultural cooperatives and on criticisms faced by them. The third section reviews the empirical studies that examine how cooperatives may favour sustainable practices. The last section concludes.

3.2 Economic behaviour of agricultural cooperatives

The theoretical literature about the economic behaviour of cooperatives has been built through several waves since the seminal work of Nourse in 1922 and followed by the work of Philipps (1953) and Helmberger and Hoos (1962) which present two contrasting strands: the cooperative as an extension of individual farms and the cooperative as a firm. Since then, three waves of

literature have enriched the understanding of cooperatives' economic behaviour: the first one in the eighties (Levay, 1983; Staatz, 1983; Vitaliano, 1983; Sexton, 1986), the second one at the end of the nineties (Cook, 1995; Fulton, 1995; Hart and Moore, 1996; Albæk and Schultz, 1998; Zago, 1999; Fulton and Giannakas, 2001), the last one in the 2010's (Rey and Tirole, 2007; Bontems and Fulton, 2009; Hovelaque *et al.*, 2009; Saitone and Sexton, 2009; Pennerstorfer and Weiss, 2013; Agbo *et al.*, 2015; Fulton and Pohler, 2015; Hueth and Marcoul, 2015; Mérel *et al.*, 2015; Liang and Hendrikse, 2016; Peng *et al.*, 2018). This section presents the theoretical background on the behaviour of cooperatives from the most recent ones, the second and third waves, followed by an explanation of their main theoretical weaknesses as found in the agricultural economics literature. First, the well-known weaknesses are described, then we focus on the specific issue of farmer heterogeneity.

3.2.1 Theoretical background

In the economics literature, there are various attempts to define a cooperative as a different form of economic organisation (Cook *et al.*, 2004; Soboh *et al.*, 2009). There is no agreement amongst scholars about the economic definition of agricultural cooperatives (Tortia *et al.*, 2013). Depending on theoretical reasoning, economists develop different models to assess cooperatives' economic behaviour. The difference between cooperatives and investor-owned firms is usually tied to the governance structure (Hendrikse and Bijman, 2002; Bontems and Fulton, 2009; Hueth and Marcoul, 2015; Peng *et al.*, 2018); that is to say, to the decision-making process. Table 3.1 in the appendix presents a synthesis of the different economic objectives. Cooperative members may independently decide on the quantity and quality they choose to deliver to the cooperative. In this case, the decision-making process is “decentralised”, meaning that the cooperative does not have any restrictive power on the quantity supplied by individual farmers (Albæk and Schultz, 1998). Alternatively, decision-making can be taken as “centralised” in which cooperatives maximise their profit under additional constraints as compared with investor-owned firms. Marketing cooperatives can be regarded as a constrained supply chain; that is to say that the cooperative must buy all raw material delivered by its members (Hovelaque *et al.*, 2009).

Some scholars investigate in more detail the governance structure in cooperatives by introducing a board of directors and/or managers into theoretical frameworks using principal-

agent models (Fulton and Pohler, 2015; Hueth and Marcoul, 2015). They define cooperatives as a form of coalition among farmers with similar objectives (Hueth and Marcoul, 2006; Hueth and Marcoul, 2015). In this coalition approach, the cooperative is regarded as a nexus of contracts in which farmers engage in a collective effort. This approach offers insightful results especially as regards members' involvement in the cooperative's investment choices. As Hueth and Marcoul (2015) point out, cooperative members face a trade-off between direct involvement in monitoring activity and working with a professional manager. The investment activity in the cooperative depends then on the farmers' monitoring choice, which depends on the cost structure of agent monitoring. Farmers' involvement in the monitoring activity may give the cooperative an advantage that is linked to incentive complementarity.

Theoretical works to assess the economic characteristics of cooperatives' decision-making focus on the farmers' specific role in cooperatives. As member-owned and democratically ruled enterprises, cooperatives are expected to prioritise their members' economic gains. Indeed, in contrast to investor-owned firms, the cooperative's objectives are generally not limited to profit maximisation. In the pioneering work of (Helmberger and Hoos, 1962), the cooperative maximises the price paid to farmers while the cooperative profit is equal to zero. Hence, the specificity of cooperatives refers mainly to the pricing strategy for the raw product delivered by their members. Cooperatives do not consider the price paid to farmers as a simple cost variable. Members are expected to receive higher prices from cooperatives than investor-owned firms (Sexton, 1990; Fulton and Giannakas, 2013). Accordingly, cooperatives behave like non-profit organisations that aim to improve members' welfare. Cooperatives maximise members' benefits under the constraint of ensuring their viability. In the literature, this viability condition is written as the break-even constraint. That is to say, the cooperative operates with zero profit, which ensures the compensation of the cooperative's production and operational costs. At the same time, the higher prices paid to farmers by cooperatives may force other firms to raise the prices of farmers' products, a mechanism called the competitive yardstick effect (Liang and Hendrikse, 2016; Carletti *et al.*, 2018). Intuitively, the yardstick effect may be beneficial in coping with the monopsonistic power of firms by improving farm level prices. In this case, investor-owned firms are forced to increase the prices paid to farmers in order to compete with the cooperatives.

In an imperfect competition setting, cooperative members supply more raw product than other farmers who supply through investor-owned firms (Helmberger and Hoos, 1962, Albæk and Schultz, 1998; Pennerstorfer and Weiss, 2013). Albæk and Schultz (1998) claim that this

particularity of cooperatives may give them market power in the case of oligopolistic competition, and the cooperative might dominate the market in the long-run. Bontems and Fulton (2009) investigate input procurement in two separate cases: a cooperative that maximises member welfare; and an investor-owned firm that maximises profit. Farmers' heterogeneity is characterised by the cost structure. The authors show that, when the cooperative and its members' objectives are aligned, the cooperative is more efficient than the investor-owned firm. Agbo *et al.* (2015) construct a theoretical model in which cooperative members have the opportunity to sell their product directly in a local market. They show that the coexistence of both options of selling directly through the local market and selling via a cooperative improves farmers' welfare. The originality of this study is that the local market scenario is taken to be an imperfect competition situation in which the quantity produced impacts market prices, while the cooperative is a price-taker in a completely competitive market.

Finally, agricultural cooperatives may also be defined as vertically integrated organisations which aim at maximising members' welfare (Soboh *et al.*, 2012). Agricultural cooperatives, however, should be distinguished from traditional vertical integration since farmers can behave differently in these two organisational schemes. Farmers who become vertically integrated with investor-owned firms become employees and thus have fewer incentives to improve product quality (Reimer, 2006). Incentives might be even lower with asymmetric information because of the principle-agent problem. In the case of vertical integration via cooperatives, however, farmers' economic incentives for innovations that improve quality can be preserved. More precisely, farmers who wish to improve product quality may be more numerous in the case of production via cooperatives. Hence, the creation of an agricultural cooperative provides a more efficient way of vertical coordination in terms of adoption of new farm-level practices. The theoretical literature on agricultural cooperatives explores quality choices (Hoffman, 2005; Saitone and Sexton, 2009; Pennerstorfer and Weiss, 2013; Mérel *et al.* 2015). Product differentiation often consists of two products with different quality levels. Hoffmann (2005) analyses the endogenous quality choice in an oligopolistic market, with a model of duopolistic competition (investor-owned firm versus cooperative) with differentiated products. In the case of convex variable cost with respect to product quality, the cooperative produces higher quality than an investor-owned firm. Pennerstorfer and Weiss (2013), who investigate quality choice in cooperatives, show that if the marginal return in quality improvement is increasing with total quantity supplied, the issue of overproduction of agricultural cooperatives may give them an

advantage in quality improvement. The relationship between quantity-quality decisions can thus create a positive feedback effect. Giannakas and Fulton (2005); Drivas and Giannakas (2010) investigate the innovation decision in duopolistic competition between an investor-owned firm and a cooperative. The authors examine theoretically market mechanisms with the introduction of an innovation. They show that the presence of profit maximising investor-owned firms and member-welfare maximising cooperatives can increase the innovation activity in the market. Thus, the presence of a cooperative may be welfare enhancing and socially desirable. More precisely, the involvement of the agricultural cooperative in innovation increases with producers' heterogeneity and with the level of fixed costs.

3.2.2 Major challenges faced by cooperatives

Recognised economic weaknesses

Despite their above-mentioned economic advantages, cooperatives have long been criticised in the economic literature (Cook and Chaddad, 2004). They have particularly been criticised in terms of their poor economic performance (Porter and Scully, 1987; Fulton, 1995; Notta and Vlachvei, 2007; Hirsch *et al.*, 2020). This is linked to the fact that agricultural cooperatives have limited powers to restrict the quantity supplied by farmers. In the case of imperfect competition, the cooperative has a tendency to oversupply since individual farmers do not bear the full marginal profit loss when they increase their production level (instead, they share it at the cooperative level).

A crucial weakness is that overproduction may arise when the cooperative is a price maker in the final market (Albæk and Schultz, 1998). Open membership in agricultural cooperatives is thus viewed as a deficiency, which reduces the competitive power of cooperatives because of the adverse selection problem. More precisely, the output-pooling mechanism in cooperatives may increase the number of low quality producers who benefit from average quality level (Saitone and Sexton, 2009). However, this negative effect of open memberships is mitigated by the competitive yardstick effect. Mérel *et al.* (2015) investigate the trade-off between these two effects. They compare situations of open membership and closed membership in a differentiated product setup. They show that in the open membership case, the farmers benefit from the risk-reducing advantage of the cooperative and from higher product prices.

Finally, the horizon problem in cooperatives implies that they may suffer from underinvestment issues related to intergenerational conflicts (Rey and Tirole, 2007; Giannakas *et al.*, 2016). In

the case of an investment that becomes profitable in the long run, older farmers tend to disagree with younger members about the implementation of such investment, because the former are close to exiting farming activities, meaning that they would not benefit from the realised investment. Therefore, in the context of innovative investment, the horizon problem may limit the cooperative's performance. This problem is directly linked to non-transferability issues in the cooperatives, in the sense that the members of cooperatives cannot easily liquidate their previous investment if they withdraw from the cooperative.

Member heterogeneity: a key underpinning issue

Farmers' heterogeneity, giving rise to governance issues in cooperatives, is a key underpinning issue of the above-mentioned weaknesses. Farms and farmers indeed have different characteristics, creating information asymmetry and discrepancies among members. Farmer heterogeneity in agricultural cooperatives is characterised differently in the literature (Höhler and Kühl, 2018). This heterogeneity may come from various factors such as farm size and cost structure (Plakias and Goodhue, 2015), type of product (Mérel *et al.*, 2015) or members' personal characteristics such as age, risk aversion, preferences (Elliott *et al.*, 2018). Membership heterogeneity also leads to governance issues (Hansmann 1988; Hart and Moore, 1996; Zago, 1999; Deng and Hendrikse, 2015). In an early work, Hart and Moore (1996) construct a model which examines farmer heterogeneity in a cooperative. In this approach, the dominant farmer group takes the decision about the final quality by maximising the profit of their group. Zago (1999) develops a theoretical framework to examine the quality of the final cooperative product. The heterogeneity of farmers delivering higher quality product may influence the decision-making of the cooperative. In a setup with the "one member-one vote" principle, the member group which is in the majority dominates the cooperative's choice of the quality level. In this respect, farmers with similar objectives may positively influence the cooperative's economic performance (Bontems and Fulton, 2009). Farmers may have different preferences, objectives, and goals but the most cited types of member differences that can be observed or measured are when members differ in farm level characteristics (e.g., size, leverage, and efficiency), geography, and personal characteristics (e.g., socioeconomic status, age and risk aversion).

Theoretical literature about the quality decisions in cooperatives provides useful insights into the advantages and drawbacks of cooperatives in terms of quality improvement. In these

studies, special attention is given to farmer heterogeneity (Hart and Moore, 1996; Zago, 1999; Saitone and Sexton, 2009). The general finding regarding this issue is that cooperatives' decisions with respect to product quality are dependent on the dominant farmers' group. The "median voter" makes the quality decision in the cooperative level. If farmers who have a higher incentive to invest in high quality product are in the majority, then the cooperative produces at a quality level which is even superior to the first best option. Another theoretical approach is based on quality decisions in a mixed duopoly case (cooperative versus investor-owned firm) (Giannakas and Fulton, 2005; Hoffmann, 2005; Drivas and Giannakas, 2010). The difference between the two types of organisation is often shown in the form of different objective functions. In these models, the cooperative may provide a higher quality level in the case of high innovation costs, depending on cost structure. Moreover, when the quality of products supplied by members to the cooperative is not observable, the free riding problem may emerge. Several factors can explain heterogeneity in quality at the farm level. For instance, external shocks (such as bad weather conditions) affecting agricultural production may limit some farmers' capacity to produce high-quality product (Saitone and Sexton, 2009). Moreover, farm exogenous characteristics (such as soil fertility) may create productivity disparities among farmers. Hence, farmers may have different propensities to free ride. Bonroy *et al.* (2019) analyse the free riding behaviour of cooperative members on product quality in an experimental setup. In this model, farmers' individual quality decisions affect the collective rent from the final product. Taking into account that the production cost increases as product quality increases at the farm level, free riding is characterised as a dominant strategy. However, as the authors explain, punishment may limit free riding. In their model, punishment is in the form of exclusion. In this case, the farmer has a trade-off between, on the one hand, free riding and having a non-zero probability of being excluded from the cooperative and, on the other hand, revealing the true quality information. The authors conclude that in games with few players, farmers tend to cooperate, but an increasing number of farmers increases the cases where free-riding behaviour dominates the game. As the authors suggest, one solution to this problem is to create sub-divisions within the cooperative. Indeed, reducing group size increases the incentives to cooperate. In addition, creating groups with similar characteristics (implicitly similar economic objectives) may enhance the cooperation.

As shown in this second section, the theoretical literature offers a variety of frameworks for agricultural cooperatives. The main aim of this section was to shed light on the cooperatives' distinct characteristics and their economic performance. Agricultural cooperatives, by

eliminating double marginalisation (that is to say, eliminating supply chain intermediaries and thus pricing over marginal cost at each stage in the supply chain) and by aiming to improve member welfare, may be beneficial for farmers. Nevertheless, the cooperatives' specific organisational features, combined with the issue of members' heterogeneity, can create some deficiencies linked to investment decisions (the horizon problem), to asymmetric information (free riding on quality) and to overproduction.

3.3 Empirical studies: can cooperatives influence farm sustainability?

Our objective is to assess whether cooperatives influence farm sustainability. For this, we provide a comprehensive review of the existing empirical literature linking cooperative membership and farm sustainability, in terms of economic, environmental or social dimensions. We explain the literature findings in light of the theoretical aspects of cooperatives explained in the previous section. More precisely, we examine the empirical studies that draw conclusions on at least one of the three pillars of sustainability; namely, economic, environmental or social. The results of those empirical studies are summarised in Table 3.3 in the appendix. Most empirical studies show a positive effect of agricultural cooperatives on farm sustainability. However, in this section, we also highlight some negative effects underlined in the empirical literature.

In terms of methodology, we performed a search in the EconLit and Google Scholar databases using the keywords 'agricultural cooperatives', 'cooperative membership', 'farm practices', 'innovation', 'environmentally-friendly' and 'farm sustainability' over the period 2010-2020. This search allowed us to identify potentially relevant studies. We also screened the most recent literature applied in developing countries, but only selected studies which were published in the agricultural economics literature and which deal with environmental or social issues. We also include in our review some articles that were quoted in the literature selected from the databases, as well as empirical studies that specifically examine quality issues in cooperatives, for two reasons. First, this literature illustrates well the cooperative governance issues when member heterogeneity is wide. Second, consumers may value differently some environmentally-friendly or fair trade practices and are thus willing to pay for a product with an environmental or a social attribute. Thus, we can get some insights from the literature into

how cooperatives may enhance quality. Finally, we included studies that were recommended by the reviewers of the present article.

3.3.1 Cooperatives' economic role

Cooperatives may influence the economic performance of their members. This has mostly been discussed for developing countries. A large number of empirical studies in such countries have been devoted to the impact of farmers' membership of a cooperative on the farms' productivity (Wossen *et al.*, 2017; Ma *et al.*, 2018a; Ortega *et al.*, 2019; Manda *et al.*, 2020; Zhang *et al.*, 2020) or on farmers' incomes (Ma and Abdulai, 2016; Mojo *et al.*, 2017; Hoken and Su, 2018; Kumar *et al.*, 2018; Liu *et al.*, 2019; Ofori *et al.*, 2019). These studies emphasise the positive role of joining a cooperative on members' economic sustainability. The impact of cooperative membership may vary depending on farm size. Hoken and Su (2018) and Kumar *et al.* (2018) show that the relative impact of cooperative membership on farm income is larger for small-scale farms. Wollni and Fischer (2015) find that small-scale farmers benefit from being a member of a cooperative either because of their lack of bargaining power or because the opportunity cost is too low. They also show that large-scale farms gain from being a cooperative member since they can enjoy scale economies in processing and marketing activities. This effect is demonstrated by Liu *et al.* (2019) who find a larger positive impact of cooperatives on farm income for larger farms. In developed countries, the literature gives evidence of a wider economic impact of cooperatives: impacts for non-members (yardstick effects), and a mixed effect on quality since quality requirements are higher worldwide.

From the theoretical hypothesis of cooperative pricing rules, cooperatives can provide higher prices (Milford, 2012; Hanisch *et al.*, 2013; Jardine *et al.*, 2014). Hanisch *et al.* (2013) investigate empirically the competitive yardstick effect of agricultural cooperatives on prices paid to farmers. They find that, in the European dairy sector, agricultural cooperatives offer higher farm-gate prices to farmers. Moreover, their empirical results prove that a higher market share of cooperatives increases this effect even further. The authors underline that the competitive yardstick effect is beneficial for farmers who are not cooperative members. This result is in accordance with a positive spill-over effect of agricultural cooperatives (Jardine *et al.*, 2014). One can expect that agricultural cooperatives pay farmers more than the marginal value of product. Milford (2012) also finds a pro-competitive price effect of cooperatives in

Mexico, although her hypothesis of a stronger effect when considering the cheating behaviour of intermediaries was not confirmed by her qualitative analysis.

The orientation of cooperatives towards quality differentiation may decrease the marginal cost of innovation, thus encouraging the adoption of these practices by other firms in the market. Jardine *et al.* (2014) analyse the impacts of the creation of an agricultural cooperative in Alaska's salmon fish industry. They conclude that the creation of the cooperative increased the prices received by local fishermen. Moreover, the investor-owned firms competing with the cooperative then adopted the new fishing production system. The existence of cooperatives may facilitate quality improvements in the whole supply chain by also decreasing innovation costs for other farmers who are not members of the cooperative. In the poultry sector, Cechin *et al.* (2013) also find that producers who deliver to the cooperative have, on average, higher quality performance. Cooperatives may also help farmers to cope with market imperfections. This is especially true in developing countries, where membership of cooperatives increases the probability of farmers benefitting from global markets. This opportunity to export can encourage farmers to engage in quality improvement via product differentiation. Cooperatives, by providing farmers with access to larger national and international high quality markets, may offer higher prices and more reliable contracts (Wollni and Zeller, 2007; Milford, 2012; Cechin *et al.*, 2013). Cooperatives can choose different ways to signal the product quality to consumers (Grashuis and Magnier, 2018). They can create their own brands. By doing so, cooperatives may create a product differentiation for consumers who have positive perceptions towards the cooperative product. Alternatively, they can choose to use a collective quality label, such as a geographical indication, which provides certain restrictions on the farming system and/or the processing. Fares *et al.* (2018) analyse the relationship between these two different strategies in small French cooperatives. They show that cooperatives with stronger ties to other cooperatives tend to engage in collective labels, whereas others choose to create independent brands. They also show that there is a substitution effect between the two strategies.

However, possible organisational problems in cooperatives can affect overall product quality negatively. Pennerstorfer and Weiss (2013) show that cooperatives provide lower product quality compared to investor-owned firms through the empirical part of their study on the quality choice in the Austrian wine industry. By using data about the Austrian wine market during 2004-2007, they find that the wine quality is significantly lower in cooperatives compared to investor-owned firms. One explanation provided by the authors is that the free riding problem in product quality, where members who benefit from quality rents in the

cooperative may cheat on product quality, might reduce the incentives of farmers to increase product quality. Another explanation provided is that in the Austrian wine market, the size of cooperatives is significantly higher than that of investor-owned firms. Furthermore, asymmetric information is one of the main limitations faced by farmers when considering adoption (Chavas and Nauges, 2020). In many cases, farmers struggle with foreseeing the economic benefits of new practices. Despite this, cooperatives play an important role in encouraging the adoption of environmentally-friendly practices by members.

3.3.2 Cooperatives' role in encouraging environmentally-friendly practices

Overall, agricultural cooperatives may influence farmers to adopt environmentally-friendly practices and agricultural innovation, thus increasing farm environmental sustainability (Gonzalez, 2018). Bareille *et al.* (2017) explore how the alignment of objectives between a multipurpose cooperative and its members influences member commitment. The authors show that the adoption of new agricultural practices has a small but significant effect. In other words, innovative activities may help farmers to have converging economic objectives and greater incentives to be involved in the cooperative. Furthermore, several studies show empirically the role of cooperative membership in technology adoption and in the adoption of environmentally-friendly practices (Abebaw and Haile, 2013; Ma *et al.*, 2018b; Zhou *et al.*, 2018; Ma and Abdulai, 2019; Yu *et al.*, 2021). Ma *et al.* (2018b) show that being a cooperative member increases the probability of investing in organic amendment. Yu *et al.* (2021) find that cooperative membership has a significant and positive impact on the adoption of green control techniques that include ecological regulation, biological and physical control and the scientific use of chemical pesticides. Ma and Abdulai (2019) also show the role of cooperative membership in sustainable practices by focusing on integrated pest management technology. Zhou *et al.* (2019) illustrate that farmers have some difficulties in satisfying quality restrictions in terms of pesticide use in the Chinese fruit and vegetable sector. They show empirically that the involvement of cooperatives may help farmers to reduce pesticide use. Chinese cooperatives, by being involved in the production stage via quality standards and input purchase, improve environmental quality. Consequently, in developing countries, farmers engaged in cooperatives may have higher incentives to improve the product quality (Hao *et al.*, 2018).

Other empirical studies examine the beneficial impact of technical assistance in favouring farmers' environmentally-friendly behaviour (Naziri *et al.*, 2014; Ji *et al.*, 2019). Technical assistance services can substantially influence farmers' decisions about whether to adopt the practices with higher fixed costs. Naziri *et al.* (2014) find that the technical assistance offered by cooperatives increases the farmers' propensity to change their practices by reducing pesticide residues in the vegetable sector in Vietnam. Ji *et al.* (2019) examine the Chinese hog industry and conclude that farmers who are engaged in cooperatives have significantly higher incentives to adopt safe production practices. They identify safe practices as either when the input sourcing channel meets the safety and quality standards or when a pig farmer strictly follows the recommended production methods. They include feed use, breed use, vaccination, drug use and waste disposal. They also show that the effect is heterogeneous.

Finally, by providing technical assistance and reducing transaction costs, agricultural cooperatives can also help farmers to improve their productivity and their profits (Van Herck, 2014), reduce their cost of production (Bonroy *et al.*, 2019) or adapt to specific quality requirements (Cechin *et al.*, 2013). Most studies are applied to developing countries, as mentioned by Grashuis and Su (2019). They, by reviewing the literature, show that membership of a cooperative increases farm income through better access to inputs and technical expertise (Bernard and Spielman, 2009; Fischer and Qaim, 2012; Wollni and Fischer, 2015). Cooperatives, especially those in developing countries, may help farmers adopt innovations that decrease production costs or increase farm level productivity. However, this may have adverse consequences in terms of environmental impacts through the intensification of agriculture. This is for example underlined by Abebaw and Haile (2013) in the case of Ethiopian cooperatives helping farmers to adopt fertilisers, improved seeds and pesticides to improve their production, but that may lead to detrimental impacts on the environment. In this respect, one may even argue that cooperative membership can cause deterioration in the environmental quality of products when chemical fertilisers and pesticides are adopted.

3.3.3 Cooperatives' social role

A farmer's choice to be integrated in an agricultural cooperative can be related to non-monetary factors. Many studies examine the determinants of membership commitment and the role of trust (Hansen *et al.*, 2002; Morrow *et al.*, 2004; Roe *et al.*, 2004; Nilsson *et al.*, 2009; Österberg

and Nilsson, 2009; Barraud-Didier *et al.*, 2012; Bareille *et al.*, 2017). However, empirical studies explicitly exploring the social role of cooperatives are scarce. The main conclusion of the few existing studies is that being a member of a cooperative has a positive impact (Hernández-Espallardo *et al.*, 2013; Bareille *et al.*, 2017). Hernández-Espallardo *et al.* (2013) show that “non-price” factors provide higher incentives to stay in a cooperative than prices. Farmers may prefer to accept lower prices if the cooperative can cope with transaction cost problems such as securing market access, providing information about the cooperative management and helping farmers to meet market requirements and society expectations. Bareille *et al.* (2017) find a surprising result about the effect of the territorial presence of a cooperative, which is measured as market access facilitation to all outputs produced on each farm. Members seem to be more loyal to their cooperative in areas where the cooperative is not well established.

Different aspects of the social role of cooperatives can be found in the literature such as employment (Michalek *et al.*, 2018), gender effect (Serra and Davidson, 2020) or knowledge (Hagedorn, 2014) for instance. Michalek *et al.* (2018) highlight the positive effect of cooperative membership on farm employment for the cooperative members. Serra and Davidson (2020) assess how cooperative membership can allow women smallholders to improve their economic outcomes. They show that cooperative membership significantly improves market price and quantity in the honey sector for these women. However, their membership does not allow them to increase their market power. This is in contrast to Ferguson and Kepe (2011) who show that in Uganda women extract non-monetary benefits from being part of cooperatives; namely, increased negotiating skills and ability to take decisions. Other studies deal with the provision of social capital. Zhou *et al.* (2018) show that cooperatives can help farmers to make better use of chemical inputs when associated with a high level of social capital (communication, trust and common goals). This allows the cooperative to help farmers to provide safe food. Hagedorn (2014) indicates that Lithuanian cooperatives create knowledge and capacity building for members. Yu and Huang (2020) show that societal impacts of cooperatives must be taken into account when assessing their efficiency. They define societal impacts as the services and assistance the Chinese cooperatives provide to non-members. The study of Figueiredo and Franco (2018) in Portugal also considers not only cooperative members but the rural sector in general. The authors show that agricultural cooperatives have multiple impacts on their members through training or technical support and are able to promote local development, for example by the use of local resources. In line with this, Hagedorn (2014)

mentions, for the case of cooperatives in Slovakia, that they provide social services to members and contribute to the local development. However, in contrast to the communist period where these were social objectives per se, they are nowadays “by-products” of economic objectives. This is in contrast to Bulgarian cooperatives where such non-profit activities are still very much present and take the role of safety nets in poor rural areas. Cooperatives contribute to public infrastructure such as roads and street lighting, and provide services such as kindergartens, sports facilities and inexpensive canteens and food shops.

3.4 Conclusion

The objective of this article was to assess the role of agricultural cooperatives in food supply chains in farm sustainability. Our literature review, both theoretical and empirical, shows that economists from different backgrounds study this issue. One part of the literature is mostly theoretical, and considers the behaviour of farmers in a cooperative. This approach provides analytical insights into the impacts of market power, farmers’ heterogeneity, adoption costs and the availability of quality-related information when farmers are members of a cooperative. In contrast, the other part of the literature is purely empirical and generally investigates the role of agricultural cooperatives in an ad hoc way, by introducing in the econometric analyses one driver that represents the relationship of the farmers with their cooperative. While this can help derive stylised facts about the agricultural sector, it lacks systematic conclusions which could help build scenarios and design sound recommendations. To our knowledge, there has been no academic attempt to link these two strands of literature. The empirical literature about the determinants of farmers’ adoption of sustainable practices aims at investigating a large array of determinants in order to identify the most important ones for a specific case study. In contrast, the literature on cooperatives based on industrial organisation theory focuses on a specific type of organisation and demonstrates theoretically whether it has an impact on welfare. In this case, empirical applications would necessitate some specific data that are generally lacking.

Regarding the different historical backgrounds of cooperatives and technical characteristics of agricultural sectors, one can argue that more contextual works, both at the sector and country level, are needed to fill the gap between theoretical and empirical studies. One reason is that there are more empirical studies relating to developing countries. Indeed, newly-founded and rural development-oriented cooperatives in these countries provide generally positive evidence

about quality in cooperatives. Cooperatives often provide various economic advantages to farmers by decreasing the information gap and market uncertainties. The incentives for farmers to engage in cooperatives may be linked to access to markets at the international level. By acquiring different labels (e.g. organic, fair trade) and cooperative brands, farmers may benefit from export-oriented high quality production. The major mechanism is linked to the cooperatives' impacts for coping with market imperfections in favour of farmers. In high-income countries by contrast, these effects are not so strong. Cooperatives may have cost-driven objectives to dominate markets. For example in the EU, cereal, sugar and pig meat cooperatives are oriented more towards market power via cost reduction than value creation (Höhler and Köhl, 2014). In addition, the theoretical literature investigates deeply the possible problems arising from farmers' heterogeneity and from the different economic objectives within the cooperative. Analytical results from these studies fit better with cooperatives in high-income countries where cooperatives historically have more market power. Several studies find that cooperatives can obtain efficiency gains through growing (Gezahegn et al., 2019; Pokharel and Featherstone, 2019; Musson and Rousselière, 2020). However, becoming a larger organisation may imply a decrease in membership commitment (Fulton and Giannakas 2001). Large cooperatives may thus be less efficient organisations than investor-owned firms (Hirsch et al. 2020). This is related to their governance characteristics: in the presence of heterogeneous membership, the voting system may lead to ineffective decisions because the cooperative's strategy is not accepted by all members (Hansmann, 1988; Hart and Moore, 1996, Deng and Hendrikse, 2015). It is also worth noting that all cooperatives do not act as responsible firms or truly democratic firms. For instance, large cooperatives may, at one point, find that the democratic process is too binding to stay competitive. These cooperatives are democratic only formally and in fact behave as investor-owned firms (Nilsson *et al.*, 2009). In that case, they are neither socially nor environmentally responsible either. Furthermore, legislations in many countries have allowed the cooperative firms to get external investors such as in France, Italy or China. Overall, there is a lack of studies on the role of supply chain organisation, and in particular that of cooperatives, and on the adoption of farmers' sustainable practices, whether ad hoc or theoretical. However, we believe that this is a promising avenue for research and a topical issue, in the context of the growing scarcity of public subsidies. Several solutions or incentives, both from private or public sources, have been proposed in the literature to increase the adoption of ecological practices by farmers; for example, by improving their education, delivering better extension services to them, developing specific inputs or equipment, or providing public support. This article shows that cooperatives play a non-negligible role in farm

economic sustainability and in the adoption of environmentally-friendly practices, suggesting that both public policies and private initiatives in cooperatives may be complementary. As regards social sustainability, there are only a few studies existing on the role of agricultural cooperatives. This is in line with the literature in general, where the social dimension of sustainability is still poorly investigated, due to the complexity of this dimension (encompassing both private aspects and public aspects) and to the difficulties of measuring it (Bond *et al.*, 2012). Another issue that would need further investigation is the trade-off between economic and environmental sustainability in cooperatives, and whether these objectives are compatible, complementary, “by-products” of each other, or in competition.

3.5 References

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3.6 Appendix

Table 3.1: Theoretical studies on cooperatives' economic objectives (mathematical notations are defined below the table)

Reference of the study	Market structure	Theoretical framework and main hypotheses	Objective function	Results
Agbo <i>et al.</i> (2015)	Perfectly competitive outside market and oligopolistic local market	Direct selling vs. selling through the cooperative Members' heterogeneity Homogenous product	$\max_w \pi_c = (P - w) \sum q_j$	Co-existence of direct selling and selling via cooperative may be beneficial for farmers.
Albæk and Schultz (1998)	Mixed duopoly Investor-owned firm vs. cooperative	Homogenous product	$\max_q \left(a - (Q^{iof} + Q_{-i}^c + q) \right) q - \frac{1}{2} c^F q^2$	Positive effects of overproduction: the tendency to overproduce increases cooperative market power.

Bontems and Fulton (2009)	Investor-owned firm monopoly vs. cooperative monopoly (separately examined in the article)	Principal-agent problem Information asymmetry for the cooperative Members' heterogeneity Homogenous product	Complete information case: $\max_{q(\cdot), t(\cdot)} \int_{\underline{\theta}}^{\bar{\theta}} W(\pi(\theta)) dF(\theta)$ Subject to: $\pi(\theta) = t(\theta) - \theta c^F(q(\theta)) - f \geq 0$ $\max_{q(\cdot), t(\cdot)} \int_{\underline{\theta}}^{\bar{\theta}} [R(Q) - t(\theta)] dF(\theta)$ (break even condition)	Cooperative may be more efficient when members have similar economic objectives.
Fulton and Giannakas (2001)	Mixed duopoly (Investor-owned firm vs cooperative)	Consumer heterogeneity for cooperative's and investor-owned firm's goods	Maximisation of member surplus (MS): $\max_{P, c} MS = (U - P + \lambda) x_c - \frac{1}{2} \lambda x_c^2$	Positive feedback between member commitment and cooperative reputation

Giannakas and Fulton (2005)	Mixed duopoly (Investor-owned firm vs supply cooperative)	Farmer heterogeneity Cost reducing innovation	Maximisation of member welfare (MW): $\max_P MW = (P^{Farm} - P) X_c - \frac{1}{2} \mu X_c^2$	The presence of a cooperative may promote adoption rate of the innovation.
Hart and Moore (1996)	Consumer cooperative median voter	Median voter Members' heterogeneity Homogenous product	$\max U_i (P) = \frac{q_i (\bar{v} - P)^2}{\bar{v} - \underline{v}} + \frac{\left[\frac{1}{2N-1}\right] Q (\bar{v} - P) (P - c^F)}{\bar{v} - \underline{v}}$	The cooperative is first best efficient if, and only if, the median voter has average preferences.
Hoffmann (2005)	Mixed duopoly (Investor-owned firm vs. cooperative)	Quality choice	$\Pi_c = P_i q_i - c^F_i - c^C_i$ i = {L, H} (L)low quality and (H) for high quality	In the presence of variable cost of quality in farm level, the cooperative provide higher quality than the IOF.

Hovelaque <i>et al.</i> (2009)	Cooperative	Stochastic demand for differentiated products	$\max_{Q_i} \pi_c = (PE(Q, X) - c^F Q) - F - A$	The cooperative has an advantageous position when the prices of basic products increase.
Liang and Hendrikse (2016)	Mixed duopsony (Investor-owned form vs. cooperative)	<p>Quality choice in a differentiated final market.</p> <p>Cooperative has pooling price strategy.</p> <p>Heterogeneity in farmers' quality.</p>	<p>farmer's payoff in cooperative:</p> $(P - c - \frac{F}{N})$ <p>IOF's payoff:</p> $(PQ - \sum wq - F)$	<p>High quality farmers tend deliver their product to the IOF rather than the cooperative.</p> <p>The presence of the cooperative decrease market prices.</p>
Peng <i>et al.</i> (2018)	Cooperative (monopoly)	Process and product innovations choices in decentralised and centralised governance structures	<p>Decentralised cooperative</p> <p>Farmer i's payoff:</p> $\pi_i = (\bar{v}c + d - Q)q_i - c_i^F q_i - \frac{1}{2}r(hc)_i^2 - \frac{1}{2}\epsilon(vc)_i^2$	Decentralised cooperative dominates when communication costs are intermediate.

Centralised cooperative

Cooperative payoff:

$$\begin{aligned} \pi_c = & (\bar{v}c + d - Q)(q_1 + \\ & q_2) - c_1^F q_1 - c_2^F q_2 - \\ & \frac{1}{2}r(hc)_1^2 - \frac{1}{2}r(hc)_2^2 - \\ & \frac{1}{2}\epsilon((vc)_1 + (vc)_2)^2 \end{aligned}$$

Pennerstorfer and Weiss (2013)	Investor-owned firm monopoly vs. cooperative monopoly (separately examined in the article)	Homogenous final product	$\max_{q,k} \pi_c = P(Q, K)q - c(q, k)$	Overproduction may decrease marginal costs in quality improvement.
Saitone and Sexton (2009)	Cooperative monopoly and mixed market case (separately examined in the article)	Quality pooling Vertical product differentiation	$\max_{0 \leq \delta \leq 1} MW$	Quality pooling may decrease incentives of farmers to overproduce high-quality product.
Soboh <i>et al.</i> (2012)	Perfect competition	Study of cooperative efficiency through the comparison with investor-owned firm Homogenous final product	$\max_{w,Q,x} \pi_c = PQ + q^*w - xz$ <p>Subject to:</p> $PQ - q^*w - xz \geq 0$ $q^* = \sum q$	Cooperatives underperform compared to investor-owned firms in terms of efficiency.

Wollni and Fischer (2015)	Mixed oligopsony	Farmers have the choice to deliver their produce to a cooperative or to an investor-owned firm	$\max_{\delta_i} \pi_i = R_i^{iof} + R_i^c + g_i^u - c_i^{iof} - c_i^c$	Delivering to cooperatives is more profitable for small-scale farmers than large-scale farmers.
Zago (1999)	Consumer demand depends on quality (market structure not indicated in the article)	Median voter Heterogeneity Pooling quality final product (homogenous final product)	High quality majority(H): $\max_{w^H, k^H} (w^H - c^F(w^H, H))$ <p>Subject to incentive compatible constraints, participation constraint and break even constraint.</p>	The quality level decided by the high quality majority is higher than first best scenario.

Table 3.2: Mathematical notations

A	Retaining earning of cooperative
c^F	Farmer's cost of production
c^C	Cooperative level cost of production
ϵ	Cost coefficient for vertical communication
F	Fixed cost of cooperative
g_i^u	Individual payoff from the public collective good
hc	Intensity of horizontal communication
k	Product quality of raw product
K	Product quality in cooperative level
MW	Member welfare
MS	Member surplus
$NARP$	Net average revenue product
N	Number of members
P	Price
Π_C	Cooperative profit

q	Quantity produced at the farm level
Q	Quantity produced at the cooperative level
R	Revenue
λ	Utility enhancement variable linked to cooperative good
U	Utility
vc	Intensity of vertical communication
\overline{vc}	Average level of vertical communication
w	Price paid to farmers for raw product
W	Cooperative manager's maximisation function
r	Cost coefficient for horizontal communication
x	Quantity of inputs except from raw product delivered by farmers
X_c	Cooperative quantity
y	Parameter for consumer disutility
\overline{v}	Cooperative price level where the demand is zero
\underline{v}	Cooperative price level where the demand stops rising
z	Price of inputs except from raw product delivered by farmers

Table 3.3: Empirical studies on cooperative membership and farm sustainability

Authors	Data	Methodology	Impact of cooperative membership on farm sustainability dimension: positive significant impact (+), negative significant impact (-), non-significant impact (NS)		
			Economic	Environmental	Social
Abdul-Rahaman and Abdulai (2018)	2016 Ghana Rice	Propensity Score Matching (PSM) Stochastic Production Frontier (SPF)	Farm yield (+) Technical efficiency (+)		
Abebaw and Haile (2013)	2009 Ethiopia Crop	PSM	Technology adoption (+)		
Bareille et al. (2017)	2013 France	Multinomial Probit	Supply services (+) Sales (+) Multi-output (-)	Innovation (+)	Territorial presence (-)

Bernard <i>et al.</i> (2008)	2005 Ethiopia Cereals	Propensity Score Matching	Prices (+) Share of production (NS)		
Cechin <i>et al.</i> (2013)	2010-2011 Brazil Broiler	Non-parametric tests	Market risk (-) Investment requirements (-)	Average quality (+)	Buyer independence (-) Technical support (+)
Ferguson and Kepe (2011)	2009 Uganda	Qualitative Analysis			Women participation (+)
Figueiredo and Franco (2018)	2016-2017 Portugal Wine	Multivariate statistical analysis			Local development (+)
Fischer and Qaim (2012)	2009 Kenya Banana	PSM	Household income (+) Technology adoption (+)		

Hanisch, <i>et al.</i> (2013)	2000-2010 European Union (27 member states) Dairy		Price, yardstick effect (+)		
Hao <i>et al.</i> (2018)	2015 China Apple	ESR		Food quality (+)	
Hernández-Espallardo <i>et al.</i> (2013)	2009-2010 Spain Fruits and vegetables	Ordinary least squares	Price (+)		Safeguards (+) Adaptation (+)
Hoken and Su (2018)	2007 and 2010 China Rice	PSM	Farm Income (+)		Small-scale farmers (+)

Jardine et al. (2014)	1971-2001 US-Alaska Salmon fishery	Difference-in-differences (DID)	Market prices (+)	Product quality (+)	
Ji et al. (2019)	2015-2016 China Hog	PSM		Safe production practices (+) (breed use, feed use, vaccination, drug use, waste disposal)	
Kumar et al. (2018)	2007 and 2015 India Dairy	Endogenous Switching Regression (ESR)	Farm yield (+) Farm profit (+)	Food safety (+)	
Liu et al. (2019)	2017 China Rice	PSM, ESR Inverse Probability Weighted Adjusted Regression	Farm Income (+)		Small-scale farmers (+ to a lesser extent)

		(IPWRA)			
Ma and Abdulai (2016)	2013 China Apple	ESR	Farm yield (+) Household Income (+)		Small-scale farmers (+)
Ma <i>et al.</i> (2018a)	2013 China Apple	PSM and SPF	Technical efficiency (+)		
Ma <i>et al.</i> (2018b)	2013 China Apple	Recursive Bivariate Probit		Organic soil amendments (+) But also chemical fertiliser to a lesser extent (+)	
Manda <i>et al.</i> (2020)	2012 and 2015 Zambia Maize	Combination of PSM with DID	Technology adoption (+)		

Michalek <i>et al.</i> (2018)	2006, 2015 Slovakia	Combination of PSM with DID	Gross value added (+) Farm profits (+) Labour productivity (+)		Farm employment (+)
Milford (2012)	2001-2007 Mexico Coffee	Ordinary Least Squares (OLS)	Yardstick effect (+)		Intermediaries cheating behaviour (-)
Mojo <i>et al.</i> (2017)	2014 Ethiopia Coffee	PSM and ESR	Farm economic performance (+) Household Income (+)		
Naziri <i>et al.</i> (2014)	2009 Vietnam Vegetables	OLS and Maximum Likelihood Estimator		Pesticides residues (-)	
Ofori <i>et al.</i> (2019)	2018 Cambodia Vegetables	PSM	Farm income (NS)		Information transmission (+)

Ortega <i>et al.</i> (2019)	2015-2016 Rwanda Coffee	PSM	Farm Income (+) Access to farm inputs (+)		
Pennerstorfer and Weiss (2013)	2004-2007 Austria Wine	Random- Effects (RE), Error Component Two-Stage Least Squares (EC2SLS)		Food quality (-)	
Serra and Davidson (2020)	2012 Ethiopia Honey	Coarsened Exact Matching	Market price (+) Production quantity (+)		Women participation (+)
Wollni and Fischer (2015)	2004 Costa Rica Coffee	Regression using the Bernoulli log- likelihood function and	Delivery of large-scale farmers to exploit scale economies in processing and marketing (+)		Delivery of small-scale farmers (+)

		double hurdle model			
Wossen <i>et al.</i> (2017)	2015 Nigeria Cassava	PSM and ESR IPWRA	Technology adoption (+) Household income (+)		
Yu and Huang (2020)	2010 China Various types (mostly fruits and vegetables)	SPF			Societal impact (+)
Yu <i>et al.</i> (2021)	2017 China Vegetable	ESR		Adoption of green control Techniques (+)	
Zhang <i>et al.</i> (2020)	2014 China	PSM and	Technology adoption (+)		

		Negative Binomial and Zero-Inflated Negative Binomial models			
Zhou et al. (2018)	2014 China Vegetables	Multinomial Logit		The use of chemical inputs under the guidance of cooperatives (+)	
Zhou et al (2019)	2017 China Fruits and Vegetables	Logit and OLS		Safety standard via quality control of cooperatives (+)	

Note: NS means non significant, + positively significant, - negatively significant

Chapter 4 Marketing channels and farmers' participation in organic certification: A European case study *

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4.1 Introduction

Organic farming is one widely accepted and recognised way of environmentally-friendly agricultural production. The organic certification is delivered to farms upon compliance with various obligations regarding environmentally-friendly farm practices. On the consumer side, organic certification is one of the mostly known environmental label for food products. With increasing concerns on environmental quality of food products, we observe an increase in organic consumption in the Europe Union (EU).

In this context, policy makers are getting increasingly interested in factors influencing the conversion of farmers to organic farming, in other words the adoption choice of farmers as regard organic practices. The literature already provides a rich set of empirical studies about different factors, which possibly play a role on farmers' tendencies toward organic production. Firstly, socio-demographic characteristics have significant impacts on farmers' decisions, such as age, education level, political or ideological opinions and beliefs of farmers, or household composition. Burton et al. (2008) show that younger farmers have a higher tendency to produce under organic practices. Because of the significant level of commitment, farmers may perceive the conversion to organic production as a risky investment. In this respect, farmers' risk aversion may influence negatively the adoption (Kallas et al. 2010). Secondly, farms' economic characteristics such as organisational structure, size, indebtedness, main production, may also differentiate farmers' tendencies toward organic production. In addition, Latruffe and Nauges (2014) show that farmers with higher level of technical efficiency under conventional practices are more likely to adopt the organic certification. Finally, external factors like market prices and government interventions, via policies and regulations, have direct effect on the adoption decision. In terms of supply chain organisation, the literature does not provide evidence of the role of a specific organisation on adoption of specific practices. The empirical analyses only highlight the negative effects of the absence of market for the organic production (which is thus sold on the conventional product market) or the distance to processing firms (Rigby et al. 2001). The role of specific marketing channels on the adoption of organic practices has not been widely studied. With a theoretical and empirical literature review, Candemir et al. (2021) suggest that cooperative membership may provide incentives to farmers to adopt sustainable practices. But no wider study on the role of diverse marketing channels exist.

In theory, the choice of marketing channels may influence significantly the choice of farming practices, through farmers' perception of risk, investment costs, social concerns and targeted

consumers. Depending on product characteristics, direct selling of farm output may generate higher revenue for farms (Corsi et al. 2018). Direct selling, in this sense, may encourage farmers to make investment decisions toward more environmentally-friendly practices. On the other hand, vertical coordination in supply chains can give farmers more stability and eventually decrease the perceived risks in agricultural markets. Farmers can engage in some contracting relations with different actors in upper supply chain, such as cooperatives, processors, wholesalers and retailers. Being a member of a cooperative can decrease the investment costs to switch from one production system to another (Hoffmann 2005; Drivas and Giannakas 2010). In the case of sustainable practices, this may help farmers to have a smoother transition to these practices. Moreover, the strategy of using two or more marketing channels at the same time can give a flexibility to farmers. Agbo et al. (2015) show theoretically that cooperative members who also use direct selling option may benefit from more profitable local market conditions where the competition is lower. In other words, cooperatives may help farmers to reach national or international markets, and the direct selling option may help them to obtain higher prices.

The literature on the impacts of agricultural cooperative membership is abundant for farmers economic performance (Grashuis and Su, 2019). However, we observe significantly smaller amount of academic research on the adoption of environmentally-friendly practices (Candemir et al. 2021). Cooperative membership may improve food safety (Hao et al. 2018), animal welfare (Ji et al. 2019), enhance farmers' adoption of safety standards (Zhou et al. 2019), and contribute to the reduction in pesticide use (Naziri et al. 2014). The existing studies on the role of cooperatives are mostly focused on developing countries, the literature on western countries being rather poor with the exception of Haldar and Damodaran (2021).

In summary, there is little scientific evidence on the impacts of marketing channels on the uptake of organic certification in European agriculture. Our research aims at providing empirical evidence on this issue in Europe. We use a binomial logistic regression framework applied to original data from a survey to European farmers. Various modes of marketing channels are considered, in particular cooperative but also processor, wholesaler, retailer and direct to consumer. Our findings suggest that choosing cooperatives as the main marketing option affects negatively the adoption of organic certification. We also show that the duration since first certification matters.

The rest of the article is organised as follows. The next section presents the data and the variables used, while the third section explains the empirical model. The fourth section describes the results and the fifth section concludes.

4.2 Data

4.2.1 The database

We use original data collected from a survey to farmers in 12 European countries for the year 2018. The sample includes 1,251 farms. The farm level data contain detailed information on the farms' general production related characteristics (such as utilised agricultural area-UAA, labour, specialisation, production practices, annual turnover) and farmers' characteristics (such as age, experience, education, gender). Additional information relate to farm certification in organic production and participation in agri-environmental schemes (AES) of the Common Agricultural Policy (CAP). Moreover, the data contain information on the food supply chain and more specifically on the farmers' marketing channels. The latter information is available in the form of percentages of farmer's annual output that is sold through each of the following marketing channel: retailers, wholesalers, processors, cooperatives, direct selling, and other marketing channel.

The data have missing or ambiguous information for key variables of interest for some farms. In order to cope with the missing value problem, we checked and cleaned the data. First, we excluded farms for which percentages of output in the marketing channels are missing. Secondly, we controlled the reliability of the marketing channel percentages by checking whether the sum of all possible marketing channel choices is equal to 100%. We excluded the farms which do not satisfy this condition. Finally, we kept only those farms which have available data on other key variables such as UAA or age. The final sample used contains data for 680 farms from 7 European countries (France, Germany, Greece, Ireland, Romania, Sweden and Poland) (Table 4.1).

Table 4.1: Number of farms in each country where the survey took place

Country	Number of farms in initial database	Number of farms after cleaning the data
Austria	94	-
Germany	51	49
Greece	108	101
England	67	-
France	229	213
Hungary	120	-
Ireland	33	24
Italy	100	-
Poland	100	88
Romania	52	52
Scotland	113	-
Sweden	184	153
Total	1,251	680

4.2.2 Farmers' participation in organic farming

In our study, we use two dependent variables to proxy the participation in organic farming. First, the variable '*Organic certification in 2018*' represents farms that have the organic certification at the time of the survey in 2018. In the sample of 680 farms from 7 countries, certified organic farms account for 25.9 % (176 farms), while in the EU organic farming was representing only 1.6 % of the EU farm holdings in 2016 (Eurostat 2021). Organic farms are thus over-represented in our sample.

Table 4.2 shows the frequency of organic certification per country and farm production type, namely livestock farms (i.e. farms specialised in dairy, beef cattle, mixed livestock, pig, poultry or sheep-goats) or non-livestock farms (farms specialised in field crops, fruit and vegetables or

permanent crops). In the livestock sector, organic certification represents 22.7 % of the farms in our sample (90 out of 397). Moreover, the share of livestock organic farms is distributed differently across countries. We observe that this share reaches 50.0 % and 31.4 % in Ireland and France respectively. Whereas in Romania and Sweden, certified organic farms constitute 11.5 % and 12 % of farms, respectively. In Germany, only four livestock farms out of 17 (23.5 %) are certified as organic in 2018. In Poland, we have a similar pattern, with 21.1 % of the livestock farms participating in organic certification. Specifically for the dairy sector, we see that only 37 of 223 dairy farms are certified as organic. In the non-livestock sector, certified organic farms represent 30.2 % of the sample (86 out of 293). The figures for France, Greece and Sweden are 52.5 %, 28.4 % and 16.7 % respectively.

The second dependent variable that we use is '*Newly certified organic in 2018*', that is to say farms that are certified organic in 2018 and have not been certified before this date. The farms in our sample which are classified as '*Newly certified organic in 2018*' represent 19.9 % of the sample (135 out of 680). These farms represent 76.7 % of those farms which have organic certification in 2018.

Table 4.2: Organic certification per country and farm production type in the sample used

Countries	All livestock farms				Dairy livestock farms		Non-livestock farms		All farms
	Certified organic		Non organic		Certified organic	Non organic	Certified organic	Non organic	
	Number of farms	%	Number of farms	%	Number of farms	Number of farms	Number of farms	Number of farms	
Germany	4	23.5	13	76.5	3	12	3	29	49
Greece	-	-	-	-	-	-	39	62	101
France	48	31.4	105	68.6	21	77	32	28	213
Ireland	10	50.0	10	50.0	3	3	3	1	24
Poland	8	21.1	30	79.0	2	14	3	47	88
Romania	6	11.5	46	88.5	6	46	-	-	52
Sweden	14	12.0	103	88.0	2	31	6	30	153
Total	90	22.7	307	77.3	37	187	86	197	680

4.2.3 Farmers' choice about marketing channels

We investigate the role of marketing channels on the participation in organic farming certification. In the database, the percentage values of the turnover in different marketing channels in 2018 are reported. There are 6 different marketing channels: (1) *Retailer*, (2) *Processor*, (3) *Wholesaler*, (4) *Direct selling*, (5) *Cooperative* and (6) *Other*. Table 4.3 describes the different marketing channels which are dominant for the farms, and reports their frequency in our sample.

Table 4.3: Frequency and classification of dominant marketing channel strategies in our sample

Dominant marketing channels	Definition	Number of farms with this dominant marketing channel	Share of farms with this dominant marketing channel
Retailers	At least 50 % of the farm turnover from retailers	26	3.8
Wholesalers	At least 50 % of the farm turnover from wholesalers	81	11.9
Processors	At least 50 % of the farm turnover from processors	170	25.0
Cooperatives	At least 50 % of the farm turnover from cooperatives	266	39.1
Direct selling	At least 50 % of the farm turnover from direct selling to consumers	59	8.7
Other	At least 50 % of the farm turnover from other marketing channel	34	5.0
Without dominant channel	No channel with more than 50 % of the farm turnover	44	6.5
All	-	680	100

In this study, we choose to associate farms with a “*dominant*” marketing channel to differentiate them more accurately in terms of market channel strategies. This classification is done by defining farms with a marketing channel if the percentage value of the farm turnover coming from this marketing channel is higher or equal to 50%. If no specific dominant marketing channel is identified, then farms are classified in the “*without dominant*” marketing channel category. A detailed explanation of this classification is provided in Appendix A. We observe that the “*cooperative*” marketing channel is the most common dominant channel and represents 39.1 % of our sample, followed by the “*processor*” marketing channel with 25.0 % of the farms. These two types of vertical relations cover 64.1 % of farms in our sample. The other dominant channels are represented as follows. The “*wholesaler*” marketing channel is chosen as a dominant strategy for 11.9 % of the farms. This share reaches 8.7 % for “*direct selling*”, 5.0 % for the “*other*” category and 3.8 % for the “*retailer*” marketing channels. Finally, 6.5 % of the farms have no dominant marketing channel strategy.

Figure 4.1 describes the frequencies of the farms depending on these marketing channels in the 7 European countries (Germany, France, Greece, Poland, Romania and Sweden). These statistics give a first glance on the diversity of channels per country by using mean values of percentages of marketing channels. We observe that cooperatives are among the mostly chosen marketing channels for countries such as France, Sweden and Ireland. The processor channel is dominant in Romania and Poland.

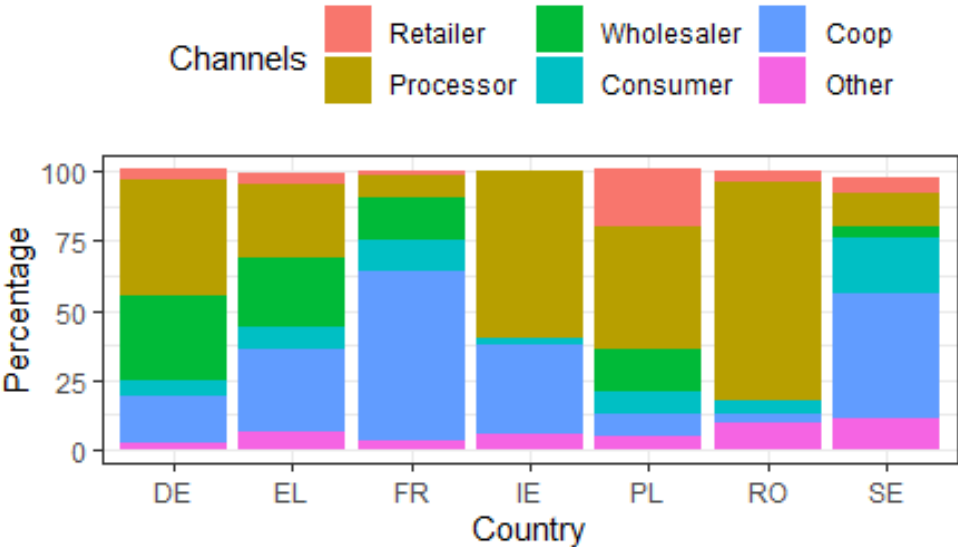


Figure 4.1: Share of farms per marketing channel by countries

Figure 4.2 provides distributions of farms per marketing channel per country and per production specialisation. It illustrates the dominant marketing channel strategies of farms. We analyse the marketing channels for two types of specialisation. The first group represents *Livestock* farms and includes farms specialised in dairy, beef cattle, poultry, pig, sheep-goat and mixed livestock farms. The second group represents *Crop* farms and includes farms specialised in cereals, oilseeds, protein crops, other field crops, fruits and vegetables, permanent crops, as well mixed crops and livestock farms. Note that the latter are thus not included in our classification of livestock farms. Countries have very heterogeneous characteristics for both farm specialisations and marketing channels in our sample. In Germany, non-livestock farms have a balanced distribution across marketing channels. Wholesaler, cooperative and processor channels are the main chosen options in general. However, livestock farms mostly choose processors as marketing channel. The Greek farms in our sample are non-livestock farms and mainly

specialised in olive. Here also wholesaler, cooperative and processor options are mostly chosen. In France, there are mostly livestock farms and more precisely dairy or beef cattle farms. We have a balanced pattern for marketing channels for both livestock and non-livestock farms. One should also note that cooperative is the most chosen marketing channel in France. In Ireland, wholesaler and cooperative options dominate for both non-livestock and livestock farms. In Poland, non-livestock farms have very diversified choices of marketing channels. The most chosen channels are processor, retailer and wholesaler. Polish livestock farms choose largely the processor marketing channel. In Romania, where farms are only dairy farms in our sample, most of them use processor as marketing channel. In Sweden, the data show very diversified portfolio for both livestock and non-livestock farms. At first glance, the cooperative marketing channel seems to be a significant marketing option. More interestingly, direct selling appears as important. These diversified marketing choices depending on the specialisations and countries show that there is a high tendency for livestock farms to develop vertical relationships with processors.

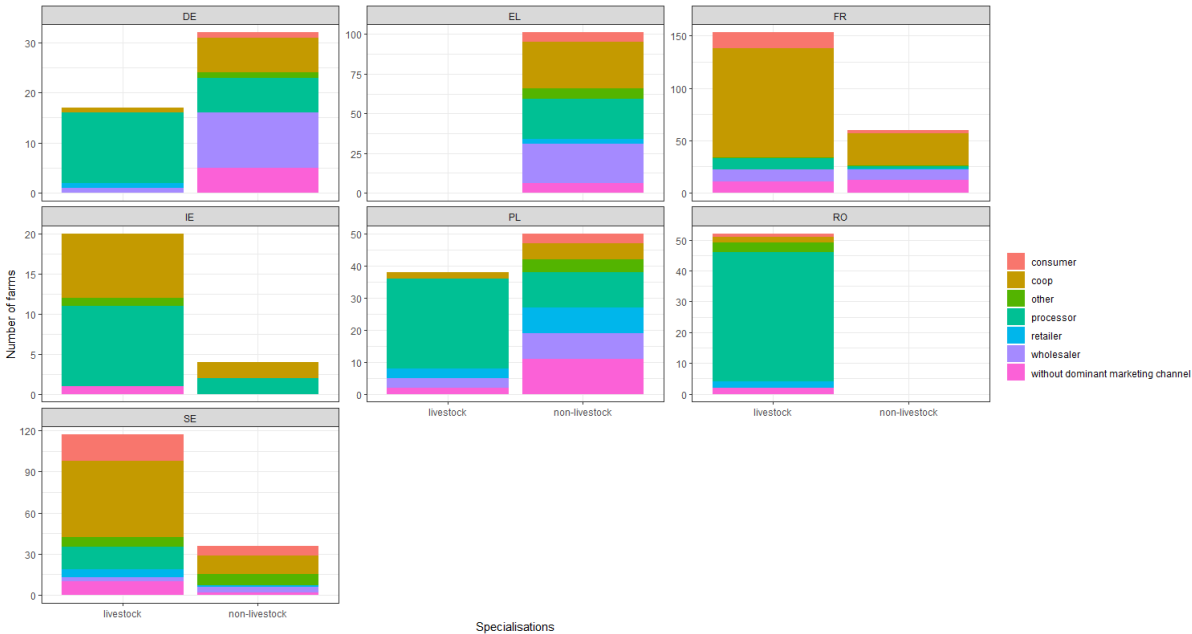


Figure 4.2: Dominant marketing channel for livestock farms and non-livestock farms (livestock refers to all animal related specialisations except mixed crops and livestock farms)

In Table 4.4, we show the number of certified organic farms per dominant marketing channel for the whole sample and France only. When we differentiate farms by marketing strategies we see diverging tendencies with respect to channels. For the whole sample containing seven countries, in the cooperative group which is the most frequent group in the sample in general (266 farms have this dominant channel), there are only 9.2 % of certified organic farms. In the second largest group of dominant strategy, namely farms resorting to the processor channel (170 farms), only 14.2 % of the farms are in certified organic production. This share is also rather low for the other dominant strategy with 13.5 %. On the other hand, 42.4 %, 40.7 % and 31.8% of farms that are engaged in direct selling, wholesaler and no dominant strategies, respectively, are certified organic farms. We observe similar diversified portfolio for the subsample of French farms. For the direct selling and wholesaler options, the share of organic farms reaches to 71.4 % and 72.7 %, respectively. Whereas, only 23.7 % of the farms who commercialise mainly through cooperative are in certified organic production. Note that other marketing channels in the French subsample have very limited number of observations.

Table 4.4: Number of certified organic farms per marketing channel in the total sample (680 farms) and in France only

		All countries				France only			
		Non organic farms		Certified organic farms		Non organic farms		Certified organic farms	
		#	%	#	%	#	%	#	%
Dominant Marketing Channels	Retailer	22	84.6	4	15.4	-	0.0	1	100.0
	Processor	129	75.9	41	14.2	8	61.5	5	38.5
	Wholesaler	48	59.3	33	40.7	6	27.3	16	72.7
	Direct selling	34	57.6	25	42.4	6	28.6	15	71.4
	Cooperative	215	80.8	51	9.2	106	76.3	33	23.7
	Other	26	76.5	8	13.5	1	33.3	2	66.7
	Not dominant	30	68.2	14	31.8	6	42.9	8	57.1
	Total	504	64.1	176	25.9	134	62.6	80	37.4

4.2.4 Other variables used in the econometric model

Table 4.5 describes all variables used in the econometric model. We use two variables to control for the farm location, *Country* and *Less Favoured Areas (LFA)*. 51 % of the surveyed farms are located in LFA. We also control for farm characteristics. The average farmland (*UAA*) is approximately 90 hectares. However, farm heterogeneity is very high as the standard deviation is 425 hectares. Farmers who reach a *Higher education* degree represent 72% of our sample. On average, farmers are 50 years old. We also control for specialisations (*Livestock, Dairy*).

Table 4.5: Definition of the variables used

Variables	Definition	Mean	Sd
Certified organic in 2018	1 if the farm has the organic certification in 2018, 0 otherwise	0.26	0.44
Newly certified organic in 2018	1 if the farm has the organic certification in 2018 AND has not been previously certified, 0 otherwise	0.20	0.40
Coop	1 if the dominant marketing channel is cooperative, 0 otherwise	0.39	0.49
Retailer	1 if the dominant marketing channel is retailer, 0 otherwise	0.04	0.19
Wholesaler	1 if the dominant marketing channel is wholesaler, 0 otherwise	0.12	0.32
Direct selling	1 if the dominant marketing channel is direct selling, 0 otherwise	0.09	0.28
Processor	1 if the dominant marketing channel is processor, 0 otherwise	0.25	0.43
Other	1 if the dominant marketing channels is 'other', 0 otherwise	0.05	0.22
Without dominant	1 if the farm has no dominant marketing channels, 0 otherwise	0.06	0.25
Country	Categorical variable for 7 countries (taking the form of individual dummies for each country)		
UAA	Utilised agricultural area in hectares	89.6	425.9
LFA	1 if the farm is located in Less Favoured Areas, 0 otherwise	51.2	50.0
Higher education	1 if the farmer has high general or agricultural education (high school and/or university level), 0 otherwise	0.72	0.45
Age	Farmer's age	50.6	11.7
Dairy	1 if the farm is specialised in dairy, 0 otherwise	0.32	0.47
Dairy × coop	1 if the farm is specialised in dairy and uses the cooperative as a dominant strategy, 0 otherwise	0.16	0.37
Livestock	1 if the farm is specialised in livestock (dairy, beef cattle, pig, poultry, sheep-goat, mixed livestock,), 0 otherwise	0.58	0.49

4.3 Empirical model

We investigate the role of marketing channels on the adoption of organic farming considering only certified farms (not farms in conversion to organic farming). We assume that decisions are not simultaneous and that farmers' choice of marketing channels has been done before the decision to adopt or not organic farming. This assumption is based on the fact that European farms are mainly of family nature, in which marketing channel choices are persisting over time. We define being certified organic farming or not (*'Certified organic in 2018'*) or recently certified (*'Newly certified organic in 2018'*) as the alternative dependent variables, and the marketing channel type as the main explanatory variable. We include other explanatory variables (age, education, UAA, specialisation, LFA, country) to control for farm characteristics that could be determining factors behind the adoption of organic farming (see Introduction).

In order to examine the impact of marketing channel decision of farms in certified organic production participation, we use a binomial logistic regression approach. The dependent variable Y_i has a binary form. In the case farmers are under certified organic farming $Y_i = 1$, and $Y_i = 0$ otherwise. The probability of being certified organic ($Y_i = 1$) is taken as a cumulative distribution function of explanatory variables in the logistic regression. Let $P(Y_i = 1)$ be the probability that the farm is certified organic and $P(Y_i = 0)$ the probability that the farm is not certified in organic farming. Note that $(Y_i = 0) = 1 - P(Y_i = 1)$. In this empirical part, we test three hypotheses, described below (H1, H2, H3).

A special attention is given to the marketing through agricultural cooperatives. Cooperative organisations are important economic actors in European supply chains and they may have significant effects on the development of organic farming through two effects. First, they can positively influence the adoption of agricultural organic farming as they allow farmers to have better access to market, decrease their investment costs through pooling and reach reliable technical information on agricultural practices (Candemir et al. 2021). Also, their unique organisational form may help farmers to increase profits as they integrate operations backward and forward (Ma et al. 2018; Haldar and Damodaran 2021). In this regard, we expect the adoption of new practices to be less costly and risky to cooperative members. Second, cooperatives can also have a negative influence on the adoption of organic farming as they suffer from some governance issues. Farmer heterogeneity may bring reluctance for

implementing optimal investments and may create some inertia in the context of changing markets (Candemir et al. 2021). Therefore, the impact of agricultural cooperative is ambiguous.

H1: Agricultural cooperatives influence the certification in organic farming.

The logistic regression model to test H1 is as follows:

$$\ln \left(\frac{P(Y_i = 1)}{P(Y_i = 0)} \right) = b_0 + b_1 coop_i + b_2 dair y_i + b_3 dair y_i * coop_i + b_4 education_i + b_5 UAA_i + b_6 age_i + b_7 countr y_i + b_8 LFA_i + u_i \quad (1)$$

where i is the farm, Y is the dependent variable ‘*Organic certified in 2018*’, the explanatory variables are defined in Table 4.5, u is the error term and b_0 to b_8 are parameters to be estimated.

In Model (1), we investigate the effects of using cooperative marketing channel dominantly on the probability of being certified organic, by controlling for farm characteristics. Note that the reference group is constituted of farmers who do not use cooperative option as a dominant strategy. We also check the effect of using a cooperative channel depending on the specialisation in dairy or not, with a cross term, in order to control for the fact that dairy farms in our sample mainly use this marketing channel.

Farmers have various channels in agri-food supply chains to sell their farm-level products. Moreover, some farmers may choose to use different marketing channels simultaneously such as direct selling and selling through cooperatives (Agbo et al. 2015). These marketing channel choices can have crucial importance for farmers’ production strategies. Different types of supply chain organisations may have significantly diverging influence in the context of environmentally-friendly production (Meemken et al. 2021).

H2: Marketing channels affect differently the adoption of organic farming.

The logistic regression model to test H2 is as follows:

$$\ln \left(\frac{P(Y_i = 1)}{P(Y_i = 0)} \right) = b_0 + b_1 coop_i + b_2 directselling_i + b_3 processor_i + b_4 wholesaler_i + b_5 retailer_i + b_6 other_i + b_7 dair y_i + b_8 dair y_i * coop_i + b_9 education_i + b_{10} UAA_i + b_{11} age_i + b_{12} countr y_i + b_{13} LFA_i + u_i \quad (2)$$

where i is the farm, Y is the dependent variable ‘*Organic certified in 2018*’, the explanatory variables are defined in Table 4.5, u is the error term and b_0 to b_{13} are parameters to be estimated.

In Model (2), we analyse the possible impacts of six different dominant marketing channels (cooperatives, direct selling, processor, wholesaler, retailer and other) on the probability of having organic certification. Note that the reference group for the marketing channels is the *without dominant channel* status. Thus, corresponding effects of each dominant marketing channel are relative to without dominant channel group.

In the last years, the European organic production has been experiencing a significant increase. In 2018, the agricultural area of organic farming has increased by 7.6 % and the organic farming was representing 7.5 % of the European UAA in 2018 (this ratio was at the level of 7.2 % in 2017) (Agence Bio 2019). This rising trend can be explained by decreasing risks to adopt in the case of well-developed EU organic farming markets, compared to early years of EU organic label. In this logic, it may be expected that more recent adopters are more market-oriented than earlier adopters who have possibly bared larger risks (Läpple and Rensburg 2011). If the recent adopters have different perspectives, perceptions and objectives regarding organic production, the impact of marketing channels may vary.

H3: Marketing channels may have different impacts for early and recent adopters in organic farming certification

We investigate whether the timing of certification modifies the role of market channel on the choice of being certified organic. Specifically, the logistic regression model is used to investigate the impacts of marketing channels on *newly certified organic* farmers to test H3, written as follows, for the specific case of cooperatives (Model (1a)) and the general case of all channels (Model (2a)):

$$\ln \left(\frac{P(Y_{new,i}=1)}{P(Y_{new,i}=0)} \right) = b_0 + b_1 coop_i + b_2 dair y_i + b_3 dair y_i * coop_i + b_4 education_i + b_5 UAA_i + b_6 age_i + b_7 country_i + b_8 LFA_i + u_i \quad (1a)$$

$$\ln \left(\frac{P(Y_{new,i}=1)}{P(Y_{new,i}=0)} \right) = b_0 + b_1 coop_i + b_2 directselling_i + b_3 processor_i + b_4 wholesaler_i + b_5 retailer_i + b_6 other_i + b_7 dair y_i + b_8 dair y_i * coop_i + b_9 education_i + b_{10} UAA_i + b_{11} age_i + b_{12} country_i + b_{13} LFA_i + u_i \quad (2a)$$

where i is the farm, Y_{new} is ‘Newly organic certified in 2018’, the explanatory variables are defined in Table 4.5, u is the error term and b_0 to b_{13} are parameters to be estimated.

Models (1a) and (2a) are similar to Models (1) and (2) respectively, except for a change in the dependent variable. In this case, $P(Y_{new,i} = 1)$ defines the probability of getting the organic certification in 2018 but not being certified before this date.

In order to get more interpretable result from our logistic regressions, we calculate *average marginal of effects*. By starting from log odd-ratio from the logistic regression, $\ln\left(\frac{P}{1-P}\right)$ as shown in Models (1), (2), (1a) and (2a), we get the probability of having organic certification. The latter can be expressed as a function of explanatory variables:

$$p_i = \frac{e^{\beta X_i}}{1 + e^{\beta X_i}} \quad (3)$$

where i is the farm, X is the vector of explanatory variables and β is the vector of parameters associated to the explanatory variables and estimated in the models.

The marginal effects are calculated by taking the derivatives of the probability p with respect to each variable. For instance, the marginal effect of having cooperative as a dominant channel, can be shown as:

$$\frac{\partial p_i}{\partial coop_i} = \frac{b_1 e^{\beta X_i}}{(1 + e^{\beta X_i})^2} \quad (4)$$

Where i is the farm, X is the vector of explanatory variables, β is the vector of parameters associated to the explanatory variables and estimated in the models, and b_1 stands particularly for the parameter for the dummy variable related to using cooperatives as a dominant channel.

Using equation (4) in the results section, we provide marginal effects for the cooperative variable and for each explanatory variable in our four models. Note that estimation results from the logistic regression coefficients are provided in Appendix B.

4.4 Results

4.4.1 Results for the whole sample

Table 4.6 reports the marginal effects for four models. In Models (1) and (2), the binary variable ‘*Certified organic in 2018*’ is used as dependent variable. In Model (1), we focus on the cooperative marketing channels as the main explanatory variable while in Model (2) we add the other marketing channels, with the reference group being no dominant marketing channel. We find that, in both models, cooperative as a dominant marketing channel has a negative and significant effect on the probability of organic certification. This indicates that using the cooperative marketing channels decreases the probability of being certified organic compared to other types or no dominant marketing channel. This impact decreases (in absolute terms) in Model (2). The cross term cooperative and dairy has no significant effect, suggesting that the main effect of the cooperative channel is the same regardless of the production specialisation.

In Model (2), we find that other types of marketing channels have no significant effect on the probability of organic certification compared to the reference category of no dominant channel, confirming Model (1) results. In both models, we find that dairy farming has a negative and significant impact on the probability of organic certification. Other farm characteristics related variables, such as farm size and education, have non-significant impacts, while farmers’ age has a significant positive impact. Country dummies also have a significant impact, revealing that certified organic farms are mainly in the Greece, France and Ireland subsamples.

In Models (1a) and (2a), we focus on the farms that are ‘*Newly certified organic in 2018*’. In Model (1a), we find that the cooperative marketing channel has a negative and significant marginal effect on the probability of recent organic certification, similar to the effect on the probability of longer organic certification in Model (1). However, in Model (2a) the significance of the cooperative variable disappears when adding other marketing channel options.

Table 4.6: Marginal effects from the binomial regression for the four models: whole sample

	Certified organic in 2018		Newly certified organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
Coop	-0.21 ***	-0.16 *	-0.20 ***	-0.13
	(0.04)	(0.07)	(0.04)	(0.07)
Dairy x coop	0.08	0.09	0.06	0.08
	(0.08)	(0.08)	(0.08)	(0.08)
Dairy	-0.16 **	-0.17 **	-0.12	-0.14 *
	(0.06)	(0.06)	(0.06)	(0.06)
Higher education	-0.03	-0.03	-0.02	-0.02
	(0.04)	(0.04)	(0.04)	(0.04)
UAA	-0.0001	-0.0001	-0.00004	-0.00004
	(0.0002)	(0.0002)	(0.00008)	(0.00008)
Age	0.004**	0.004 **	0.004 **	0.005 **
	(0.001)	(0.001)	(0.001)	(0.001)
Greece	0.16 *	0.16 **	0.17 **	0.17 **
	(0.06)	(0.06)	(0.06)	(0.06)
France	0.36 ***	0.36 ***	0.26 ***	0.26 ***
	(0.06)	(0.06)	(0.06)	(0.06)
Ireland	0.40 ***	0.41 ***	0.41 ***	0.40 ***
	(0.11)	(0.11)	(0.11)	(0.11)
Poland	-0.04	-0.03	-0.03	-0.02
	(0.05)	(0.05)	(0.05)	(0.05)
Romania	0.03	0.04	-0.05	-0.04

	(0.08)	(0.09)	(0.07)	(0.07)
Sweden	-0.03	-0.02	-0.03	-0.03
	(0.05)	(0.05)	(0.05)	(0.05)
LFA	0.01	0.01	0.01	0.00
	(0.03)	(0.03)	(0.03)	(0.03)
Direct selling		0.09		0.10
		(0.07)		(0.08)
Processor		0.05		0.09
		(0.07)		(0.07)
Retailer		-0.01		0.04
		(0.11)		(0.10)
Wholesaler		0.07		0.07
		(0.07)		(0.07)
Other		-0.03		-0.01
		(0.09)		(0.09)
Number of observations	680	680	625	625
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

4.4.2 Robustness checks

We conduct some robustness checks on more homogenous subsamples. Three subsamples are used: livestock farms, dairy farms and French farms. Moreover, in a fourth check, we use a different dependent variable, namely the participation in an AES, to investigate the effect of marketing channels on the adoption of environmentally-friendly practices that are not organic practices.

4.4.2.1 Livestock farms

The subsample of farms with livestock specialisation includes 397 farms. In Table 4.7, we report marginal effects for this estimation of the four models on this subsample. We find that the significance and magnitude of the coefficient associated to the cooperative marketing channel are lower for this subsample than for the whole sample in Models (1) and (1a) (Table 4.6). The coefficient becomes non-significant in Models (2) and (2a) where other marketing channels are included. The impact of dairy specialisation remains significant and negative in Models (1), (2) and (1a), while it is non-significant in Model (2a). We find that higher education has a negative effect in Models (1) and (2), while this effect is non-significant for newly certified farms (Models (1a) and (2a)). This suggests that a higher education in livestock farming decreases the probability of being organic in 2018 and for the years before. Although this is counterintuitive (more educated farmers are expected to take more risk and to be more skilled to apply new practices), this is in line with findings on French livestock farms regarding the engagement in AES (Davidova et al. 2021; Dakpo et al. 2021), revealing that education in this country may be more adequate for productivist practices than environmentally-friendly practices.

Table 4.7: Marginal effects from the binomial regression for the four models: livestock subsample

	Certified organic in 2018		Newly certified organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
Coop	-0.14 *	-0.06	-0.12 *	-0.02
	(0.06)	(0.10)	(0.06)	(0.11)
Dairy x coop	0.09	0.07	0.09	0.08
	(0.09)	(0.09)	(0.09)	(0.09)
Dairy	-0.17 **	-0.16 *	-0.13 *	-0.12
	(0.06)	(0.07)	(0.06)	(0.06)
Higher education	-0.11 *	-0.10 *	-0.09	-0.08
	(0.05)	(0.05)	(0.05)	(0.05)

UAA	-0.00004	-0.00003	-0.00002	-0.00002
	(0.00007)	(0.00006)	(0.00005)	(0.00005)
Age	0.003478	0.003363	0.003662 *	0.003500
	(0.001839)	(0.001842)	(0.001806)	(0.001798)
France	0.13	0.05	0.02	-0.03
	(0.13)	(0.14)	(0.13)	(0.14)
Ireland	0.15	0.14	0.16	0.15
	(0.16)	(0.16)	(0.16)	(0.17)
Poland	-0.07	-0.08	-0.04	-0.04
	(0.13)	(0.14)	(0.14)	(0.14)
Romania	-0.14	-0.14	-0.19	-0.21
	(0.12)	(0.13)	(0.12)	(0.12)
Sweden	-0.21	-0.25	-0.21	-0.24
	(0.12)	(0.13)	(0.12)	(0.13)
LFA	0.05	0.03	0.05	0.03
	(0.05)	(0.05)	(0.04)	(0.04)
Direct selling		0.18		0.19
		(0.10)		(0.11)
Processor		0.03		0.08
		(0.10)		(0.11)
Retailer		-0.10		-0.02
		(0.18)		(0.17)
Wholesaler		0.08		0.01
		(0.12)		(0.14)
Other		-0.15		-0.05

		(0.18)		(0.17)
Number of observations	397	397	355	355
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

4.4.2.2 Dairy farms

The subsample of farms with dairy specialisation consists in 220 farms. The results of the estimation of the four models on this subsample (Table 4.8) show significantly different pattern from the larger subsample of livestock farms. First of all, cooperative as the dominant marketing channel, similar to any other marketing channels, has no significant effect in all four models. The negative impact of higher education remains significant in Models (1) and (2) and is non-significant in Models (1a) and (2a) like in the case of the livestock subsample. Interestingly, being in LFA positively influences the probability of being certified organic in all four models. This suggests that the AES are suitable for dairy farming in disadvantaged areas and help them switch to organic practices.

Table 4.8: Marginal effects from the binomial regression for the four models: dairy subsample

	Certified organic in 2018		Newly certified organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
Coop	-0.03	1.81	-0.02	1.34
	(0.06)	(222.85)	(0.06)	(252.72)
Higher education	-0.16 **	-0.15 *	-0.11	-0.11
	(0.06)	(0.06)	(0.06)	(0.06)
UAA	-0.0000046	-0.0000074	0.0000096	0.0000088
	(0.000125)	(0.000126)	(0.000084)	(0.000083)
Age	0.0028286	0.0025975	0.0030031	0.0029869
	(0.002328)	(0.002343)	(0.002193)	(0.00222)

France	0.19	0.15	0.10	0.09
	(0.11)	(0.12)	(0.12)	(0.12)
Ireland	0.37	0.34	0.38	0.35
	(0.20)	(0.20)	(0.20)	(0.20)
Poland	0.03	0.05	0.05	0.07
	(0.15)	(0.15)	(0.15)	(0.15)
Romania	-0.11	-0.10	-0.14	-0.13
	(0.09)	(0.09)	(0.09)	(0.09)
Sweden	-0.15	-0.16	-0.15	-0.15
	(0.09)	(0.10)	(0.10)	(0.10)
LFA	0.19 **	0.18 **	0.15 **	0.15 **
	(0.06)	(0.06)	(0.05)	(0.06)
Direct selling		1.94		1.39
		(222.85)		(252.72)
Processor		1.81		1.36
		(222.85)		(252.72)
Retailer		-0.03		-0.09
		(315.81)		(305.73)
Wholesaler		1.91		1.36
		(222.85)		(252.72)
Other		-0.01		-0.01
		(340.75)		(325.36)
Number of observations	220	220	201	201
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

4.4.2.3 French farms

The French subsample has 213 observations. In France, the impact of the choice of cooperative as the dominant marketing channel is negative and significant in Models (1), (2) and (1a) (Table 4.9). However, the effect is non-significant in Model (2a). Dairy specialisation has a negative impact in the four models. The negative impact of higher education found for the livestock subsample is confirmed also for the French subsample in the four models. Similarly to the dairy subsample case, being located in LFA increases the probability of being certified as organic.

Table 4.9: Marginal effects from the binomial regression for the four models: French subsample

	Certified organic in 2018		Newly certified organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
Coop	-0.26 ***	-0.21 *	-0.27 ***	-0.16
	(0.06)	(0.10)	(0.06)	(0.11)
Dairy x coop	0.16	0.20	0.17	0.33 *
	(0.12)	(0.14)	(0.12)	(0.17)
Dairy	-0.26 **	-0.30 **	-0.22 *	-0.36 *
	(0.09)	(0.11)	(0.09)	(0.15)
Higher education	-0.26 ***	-0.25 ***	-0.21 **	-0.23 ***
	(0.07)	(0.07)	(0.07)	(0.07)
UAA	-0.00189 **	-0.00186 **	-0.00099	-0.00086
	(0.00061)	(0.00062)	(0.00064)	(0.00062)
Age	0.00087	0.00141	0.00161	0.00184
	(0.00265)	(0.00272)	(0.00266)	(0.00275)
LFA	0.20 ***	0.20 ***	0.18 **	0.20 ***
	(0.06)	(0.06)	(0.06)	(0.06)
Direct selling		0.02		0.06

		(0.13)		(0.13)
Processor		0.13		0.33
		(0.17)		(0.19)
Retailer		2.22		2.16
		(136.86)		(188.09)
Wholesaler		0.11		0.15
		(0.13)		(0.13)
Other		-0.02		0.12
		(0.22)		(0.20)
Number of observations	213	213	176	176
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

4.4.2.4 AES as dependent variable

We use an alternative proxy of the adoption of environmentally-friendly practices, namely the engagement in AES as the dependent variable. AES are 5-year contracts that farmers can voluntarily engage in, and receive a payment in exchange of applying environmentally-friendly practices. The AES are locally (at the national or regional level) defined and may encompass having a low livestock density on the farm, applying cover crops, keeping hedges etc. There exists a specific AES for converting to organic farming, so that farmers receive a compensatory payment for the costs incurred upon conversion while they cannot sell yet their product under the organic certification. In some countries, there exists also an AES for maintenance in organic farming that is to say after organic certification has been obtained.

Here, the variable AES that we use in Models (1b) and (2b) excludes the specific schemes for organic farming, while in Models (1c) and (2c) we use organic AES participation only as a dependent variable. We find that the cooperative marketing channel has a negative and significant impact only in Model (2c) in which we use the organic AES participation as the dependent variable (Table 4.10). This impact becomes non-significant when we add other

marketing channels. This is in line with the results above with certified organic as the dependent variable, only in Model (1c).

Table 4.10: Marginal effects from the binomial regression for the four models and AES participation

	Non-organic AES		Organic AES	
	Model (1b)	Model (2b)	Model (1c)	Model (2c)
Coop	0.02	0.02	-0.10 **	-0.08
	(0.04)	(0.07)	(0.04)	(0.07)
Dairy x coop	0.11	0.11	-0.03	-0.01
	(0.08)	(0.08)	(0.08)	(0.08)
Dairy	-0.06	-0.06	0.02	-0.00
	(0.06)	(0.07)	(0.06)	(0.06)
Higher education	0.07	0.07 *	0.03	0.03
	(0.04)	(0.04)	(0.04)	(0.04)
UAA	-0.0000657	-0.0000665	0.0000001	-0.0000016
	(0.0000715)	(0.0000719)	(0.0000307)	(0.0000304)
Age	0.0003874	0.0004644	0.0022538	0.0023012
	(0.0013999)	(0.0013987)	(0.0013806)	(0.0013806)
Greece	-0.49 ***	-0.48 ***	0.05	0.05
	(0.08)	(0.08)	(0.06)	(0.06)
France	-0.39 ***	-0.39 ***	0.11	0.10
	(0.08)	(0.08)	(0.06)	(0.06)
Ireland	0.18	0.19	0.39 ***	0.38 ***
	(0.12)	(0.12)	(0.11)	(0.11)
Poland	-0.48 ***	-0.47 ***	-0.07	-0.08

	(0.08)	(0.08)	(0.05)	(0.05)
Romania	0.10	0.11	0.02	0.02
	(0.11)	(0.11)	(0.07)	(0.07)
Sweden	-0.04	-0.03	0.14 *	0.13
	(0.09)	(0.10)	(0.06)	(0.07)
LFA	0.04	0.04	0.07 *	0.06
	(0.03)	(0.03)	(0.03)	(0.03)
Direct selling		0.02		0.09
		(0.08)		(0.07)
Processor		-0.01		0.05
		(0.08)		(0.07)
Retailer		0.01		-0.07
		(0.10)		(0.11)
Wholesaler		0.01		-0.01
		(0.08)		(0.08)
Other		-0.08		-0.04
		(0.09)		(0.09)
Number of observations	680	680	680	680
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

4.5 Conclusion

We investigated here the role of marketing channel on the decision to adopt environmentally-friendly practices, using original farm-level data in several EU countries. In doing so we contribute to the empirical literature on the effects of cooperative in developed countries. Recently, most empirical studies focus on developing countries and find a positive effect of

cooperative marketing channel on the adoption of environmentally-friendly practices (Ma et al. 2018; Naziri et al. 2014). Contrary to the previous empirical studies in developing countries, we find a negative impact of cooperative marketing channel on the adoption of organic certification for our European sample. The cooperatives in Western countries are historically well established and have significantly different firm strategies than farmer organisations in developing countries. The long cooperative existence may create inertia towards changes in agricultural practices and more specifically toward the participation in organic farming. Another explanation may be that farms in cooperatives benefit from marketing contracts and prices for products generated with specific environmentally-friendly practices, and they do not feel the need to go through the complex and long organic certification.

The second interesting finding of our analysis is that the impacts of marketing channels on the adoption of organic practices may be different for newly certified farms. More precisely, when taking into account all dominant marketing channels for newly certified farmers, the impact of marketing channels becomes non-significant for all dominant channels. Farmers' decision toward organic farming may have different motivations depending whether farmers have got the certification previously. This highlights the changing perceptions and motivations of farmers in terms of environmentally-friendly practices. In earlier times, farmers chose to be engaged in these practices by taking the risk of selling their products in new and underdeveloped markets more because of their ideological motivations. On the other hand, in recent times, farmers adopt organic practices because they have waited for the development of markets and profitability of the environmentally-friendly practices (Bianco et al. 2019). In the case of organic production, new entrants may have more market-oriented objectives than pioneers. Regarding the impacts of marketing channels, this differentiation between certification time suggests that the economic mechanism in supply chain organisation may evolve when farmers interested in the adoption of organic production are for rather profit-seeking reasons or when the organic farming markets are more developed. This point offers insights and motivations for further research which can analyse deeper the changing dynamics in environmentally-friendly agricultural production.

4.6 References

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4.6 Appendices

4.6.1 Appendix A: Exclusion of some farms from the initial sample and creation of dominant marketing channel variables

The initial sample of our original survey contains a variable which provides information on selling choices of farmers in terms of percentages of turnover obtained through different channels. These percentages are given for 6 different channels. We excluded observations where the variables of interest are not presented or having incoherencies. Typically, for the marketing channel variables we kept only farms for which the sum of marketing channel options reaches 100%. In the end, we reduced the sample size from 1,251 to 680.

As it is mentioned in the data description of the main text, the main variable of this analysis is the one concerning marketing channel choices. In Figure 4.3, we observe these choices in percentages in our sample of 680 farms. In this figure, we illustrate the frequencies of farmers' selling shares choices for six channels in percentages. The figures on the x-axis represent the percentages and the y-axis shows the frequency of each percentage for the corresponding channels. Note also that we kept only non-zero values for each corresponding channel.

We observe that cooperative and processor channels are the main options chosen by farmers. 332 of farms out of 680 marketed their production at least for some output in 2018. For the other channels, the figures are as follows: 176 for wholesaler channel, 168 for direct selling, 90 for the other channels and 89 for retailer channel. One can notice that choosing cooperative and processor channels are the principal strategies of farms. Moreover, particularly for these two channels, there is a high frequency at 100%. Meaning that the majority of farms choosing cooperatives and processors prefer to use them for all their farm level output. Whereas, for the other channels we observe relatively balanced distribution. Regarding this distribution, we choose to create a variable, which classify farms with a dominant marketing channel. The first reason is to simplify the empirical work by classifying farms with a unique channel. Secondly, the higher presence of total engagement in cooperative and processor options limits some possible attempts to analyse impacts of simultaneous usage of multiple marketing channels. We decide to define farms with a dominant channel when the farm chooses to use any particular option for a share of farm turnover higher or equal to 50 %. Otherwise, we define farms as *without dominant channel*. Note that for some cases we have equal share of farm turnover

between two channels (50 %-50 %). In this case, we also define the farms as without dominant channel.

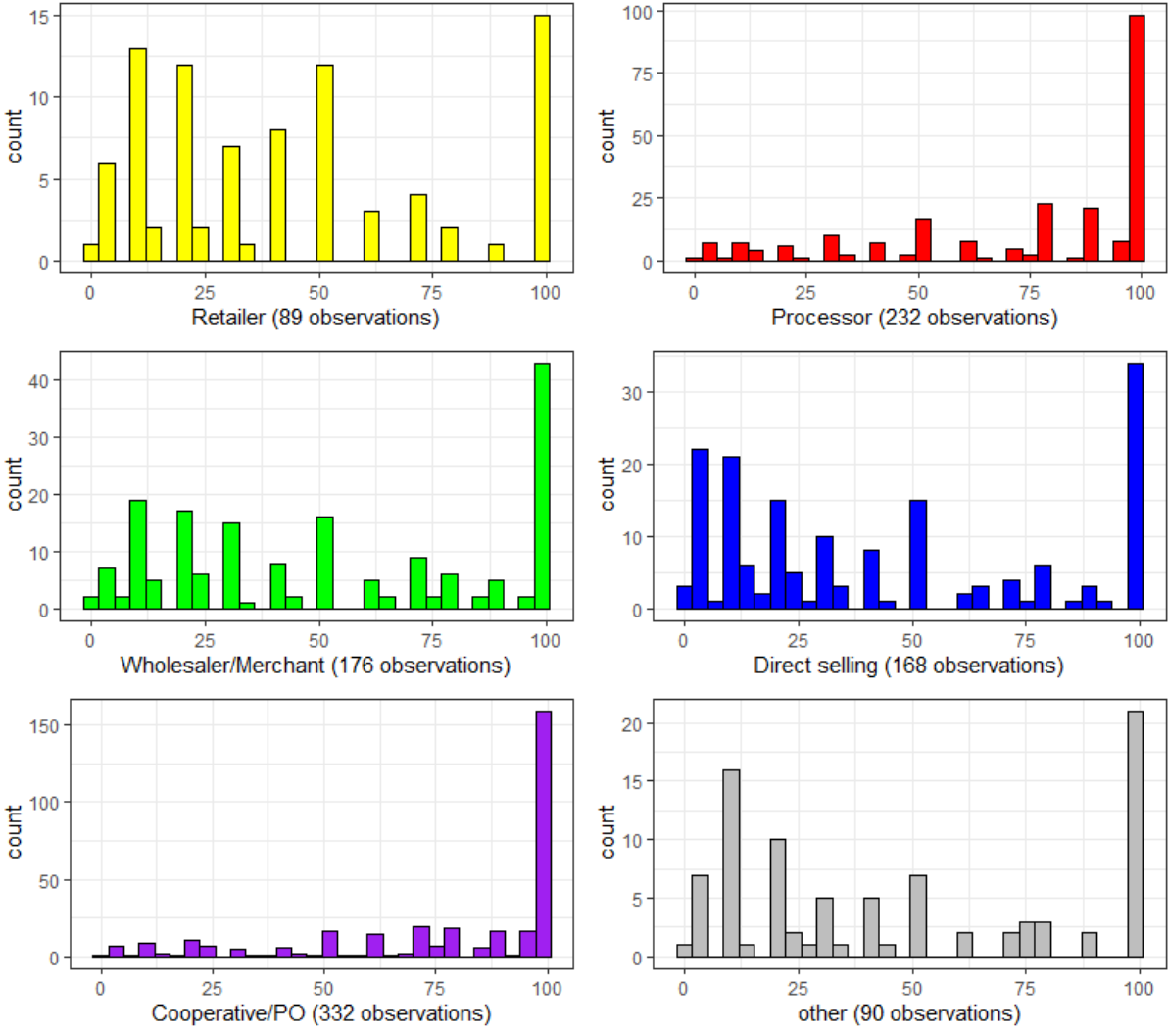


Figure 4.3: Distribution of marketing channel choice of farms in percentages (680 farms)

4.6.2 Appendix B: Logit regression results

In this section, we provide binomial regression results for four model used in the study. Table 4.11 shows the estimation results for the main sample used (680 farms). In Tables 4.12 to 4.15, we provide the same results for subsamples used in robustness checks.

Table 4.11: Binomial logistic regression estimation results for certified organic production

	Certified organic in 2018		Newly certified organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
(Intercept)	-2.48 ***	-2.86 ***	-2.82 ***	-3.38 ***
	(0.70)	(0.81)	(0.74)	(0.87)
Coop	-1.36 ***	-1.06 *	-1.38 ***	-0.93
	(0.27)	(0.43)	(0.29)	(0.50)
Dairy x coop	0.54	0.60	0.43	0.58
	(0.51)	(0.52)	(0.57)	(0.58)
Dairy	-1.04 **	-1.10 **	-0.83	-0.99 *
	(0.40)	(0.42)	(0.43)	(0.46)
Higher education	-0.21	-0.19	-0.14	-0.12
	(0.23)	(0.24)	(0.25)	(0.26)
UAA	-0.00073	-0.00064	-0.00030	-0.00030
	(0.00139)	(0.00129)	(0.00057)	(0.00054)
Age	0.02634 **	0.02725 **	0.03076 **	0.03225 **
	(0.00909)	(0.00921)	(0.00997)	(0.01014)
Greece	1.08 *	1.12 *	1.14 *	1.16 *

	(0.49)	(0.49)	(0.49)	(0.49)
France	2.08 ***	2.09 ***	1.59 ***	1.63 ***
	(0.47)	(0.48)	(0.48)	(0.49)
Ireland	2.27 ***	2.33 ***	2.29 ***	2.28 ***
	(0.62)	(0.63)	(0.63)	(0.64)
Poland	-0.37	-0.28	-0.28	-0.23
	(0.54)	(0.55)	(0.54)	(0.55)
Romania	0.22	0.33	-0.51	-0.45
	(0.70)	(0.71)	(0.82)	(0.82)
Sweden	-0.29	-0.23	-0.33	-0.30
	(0.51)	(0.53)	(0.52)	(0.55)
LFA	0.08	0.04	0.04	0.02
	(0.21)	(0.21)	(0.23)	(0.23)
Direct selling		0.57		0.72
		(0.48)		(0.55)
Other		-0.20		-0.05
		(0.58)		(0.64)
Processor		0.35		0.63
		(0.45)		(0.51)
Retailer		-0.05		0.29
		(0.68)		(0.72)
Wholesaler		0.43		0.51
		(0.45)		(0.51)

Number of observations	680	680	625	625
AIC	680.60	687.08	583.71	589.98
BIC	743.90	773.00	645.83	674.30
Pseudo R2	0.25	0.25	0.22	0.23
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

Table 4.12: Binomial logistic regression estimation results for certified organic production in the livestock subsample

	Organic in 2018		Newly certified in organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
(Intercept)	-1.00	-1.12	-1.48	-1.93
	(1.07)	(1.25)	(1.18)	(1.44)
Coop	-0.91 *	-0.39	-0.94 *	-0.15
	(0.41)	(0.67)	(0.48)	(0.90)
Dairy x coop	0.58	0.48	0.69	0.64
	(0.59)	(0.62)	(0.69)	(0.73)
Dairy	-1.16 **	-1.11 *	-1.03 *	-1.02
	(0.44)	(0.48)	(0.50)	(0.55)
Higher education	-0.73 *	-0.70 *	-0.69	-0.69
	(0.34)	(0.35)	(0.39)	(0.40)
UAA	-0.000237	-0.000182	-0.000190	-0.000157
	(0.000485)	(0.000439)	(0.000412)	(0.000390)

Age	0.023342	0.023157	0.029380 *	0.028968
	(0.012499)	(0.012835)	(0.014647)	(0.015041)
France	0.67	0.28	0.11	-0.15
	(0.70)	(0.75)	(0.74)	(0.79)
Ireland	0.75	0.71	0.82	0.74
	(0.83)	(0.84)	(0.85)	(0.86)
Poland	-0.44	-0.48	-0.23	-0.24
	(0.80)	(0.81)	(0.81)	(0.82)
Romania	-0.93	-0.91	-1.58	-1.62
	(0.76)	(0.76)	(0.87)	(0.87)
Sweden	-1.77 *	-2.09 *	-1.82 *	-2.12 *
	(0.78)	(0.83)	(0.81)	(0.87)
LFA	0.36	0.24	0.37	0.28
	(0.31)	(0.32)	(0.35)	(0.37)
Direct selling		1.21		1.60
		(0.70)		(0.92)
Other		-1.03		-0.42
		(1.26)		(1.38)
Processor		0.18		0.62
		(0.71)		(0.92)
Retailer		-0.67		-0.19
		(1.25)		(1.39)
Wholesaler		0.56		0.06

		(0.79)		(1.15)
Number of observations	397	397	355	355
AIC	394.52	396.17	312.49	314.53
BIC	446.31	467.88	362.83	384.23
Pseudo R2	0.20	0.23	0.17	0.21
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

Table 4.13: Binomial logistic regression estimation results for certified organic production in the dairy subsample

	Organic in 2018		Newly certified in organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
(Intercept)	-2.77 *	-18.13	-3.47 *	-17.98
	(1.35)	(1893.22)	(1.60)	(2721.42)
Coop	-0.26	15.42	-0.19	14.43
	(0.51)	(1893.22)	(0.62)	(2721.42)
Higher education	-1.31 *	-1.31 *	-1.13	-1.17
	(0.52)	(0.54)	(0.66)	(0.67)
UAA	-0.000038	-0.000063	0.000103	0.000094
	(0.001043)	(0.001049)	(0.000896)	(0.000897)
Age	0.023566	0.022067	0.032142	0.032165
	(0.02)	(0.02)	(0.02)	(0.02)
France	1.25	1.00	0.74	0.67

	(0.85)	(0.90)	(0.90)	(0.96)
Ireland	2.20	2.08	2.28	2.22
	(1.24)	(1.25)	(1.27)	(1.29)
Poland	0.23	0.38	0.38	0.56
	(1.12)	(1.12)	(1.15)	(1.15)
Romania	-1.23	-1.04	-1.83	-1.73
	(0.83)	(0.85)	(0.96)	(0.97)
Sweden	-2.30	-2.39	-2.30	-2.34
	(1.21)	(1.25)	(1.29)	(1.33)
LFA	1.57 **	1.50 **	1.64 **	1.58 **
	(0.51)	(0.52)	(0.60)	(0.61)
Direct selling		16.45		14.93
		(1893.22)		(2721.42)
Other		-0.06		-0.09
		(2894.90)		(3503.74)
Processor		15.41		14.60
		(1893.22)		(2721.42)
Retailer		-0.25		-1.01
		(2683.02)		(3292.26)
Wholesaler		16.18		14.65
		(1893.22)		(2721.42)
Number of observations	220	220	201	201
AIC	193.39	199.21	149.87	158.27

BIC	230.72	253.51	186.20	211.12
Pseudo R2	0.20	0.23	0.21	0.22
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

Table 4.14: Binomial logistic regression estimation results for certified organic production in the France subsample

	Organic in 2018		Newly certified in organic in 2018	
	Model (1)	Model (2)	Model (1a)	Model (2a)
(Intercept)	2.85 *	2.32	1.51	0.63
	(1.13)	(1.31)	(1.32)	(1.57)
Coop	-1.69 ***	-1.38 *	-1.97 ***	-1.27
	(0.47)	(0.67)	(0.55)	(0.84)
Dairy x coop	1.02	1.30	1.25	2.55
	(0.77)	(0.90)	(0.94)	(1.34)
Dairy	-1.65 **	-1.92 *	-1.61 *	-2.82 *
	(0.62)	(0.77)	(0.73)	(1.20)
Higher education	-1.66 ***	-1.64 ***	-1.58 **	-1.75 **
	(0.48)	(0.49)	(0.55)	(0.57)
UAA	-0.012028 **	-0.012012 **	-0.007369	-0.006627
	(0.004126)	(0.004234)	(0.004821)	(0.004885)
Age	0.005547	0.009102	0.011967	0.014218
	(0.016899)	(0.017615)	(0.019814)	(0.021340)

LFA	1.25 **	1.31 ***	1.35 **	1.57 **
	(0.39)	(0.40)	(0.46)	(0.48)
Direct selling		0.13		0.43
		(0.85)		(1.02)
Other		-0.13		0.97
		(1.41)		(1.53)
Processor		0.84		2.56
		(1.09)		(1.52)
Retailer		14.35		16.73
		(882.74)		(1455.40)
Wholesaler		0.71		1.14
		(0.83)		(1.03)
Number of observations	213	213	176	176
AIC	221.21	229.05	165.79	170.14
BIC	248.10	272.75	191.15	211.35
Pseudo R2	0.41	0.42	0.39	0.42
Standard deviations in brackets. Significance: *** p < 0.001; ** p < 0.01; * p < 0.05.				

Table 4.15: Binomial logistic regression estimation results for AES adoption

	Non-organic AES		Organic AES	
	Model (1b)	Model (2b)	Model (1c)	Model (2c)
(Intercept)	-0.41	-0.42	-2.74 ***	-2.87 ***

	(0.60)	(0.73)	(0.68)	(0.80)
Coop	0.14	0.12	-0.67 *	-0.50
	(0.26)	(0.46)	(0.26)	(0.45)
Dairy x coop	0.68	0.68	-0.22	-0.10
	(0.48)	(0.52)	(0.49)	(0.51)
Dairy	-0.39	-0.38	0.10	-0.02
	(0.38)	(0.43)	(0.36)	(0.39)
Higher education	0.47	0.47	0.21	0.21
	(0.24)	(0.24)	(0.24)	(0.24)
UAA	-0.0004165	-0.0004231	0.0000009	-0.0000103
	(0.0004541)	(0.0004584)	(0.0001990)	(0.0001990)
Age	0.0024563	0.0029540	0.0146176	0.0150855
	(0.0088792)	(0.0089017)	(0.0090013)	(0.0090985)
Greece	-2.92 ***	-2.91 ***	0.36	0.36
	(0.50)	(0.50)	(0.48)	(0.48)
France	-1.93 ***	-1.95 ***	0.72	0.66
	(0.37)	(0.39)	(0.45)	(0.46)
Ireland	0.81	0.85	2.04 ***	1.96 ***
	(0.57)	(0.58)	(0.58)	(0.59)
Poland	-2.78 ***	-2.78 ***	-0.86	-0.85
	(0.52)	(0.53)	(0.58)	(0.59)

Romania	0.41	0.46	0.14	0.13
	(0.49)	(0.50)	(0.57)	(0.57)
Sweden	-0.15	-0.13	0.90	0.86
	(0.38)	(0.40)	(0.47)	(0.49)
LFA	0.28	0.27	0.43 *	0.39
	(0.21)	(0.21)	(0.21)	(0.22)
Direct selling		0.13		0.59
		(0.52)		(0.48)
Other		-0.50		-0.28
		(0.60)		(0.59)
Processor		-0.04		0.33
		(0.50)		(0.47)
Retailer		0.08		-0.43
		(0.67)		(0.75)
Wholesaler		0.04		-0.04
		(0.53)		(0.50)
Number of observations	680	680	680	680
AIC	681.62	690.06	679.81	684.26
BIC	744.93	775.98	743.12	770.17
Pseudo R2	0.32	0.32	0.11	0.12
Standard deviations in brackets. Significance: *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.				

4.6.3 Appendix C: Supplementary material on marketing channels and farm specialisation

In this appendix we provide some additional information on the dataset. The purpose is to highlight the diversity of farms, by considering farm specialisations and dominant marketing channels in each country.

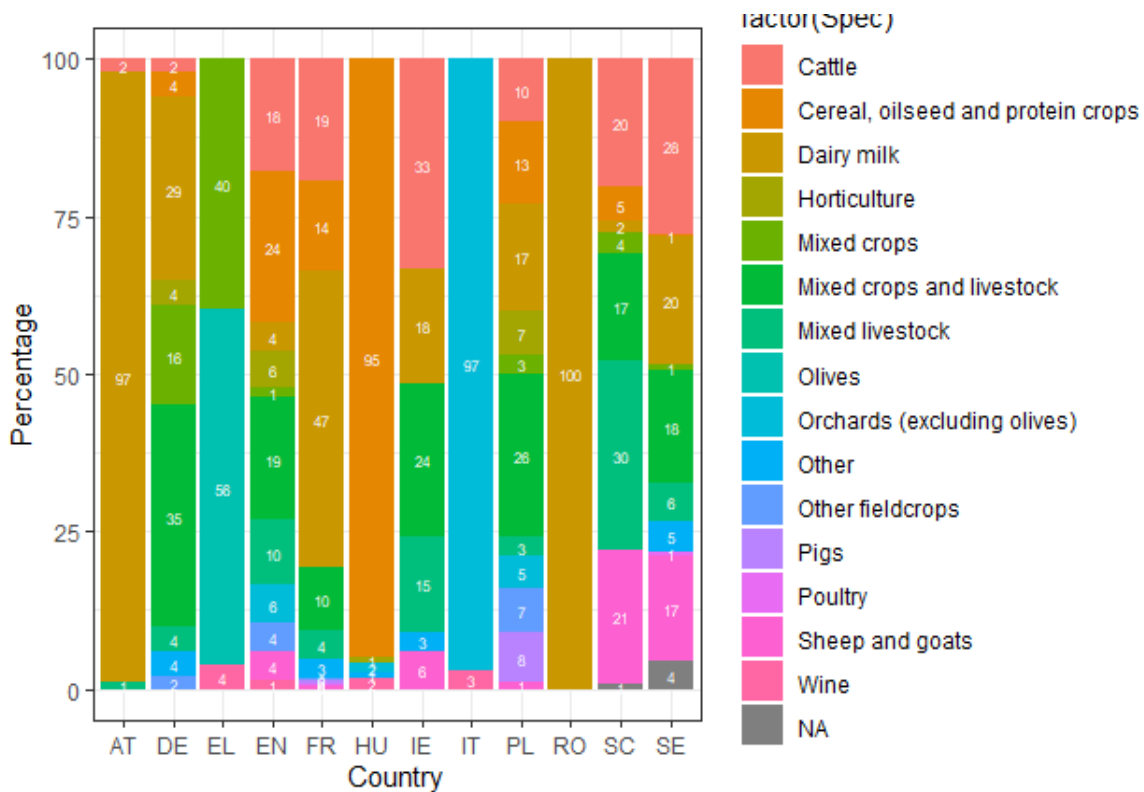


Figure 4.4: Shares of farms per specialisation for each country (N=1,251 farms)

Figure 4.4 illustrates the distribution of farm specialisations per country. Note that in this figure we show all countries from the initial dataset with 1,251 farms from 12 countries. We observe that there is significant diversity between countries. Some countries such as Austria and Romania have highly specialised in *dairy* production in our sample. Hungarian farms in our sample, on the other hand, are specialised mainly in *cereal, oilseed and protein crops*. Similarly, in Italian farms, we observe the importance of *orchards* farms in our sample. In Greece, we see that the specialisations are mainly shared between *olives* and *mixed crops*. Other farms in our sample have a more diversified specialisation portfolio. In French farms, the main specialisation is *dairy* followed by *beef cattle, cereal, oilseed and protein crops* and *mixed crops and livestock*. Among German farms in our sample, *mixed crops and livestock, dairy* and *mixed crops* are the main specialisations. Farms in England have a balanced share between various specialisations.

The main ones are *mixed crops and livestock, cereal, oilseed and protein crops* and *beef cattle*. Main specialisations in Irish farms are *mixed crops and livestock, cattle* and *dairy*. Polish farms in our sample have a very diversified specialisation portfolio. The main specialisations are *mixed crops and livestock, dairy* and *cereal, oilseed and protein crops*. In Scottish farms, the *mixed livestock* specialisation is the most frequent, followed by *sheep-goats* and *beef cattle* specialisations. Swedish farms in our sample also show diversified specialisation profiles. Most frequent ones are *beef cattle, dairy, mixed crops and livestock* and *sheep-goats*.

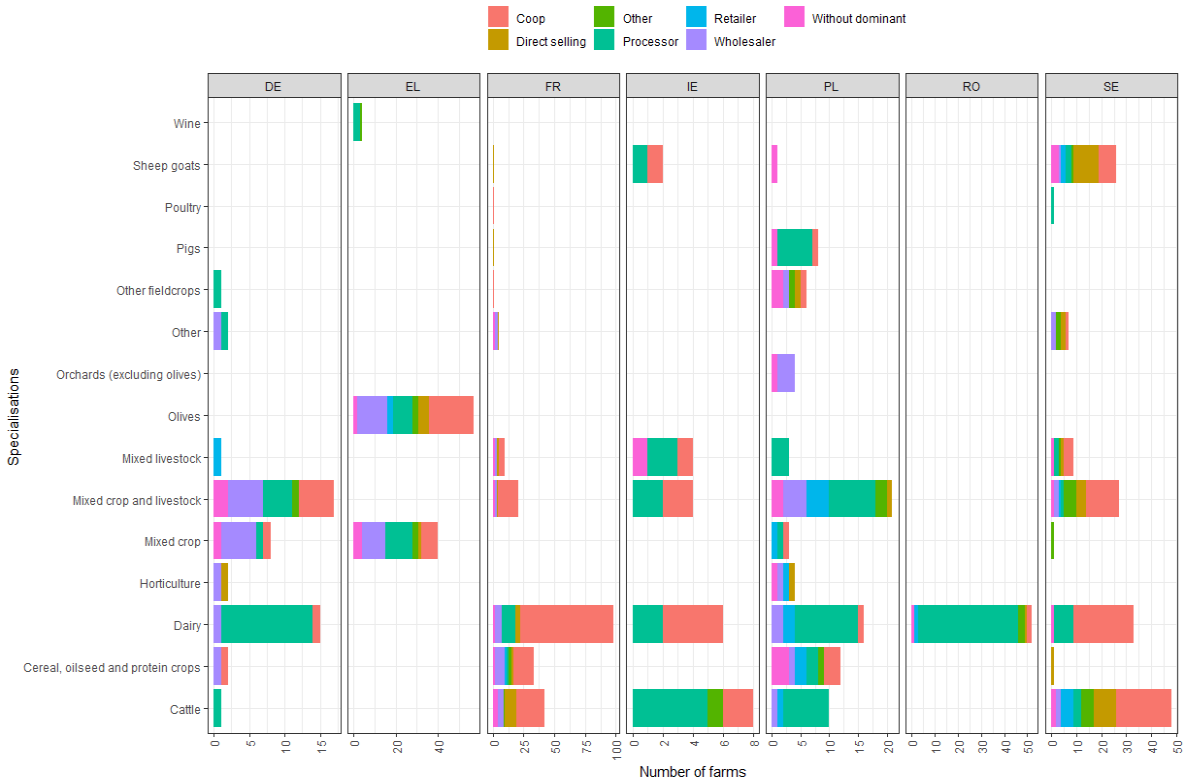


Figure 4.5: Dominant marketing channels per specialisation (680 farms)

After the illustration of the diversity in specialisations presented in Figure 4.4 for the initial sample of 1,251 farms from 12 countries, we aim at providing shares of specialisations by taking into account *dominant marketing channels*. Note that with the inclusion of the variable of dominant marketing channel, our sample size is dropped to 680 farms. Austrian, English, Hungarian, Italian and Scottish farms are excluded due to data unavailability on this topic.

Figure 4.5 presents the specialisations per country and per dominant marketing channels for 680 farms in Germany, Greece, France, Ireland, Poland, Romania and Sweden.

Among German farms, with mixed crops and livestock specialisation, we observe a balanced share of cooperatives, wholesalers and processors dominant marketing channels. On the other hand, the dairy farms in Germany choose mostly processor as a dominant channel. For mixed crop farms in the German subsample, the main option is to delivering to wholesalers. In the Greece subsample, the olive farms have a diversified share between dominant marketing channels. The main delivery option in Greek olive farms is to cooperatives followed by wholesaler and processors. Similarly, mixed crop farms in Greece have diversified choices of marketing channels. The main dominant marketing channel is processors followed by wholesalers and cooperatives. In the French subsample, dairy farms mainly choose to use cooperatives as dominant marketing channel, followed by the processor option. For cattle farms too, cooperative is the mostly chosen marketing channel, followed by the direct to consumer channel. For cereal, oilseeds, protein crops and mixed crop and livestock specialisations in France, we observe that the cooperative marketing channel is mostly chosen as a dominant delivery option. In the Irish case, we observe a balanced share between cooperatives and processors for dairy, beef cattle, mixed crop and livestock, mixed livestock, sheep-goats specialisation. Among Polish farmers in our sample, the cooperative option as a dominant channel is barely present. The processor option is the main preferred channel for dairy, beef cattle and mixed crop and livestock specialisations. For the other specialisations in Polish farmers we observe a balanced share between channels. In the Romanian case, dairy farms as the only specialisation in the subsample deliver mainly their output to processors. Finally, in Swedish farms in our sample, we observe that the cooperative option is the mainly preferred one for dairy, beef cattle and mixed crop and livestock specialisations. In the Swedish case, we see also that the direct to consumer option is highly represented compared to other countries. Particularly for sheep-goats farms, this option is the dominant marketing channel. Figures 4.6 to 4.12 provide the same information shown on Figure 4.5, but in terms of the number of farms of each dominant marketing channel for existing specialisation per country.

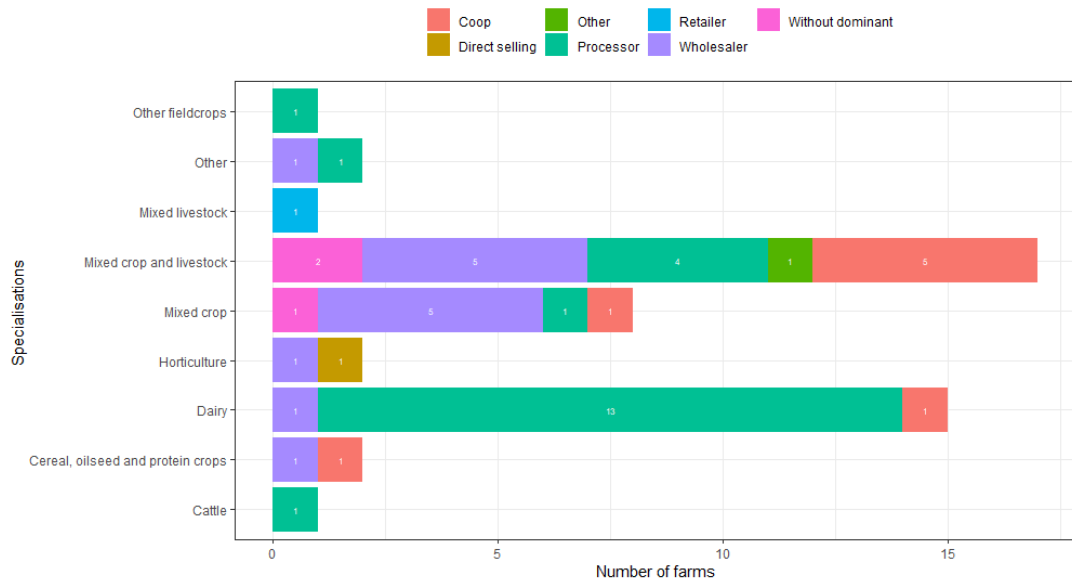


Figure 4.6: Dominant marketing channels per specialisation in Germany

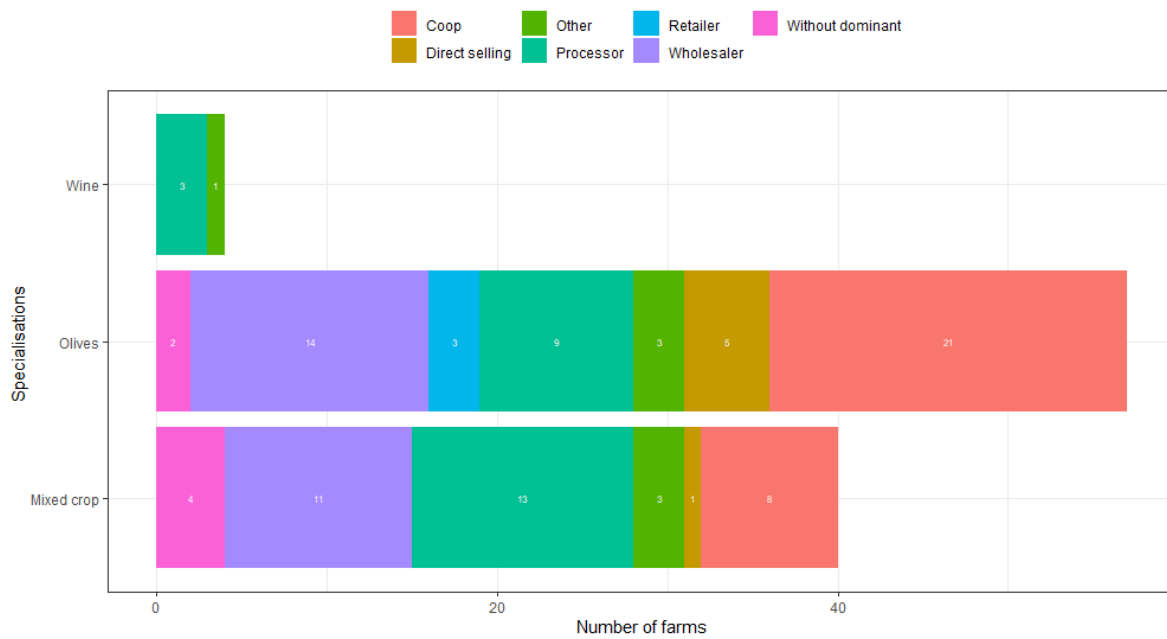


Figure 4.7: Dominant marketing channels per specialisation in Greece

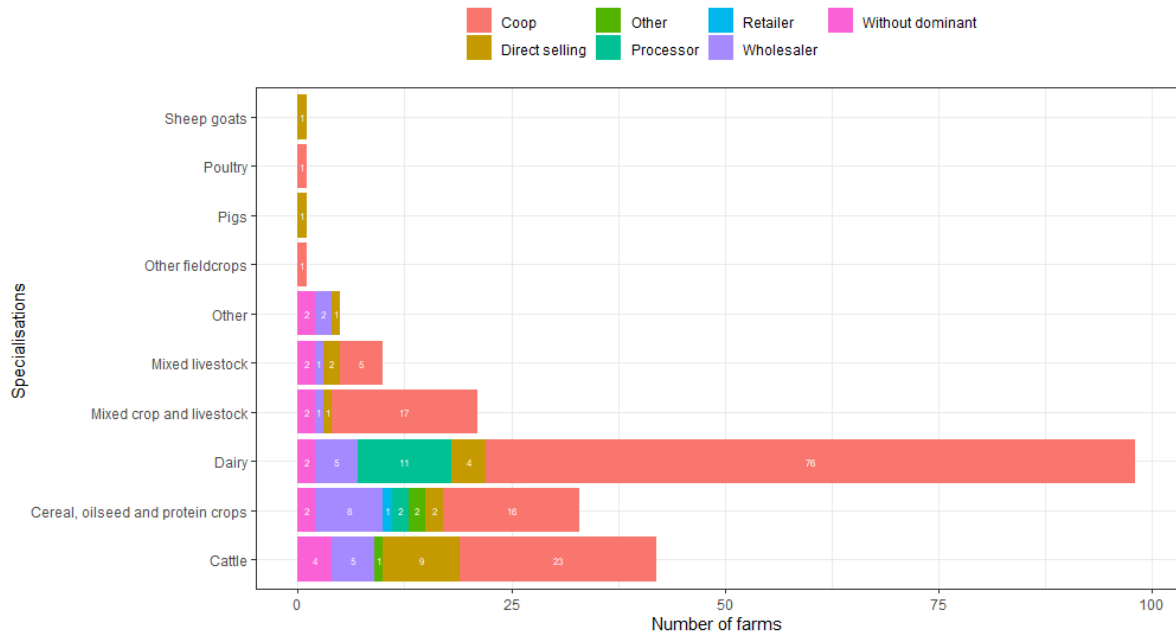


Figure 4.8: Dominant marketing channels per specialisation in France

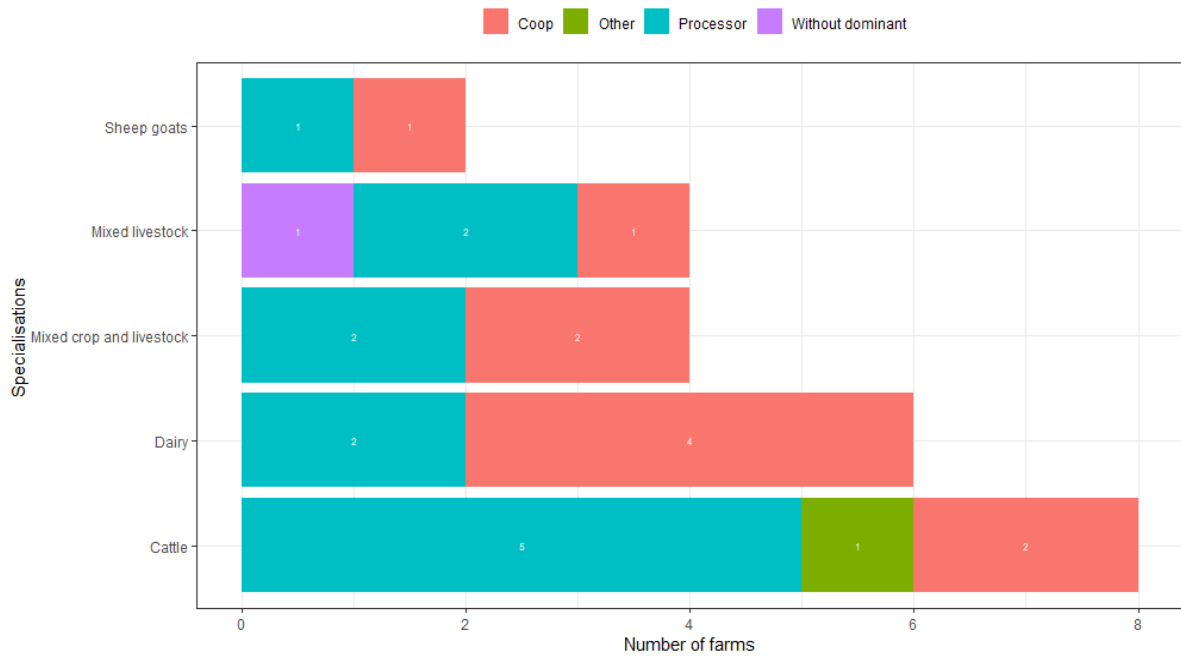


Figure 4.9: Dominant marketing channels per specialisation in Ireland

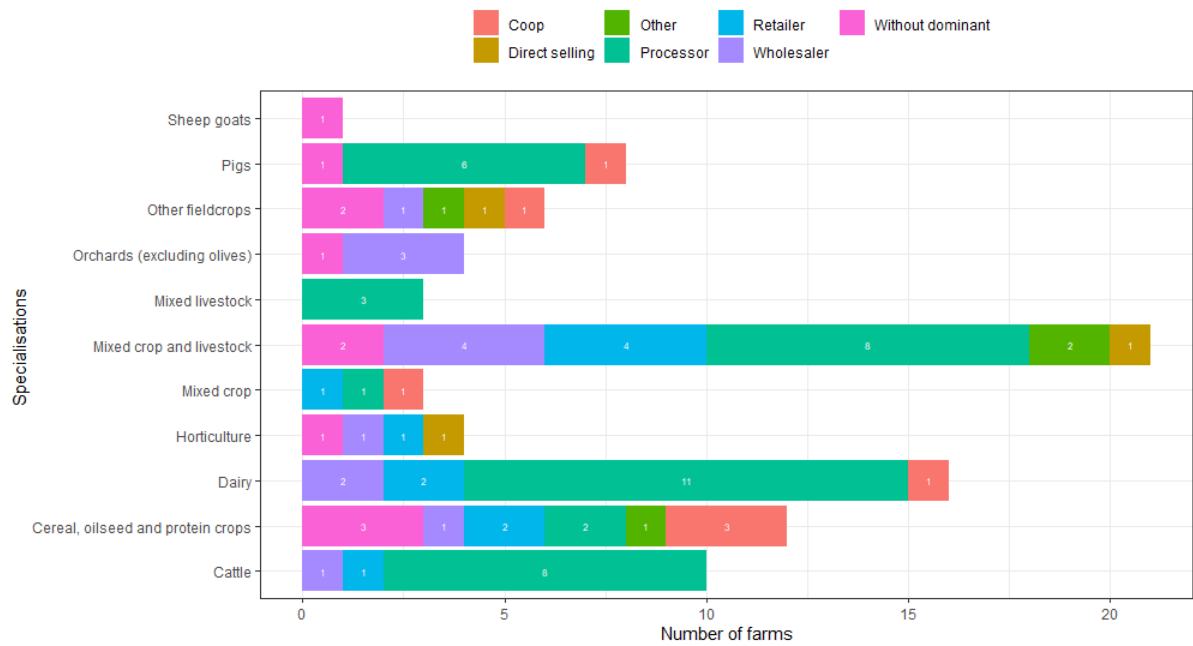


Figure 4.10: Dominant marketing channels per specialisation in Poland

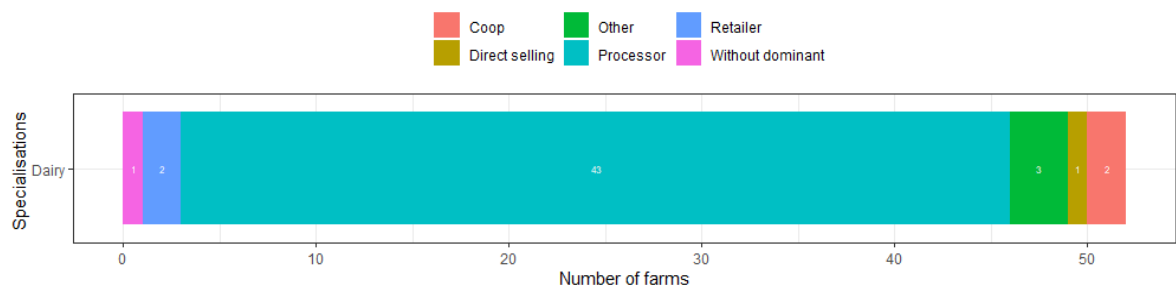


Figure 4.11: Dominant marketing channels per specialisation in Romania

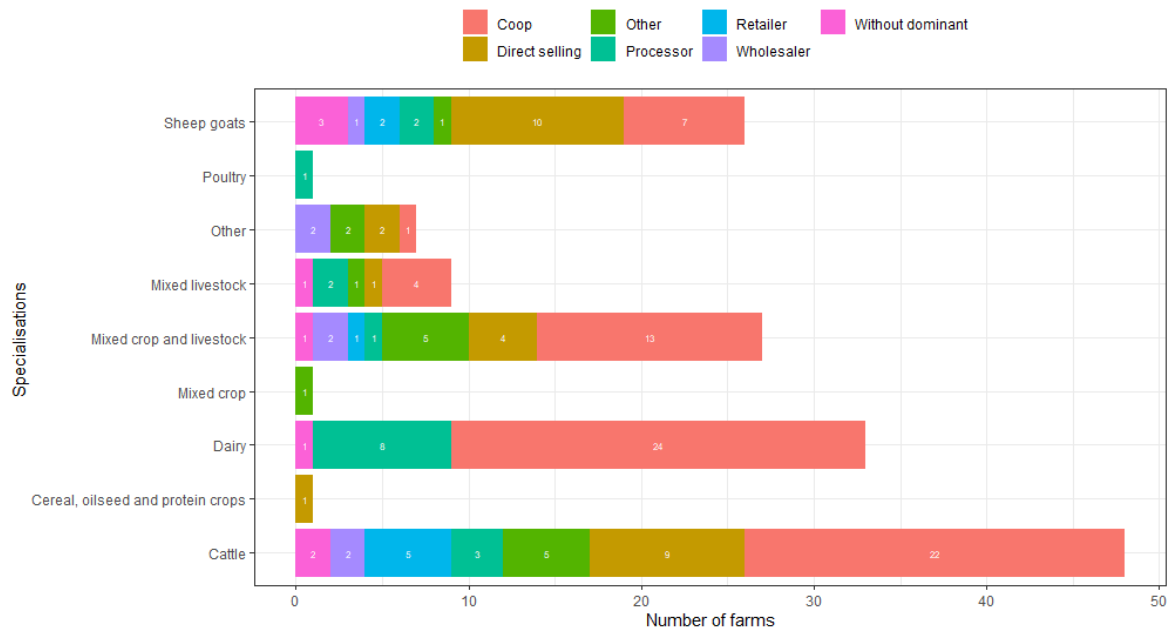


Figure 4.12: Dominant marketing channels per specialisation in Sweden

Descriptive statistics per marketing channel

In this section, we provide mean values for key variables per dominant marketing channel. Table 4.16 covers the sample of 680 farms with all specialisations from 7 countries. Table 4.17 covers only livestock farms in the sample (397 farms). Table 4.18 concerns non-livestock farms (283 farms). Finally, Table 4.19 is concentrated on dairy and beef cattle farms in France (150 observations).

This information is helpful to capture different characteristics per marketing channel and to show data availability for further statistical analysis. In these tables we give mean values for key farm characteristics. These variables are as follow: (i) UAA in ha, (ii) Arable land area in ha, (iii) Permanent grassland area in ha, (iv) Perennial crop area in ha, (v) Total LU (including cattle, poultry, pig, sheep-goats), (vi) Beef cattle and dairy LU, (vii) Total farm labour (in 100 hours), (viii) Farmers' age, (ix) Farmers' experience, (x) Share of hired labour in total labour (%), (xi) Share of rented area in total UAA (%), (xii) Annual farm turnover in 2018 (thousand Euros), (xiii) Income share from farming (%). In addition, we provide shares of farms in the total sample, namely: (xiv) Share of farms in LFA, (xv) Share of farms in Natura 2000, (xv) Share of farms in water directive areas, (xvi) Share of farmers with higher general education (%), (xvii) Share of farmers with higher agricultural education (%).

Starting with Table 4.16, we observe that there are large differences on average between farms that use different dominant channels. In the whole sample, farms using mainly cooperatives and processors have larger size compared to other channels. The UAA is 122.6 ha and 97.8 ha on average for farms delivering mainly to cooperatives and processors respectively. This average drops to 47.5 ha for farms using direct selling strategy. The farms using the cooperative option have a large herd size on average (131.0 LU) compared to other farms. These differences regarding farm size and animal production are understood better when we use subsamples taking into account the specialisations. Another interesting fact is related to differences in farmers' educational profile. The share of farmers choosing cooperatives as the main marketing channel with higher agricultural education is higher (57.5 %), but the share with general higher education is lower (16.5%) compared to farmers choosing other marketing channels. Tables 4.17 and 4.18 provide similar statistics to Table 4.16 for livestock farms only (397 farms) and non-livestock farms only (283 farms), respectively. We observe that farmers using mainly the cooperative channel have the highest farm size in terms of UAA or number of LU on average for both subsamples. This shows that farmers using cooperative as the dominant channel have

a balanced livestock and non-livestock production even if they have a major production specialisation. This is confirmed by the large arable land area in these farms. These facts are also confirmed for the French subsample for dairy and beef cattle production.

Table 4.16: Mean values for key variables per dominant channel (680 farms)

Variables	Coop	Direct selling	Other	Processor	Retailer	Wholesaler	Without dominant
Averages							
<i>UAA (ha)</i>	122.6	47.5	32.8	97.8	55.0	46.6	59.1
<i>Arable land (ha)</i>	81.6	23.1	22.1	22.2	49.8	29.1	36.3
<i>Permanent grassland (ha)</i>	20.1	23.4	9.1	13.4	4.3	11.6	21.5
<i>Perennial crops area (ha)</i>	3.4	1.3	1.0	2.2	0.8	5.2	2.0
<i>Total LU</i>	131.0	25.6	11.9	50.9	22.2	27.5	50.5
<i>Beef cattle and dairy LU</i>	74.3	21	7	35.1	15.3	18.4	28.6
<i>Total farm labour (100 AWU)</i>	49.2	31	26.8	53.2	36.7	35.5	40.4
<i>Farmers' age (years)</i>	50.8	52.1	55.7	49.4	48.7	49.3	51.2
<i>Farmers' experience (years)</i>	29.5	26	30.9	29.2	29.3	30.6	28.3
<i>Share of hired labour (%)</i>	21.6	14.5	57	25.2		40.4	21.4
<i>Share of rented area (%)</i>	43.4	45	27.3	22.2	24.6	29.4	36.3
<i>Farm turnover (1,000 €)</i>	229.4	73.2	169.5	108	24.8	92.9	86.7
<i>Income share from farming (%)</i>	59.3	42.9	33.7	58.6	43.9	59.7	54.5
Shares of farms							
<i>Share of farms in LFA (%)</i>	44.4	62.7	52.9	60	46.2	51.9	43.2
<i>Share of farms in Natura 2000</i>	15.4	15.3	11.8	16.5	7.7	18.5	20.5
<i>Share of farms in Water Directive area</i>	22.9	6.8	0	5.9	0	16.1	4.6
<i>Share of farmers with general higher education</i>	16.5	46.6	45.2	32.7	38.5	35.1	36.4
<i>Share of farmers with agricultural higher education</i>	57.5	22.4	25.8	42.9	34.6	39	38.6

Table 4.17: Mean values for key variables per dominant channel in livestock farms (397 farms)

Variables	Coop	Direct selling	Other	Processor	Retailer	Wholesaler	Without dominant
Averages							
<i>UAA (ha)</i>	137.2	59.9	27.2	125.9	95.2	84.1	79.8
<i>Arable land (ha)</i>	92.1	27.1	6.6	23	88	30.3	44.5
<i>Permanent grassland (ha)</i>	26.4	32.6	18.6	16.3	6.8	40.4	35.8
<i>Perennial crops area (ha)</i>	2.9	1.2	0	1.7	0	8.3	0.03
<i>Total LU</i>	163.2	35.7	14.4	64.6	37.9	78.7	99.1
<i>Beef cattle and dairy LU</i>	95.3	29.4	14.2	42.8	24.8	54.4	50.5
<i>Total farm labour (100 AWU)</i>	54	31.3	24.8	56.2	37.7	48.4	39.2
<i>Farmers' age (years)</i>	50.5	53.6	54.3	49.3	54.2	46.6	50
<i>Farmers' experience (years)</i>	28.8	28.3	24.8	29.2	35.2	26.1	27.8
<i>Share of hired labour (%)</i>	17.9	1.7	82.2	21.9		29.4	19.4
<i>Share of rented area (%)</i>	48.1	36.6	22.1	21.4	32.1	45	53
<i>Farm turnover (1,000 €)</i>	254.4	76.9	18.8	126.6	21.8	133.8	104.3
<i>Income share from farming (%)</i>	63.8	43	25.2	60.9	36.4	46	48.9
Shares of farms							
<i>Share of farms in LFA (%)</i>	46.3	73.7	75	63.1	30.8	44.4	57.9
<i>Share of farms in Natura 2000</i>	14.3	10.5	8.3	18	7.7	11.1	31.6
<i>Share of farms in Water Directive area</i>	20.6	7.9	0	5.7	0	16.7	5.3
<i>Share of farmers with general higher education</i>	12.2	36.8	36.4	30	38.5	13.3	26.3
<i>Share of farmers with agricultural higher education</i>	59.9	29	27.3	45.8	30.8	53.3	47.4

Table 4.18: Mean values for key variables per dominant channel in non-livestock farms (283 farms)

<i>Variables</i>	Coop	Direct selling	Other	Processor	Retailer	Wholesaler	Without dominant
Averages							
<i>UAA (ha)</i>	94.4	25.2	35.8	26.2	14.8	35.8	43.4
<i>Arable land (ha)</i>	61.3	16.6	30.3	20.3	11.6	28.8	29.8
<i>Permanent grassland (ha)</i>	7.9	6	3.9	6.2	1.5	2.9	10.3
<i>Perennial crops area (ha)</i>	4.5	1.5	1.6	3.5	1.7	4.4	3.5
<i>Total LU</i>	69.1	6.1	10.5	16	6.6	12.9	13.6
<i>Beef cattle and dairy LU</i>	34	5.8	3.1	15.8	5.9	8.1	12
<i>Total farm labour (100 AWU)</i>	40.1	30.2	27.9	45.1	35.7	31.9	41.3
<i>Farmers' age (years)</i>	51.4	49.4	56.5	49.5	43.2	50.1	52.2
<i>Farmers' experience (years)</i>	30.6	21.8	34.2	29	23.4	31.9	28.7
<i>Share of hired labour (%)</i>	33.1	35.9	48.6	46		45.9	23.3
<i>Share of rented area (%)</i>	34.4	60.2	30.2	24.2	16.5	26.2	23.7
<i>Farm turnover (1,000 €)</i>	185.3	67.8	251.7	70.4	26.9	81.2	73.1
<i>Income share from farming (%)</i>	50.7	42.9	38.8	53.1	50.2	62.3	57.4
Shares of farms							
<i>Share of farms in LFA (%)</i>	40.7	42.9	40.9	52.1	61.5	54	32
<i>Share of farms in Natura 2000</i>	17.6	23.8	13.6	12.5	7.7	20.6	12
<i>Share of farms in Water Directive area</i>	27.5	4.8	0	6.3	0	15.9	4
<i>Share of farmers with general higher education</i>	24.7	65	50	39.6	38.5	40.3	44
<i>Share of farmers with agricultural higher education</i>	52.8	10	25	35.4	38.5	35.5	32

Table 4.19: Mean values for key variables per dominant channel in French dairy and beef cattle farms (150 farms)

<i>Variables</i>	Coop/PO	Direct selling	Other	Processor	Retailer	Wholesaler	Without dominant
Averages							
<i>UAA (ha)</i>	115.4	82.6	92	127.8	120.3	123.6	115.4
<i>Arable land (ha)</i>	73.2	30.6	0	100.4	37	55.9	73.2
<i>Permanent grassland (ha)</i>	33.4	56.9	92	28.4	62	65.9	33.4
<i>Perennial crops area (ha)</i>	3.5	2.2	0	17.3	14	0	3.5
<i>Total LU</i>	221.5	63.6	53.6	307.6	115.5	194.7	221.5
<i>Beef cattle and dairy LU</i>	107	62.7	53.6	105.8	72	84	107
<i>Total farm labour (100 AWU)</i>	58.1	48.6	43.7	60.6	65.3	47.8	58.1
<i>Farmers' age (years)</i>	46.5	50.2	56	44.1	44.4	45	46.5
<i>Farmers' experience (years)</i>	23.3	25.8	27	22.1	22	23	23.3
<i>Share of hired labour (%)</i>	9.5	2.7		11.2	1.2	24.1	9.5
<i>Share of rented area (%)</i>	52.8	40.7	76.1	19.1	64.4	84.6	52.8
<i>Farm turnover (1,000 €)</i>	275	140.7	26	368.2	170.1	222.8	275
<i>Income share from farming (%)</i>	73.2	74.5	100	71.1	38	92	73.2
Shares of farms							
<i>Share of farms in LFA (%)</i>	34.6	80	100	27.3	36.4	37.5	34.6
<i>Share of farms in Natura 2000</i>	14.4	13.3	0	18.2	9.1	37.5	14.4
<i>Share of farms in Water Directive area</i>	28.9	6.7	0	0	18.2	12.5	28.9
<i>Share of farmers with general higher education</i>	6.9	40	0	9.1	11.1	12.5	6.9
<i>Share of farmers with agricultural higher education</i>	86.3	53.3	100	81.8	66.7	75	86.3

Chapter 5 General conclusion

5.1 Summary of results

This PhD's main objective was to investigate sustainability related issues at the farm level. The first question introduced in Chapter 2 deals with the evolution of farm sustainability through the assessment of farm economic and environmental performances over a long period. This study uses accountancy farm-level data in a French region over 9 years. The second part of the PhD relates to the investigation of supply chain and environmentally-friendly production with a focus on agricultural cooperatives. The PhD aims at bringing relevant scientific evidence and identifying the main issues on the subject. Chapter 3, providing a literature review on the impacts of cooperatives on farm adoption of sustainable practices, illustrates in which circumstances cooperatives can either enhance or harden the development of farm sustainability. Chapter 4, having direct links with Chapter 3, empirically investigates the role of marketing channel choices on the adoption of certified organic production using original farm-level data from a survey in several EU countries.

Main results and contributions

Firstly, the PhD stresses the importance of the evolution in time for the economic and environmental performances at the farm level. This result may have substantial importance when we treat sustainability related questions. With farm-level accountancy data in a North-East region in France for livestock farms in 2008-2016, we show that the time dimension should be taken into account when assessing trade-offs between economic performance and environmental performance to help the design of public policy tools targeted to farm sustainability. Considering the time dimension may help policy makers to assess better farm level dynamics and create more efficient medium and long-term policy measures.

Secondly, the PhD stresses the crucial question of agricultural supply chains impacts on farmers' decisions. The literature review fills the gap in scientific knowledge by providing a critical analysis on theoretical and empirical literature. It shows the ambiguous impacts of cooperatives depending on contextual and sectorial dynamics. Cooperatives may favour the adoption of sustainable practices by creating adding value through the development of labelling. They can also pool resources to develop joint R&D for farm technology innovation. However,

as our main conclusion sheds light, member heterogeneity can prevent the adoption of sustainable practices on farms when more conservative members govern the cooperative organisation.

Chapter 4 develops an empirical analysis on marketing channels choices by using a unique dataset on farm practices and choice of marketing channels in 2018 obtained from a specific survey to hundreds of farms in the EU in the frame of the H2020 financed research project LIFT. This study originally contributes to the empirical literature on cooperatives and marketing channels which is mainly focused on economic performance in developing countries. Our results show that cooperative membership has a negative impact on the adoption of organic production in our 7 country sample. We do not find any significant results related to other marketing channels, which emphasises the significant role of agricultural cooperatives in the sustainable transition at the farm level.

5.2 Limitations

The PhD, having addressed crucial questions about sustainability issues in agri-food supply chains, has some limitations. One limitation is linked to poor availability of data on environmental sustainability at farm level. In classic databases used in economic analyses, it is rare to have quantitative information on environmental impacts of farms. In Chapter 2, we attempt to identify environmental performance of farms using accountancy data that suffers from this lack of information. We identify environmental performance through indirect measures, namely the input expenditures, N value per ha and the extent of pasture area. It is therefore recommended that effort is made in the collection of environmental information besides economic information at farm level.

A second limitation is related to the time dimension. Data containing information on farming practices, such as the one used in Chapter 4, are often limited to one year in time. Even though Chapter 2 provides a new perspective on farm sustainability by highlighting the importance of stability during a 9-year period, we did not consider potential external changes during the time span; such as possible impacts of public policy changes during this time period, e.g. the abolition of EU milk quotas in 2015 (Läpple et al. 2021) and French Ecophyto policy aiming the reduction of pesticides use in farming (Guichard et al. 2017). Taking into account these

changes would require a more complex hierarchical clustering analysis accounting for panel data.

Another shortcoming of this PhD is linked to the legal and institutional definition of farmer cooperatives and producer organisations. Even in the European context, cooperation in farm production can take different names, statuses and legal definitions (Bijman et al. 2012). During our literature review in Chapter 3, we did not make a distinction between different types of farmer organisations. We assumed that the economic behaviour of farmer organisations is identical in all cases when farmers democratically control and own the organisation. The choice was made in order to give a holistic understanding about the impacts of farmers' organisations in vertical supply chains.

In Chapter 4, the impact of vertical marketing channels on the choice to produce under organic practices is investigated. Our causality assumption is that the marketing channel choices are not flexible, and that these marketing channel choices influence the choice of farming practices. The study does not consider the reverse relationship, namely that farmers' choice to be a member of a producer organisation or cooperative, would be affected by their choice of farming practices (Corsi et al. 2009). For this, a specific causal econometric model should be developed.

The last issue is related to the representativeness of our dataset in Chapter 4. In the empirical literature which aims at capturing impacts of cooperative memberships, this issue is often carefully treated (Hao et al. 2018; Ma et al. 2018). In developing countries, the decision to become a cooperative member is often simultaneous to the decision to adopt new techniques. Furthermore, these decisions may often raise some selection issues to be dealt with. The issue may not be so strong the case in developed countries where the marketing channels have often been chosen long time before the production decision. The marketing channel choice at farm gate often relates to the geographical proximity of the processing firm. However, an econometric model taking into account selection bias could be developed in future research.

5.3 Perspectives

The topics treated in this PhD have crucial importance for the development of sustainable practices in the agricultural sector in the EU. The PhD also raises some new questions that are relevant for future research agendas.

In Chapter 2, we studied the relation between economic and environmental performances by using an accountancy dataset from North-Eastern France. Giving original results and treating the importance of time dimension, this paper opens also new questions for further research. Firstly, the trade-off analysis could be extended to non-livestock production. Crop farms are more impacted by the use of pesticides and fertilisers, and may thus show different trade-offs than livestock farms in terms of economic and environmental performances. Secondly, the analysis may be replicated on farms which have already a specific environmentally-friendly certification such as organic farming, as their environmental performance (they are expected to use fewer chemical inputs) and their economic performance (they receive higher price for organic products) may be different from non-organic farms.

In this manuscript, we extensively analysed the literature on agricultural cooperatives. As stated in Chapters 3 and 4, the various sustainability issues are rarely related, especially for environmental and social sustainability (Candemir et al. 2021). Social sustainability in particular is poorly treated in the literature, and may deserve more attention from research. Moreover, the PhD points out that the theoretical literature is mainly limited to economic performance comparisons between cooperatives and investor owned firms. Although these studies offer insightful results, theoretical works could be extended by considering sustainability issues with a wider angle (Gonzalez 2018) and by treating the adoption related behaviour with a perspective that is not limited to profit maximisation framework (Weersink and Fulton 2020). Furthermore, the literature which deals with the farm marketing channel choice largely ignores the possibility of a co-existence between multiple channel choices for farmers, except for a few papers such as Pascucci et al. (2012) and Agbo et al. (2015). Further research, both theoretical and empirical, about multiple marketing channel choice, may offer a promising avenue.

As mentioned above, Chapter 3 shows that the social dimension of sustainability is rarely treated in the literature of cooperatives. This social dimension may however influence the effects of supply chain organisation in both theoretical and empirical works. Finally, as it is treated in Chapter 2, it would be very relevant to work on the synergy/trade-off relations between different sustainability components including social sustainability by taking into account the time dimension (Antle and Valdivia 2021).

We are convinced that these are promising avenues in agricultural economics to treat these questions both theoretically and empirically.

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Titre: Durabilité des exploitations et le rôle des acteurs économiques dans les filières agricoles

Mots clés : Durabilité, adoption des pratiques environnementales, filières agricoles, coopératives

Résumé : Cette thèse de doctorat étudie la durabilité des exploitations agricoles en examinant la relation entre les composantes de la durabilité et le rôle de l'organisation des filières agricoles sur la durabilité des exploitations.

La contribution de cette thèse est double. Premièrement, la thèse prend en compte la dimension temporelle dans l'analyse de la durabilité des exploitations agricoles. Elle montre que l'évolution dans le temps des efforts environnementaux a un impact sur la performance économique des exploitations en utilisant des données au niveau des exploitations d'élevage en France.

Deuxièmement, en se concentrant sur le rôle des coopératives agricoles dans le développement de pratiques durables, la thèse montre que différents types d'organisation dans les filières peuvent avoir des impacts significatifs sur la durabilité des exploitations. La revue de la littérature offre une contribution en fournissant une analyse critique de la littérature théorique et empirique. La principale conclusion de cette étude est de mettre en lumière l'importance de l'hétérogénéité entre et au sein des coopératives. La thèse montre également, en étudiant des données originales d'exploitant dans sept pays de l'UE, que le choix des coopératives comme principal mode de commercialisation peut avoir un effet négatif sur l'adoption de la certification biologique.

Title: Farm sustainability and the involvement of economic actors in the agri-food value chain

Keywords : Sustainability, adoption of environmentally-friendly, supply-chains, cooperatives

Résumé : This PhD studies farm sustainability by investigating the relation between sustainability components and the role of supply chain organisation on overall farm sustainability.

The contribution of the PhD is twofold. First, the PhD takes into account the time dimension in the analysis of farm sustainability. It shows that time evolution of environmental efforts matters in farm economic performance by using farm level data from French livestock farms. Secondly, by focusing on the role of agricultural cooperatives in the development of sustainable practices, it shows that

different types of organisational arrangement in agri-food supply chains may have significant impacts on farm sustainability. The literature review study fills the gap in scientific knowledge by providing a critical analysis on theoretical and empirical literature. It shows the diverging forms of impacts of cooperatives depending contextual and sectorial dynamics. The main conclusion of this study is shedding light on the importance of heterogeneities between and within cooperatives. The PhD also shows, by studying original farm data from seven EU countries, that choosing cooperatives as the main marketing channel may negatively affect the adoption of organic certification.